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The preservation of sound archives: A computer science based approach to quality control

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To my father, Franco Bressan
the real genius of the family

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Abstract

This thesis summarizes the authors work in the last years, which have been spent in the effort of establishing an organic connection in the many aspects involved in the preservation of audio documents. This has been achieved living first hand experiences in archival institutions and in academic research laboratories. The result is a multidisciplinary set of knowledge that is herein presented within the framework of a scientific methodology, the guiding thread of which is a computer science based approach to the quality control in the preservation process.

The thesis is organized in five parts. Part one explores the field of preservation with a focus on ethics and philology, reporting the positions of the most authoritative representatives within the international archival community with respect to the cultural dilemma of supporting preservation. In the light of these positions, the author proposes her own methodology for preservation, and details an operational protocol reflecting the theoretical principles. Part two describes the original software that the author has developed with the aim of achieving a greater control over the quality of the preservation process, supporting and automatizing its related activities. Part three reports the results of chemical, mechanical and audio analyses that have been conducted in order to advance the understanding of one of the most common restoration methods for magnetic tapes: thermal treatment. Part four describes the research projects in which the author has collaborated and within the scope of which most of the work presented herein has been carried out. The archives involved have proved an invaluable testbed for the definition of the methodology, allowing the author to perfect the procedures in the light of the problems of real-world archives. Finally, part five moves in the directions of an advanced research field in the preservation area, focused on artistic interactive multimedia installations. Sound is one of the elements that contributes to the creation of the artistic experience, and every aspect of audio preservation is comprised in this field, with the additional problems of dealing with multiple media and with real-time interaction. This parts includes important case studies that the author has taken care of, among which an interactive multimedia installation presented at the Expo 2002. During the author's work in the archives, among the most requested missing tools was an exhaustive list of symptoms and signs of degradation that affecting different types of audio media. The substantial appendix closing

this work includes the summary, obtained by crossing several sources and aligning overlapping/contradicting definitions.

Contents

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Introduction

"In preservation, no one can afford to be an island." [1, p. 14]

Computer science offers multiple possibilities to study the fields of humanities: a major topic that has been rapidly growing along the past decades is the implementation of computer engineering in musical cultural heritage, with a particular relation to the audio documents preservation: "Professional audio experience, musical knowledge, and the ability to verify or confute [...] human perceptions with precise measurement, make audio engineers and technicians [...] the best candidates for recognizing playback problems and intervening during archival transfers. [...] Ideally, an audio preservation workflow would also involve the services of a specialized programmer. [This] cuts costs, saves time and reduces the opportunity for human error" [2, p. 9] (see Subsection 6.2.2 for more details on the relation between automation and the reduction of human error).
Scholars and the general public started paying greater attention to the recordings of musical events and to their value, at a personal/collective level and for cultural/entertainment purposes. However, a systematic preservation and the fruition of these documents is complicated by their diversified nature: recordings contain other cultural- and artistic-related information that go beyond the audio signal itself. In this sense, a faithful and satisfying access to the audio document cannot be achieved without its associated contextual information, i.e., to all the content-independent information represented by the box/case, the signs on the carrier, the accompanying material and so on.

This work investigates the scientific and the technological aspects of cultural heritage preservation. More precisely, it focuses on the definition of a protocol for the re-mediation process of sound recordings, exploiting the knowledge of different research areas, from computer science to archival science, from chemistry to linguistics. The guiding thread is a computer science based approach to the particular aspect of quality control in the re-mediation process. *Re-mediation* is the action of transferring acoustic information from a medium to another medium: currently it is the only solution to the problem of carriers degradation, which eventually leads to an irreversible loss of information. The same applies to non-acoustic information, like economical, scientific or private data on digital carriers, making the problem of preservation of general interest and of pressing urgency.

In an official technical report, the UNESCO [1] claims that over half of the cultural patrimony of the world is at serious risk of vanishing, despite the attention that cultural heritage preservation has attracted, especially by the European Union which proved great awareness in financing a number of research projects in this field.
The factors that obstruct the safeguard of audiovisual documents are multiple: mainly the massive investment of human and economical resources required by digitization campaigns ("Digitization can be a costly and time-consuming affair" [3, p. 2]), not to mention teams with multi-disciplinary competences, difficult and expensive to form. As a consequence, today many archives are in fact lacking methodological and technological tools to safeguard adequately their patrimony.

The process of physical degradation that characterizes every type of audio carriers can be slowed down, by means of correct preservation policies, but not stopped. Therefore, the survival of the information contained by the document is possible only renouncing to its materiality, through a constant transfer of the information onto new carriers (for more details on the dichotomy between content and container, that characterizes audio documents, see Subsection 4.2.3).
"Copying is not a value-neutral act; a series of technical judgments and physical acts (such as manual repair) determine the quality and nature of the resulting copy. It is possible, in effect, to distort, lose or manipulate history through the judgments made and the choice and quality of the work performed. Documenting the processes involved and choices made in copying from generation to generation is essential to preserving the integrity of the work." [4] Judgements, choices and documentation require a multidisciplinary trained personnel, which naturally calls for collaborations between archives and research institutes, since this combination of competences is hardly found elsewhere. "Judgements, choices and documentation" must be translated into an operational protocol grounded in a solid methodological framework, which may occasionally bring to the development of original software tools for the management of the complex apparatus of the archival preservation routines. As a matter of fact, a total neutrality in the process of the information transfer is not realistic, which puts the spotlight on the philological problem of the documents authenticity. In the first place, the recording of an acoustic event can never be a neutral operation because the timbre quality and the plastic value of the recorded sound, which are of great importance in, e.g., contemporary music, are already influenced by the positioning of the microphones used during the recording. In addition, the processing carried out by the Tonmeister[1] is a real interpretative element added to the recording of the event. Thus, musicological and historic-critical competence becomes essential for the individuation and correct cataloguing of the information contained in audio documents:

[1] The term Tonmeister describes a person who has a detailed theoretical and practical knowledge of all aspects of sound recording. But, unlike a sound engineer, he/she must be also deeply musically trained. Both competencies have equal importance in a Tonmeister's work [5]

in the field of audio recordings (and preservation), faithfulness to the original acoustic source (or recording) can only be achieved asymptotically – conversely, the authenticity of a document must be ensured 100%. Being made of unstable base materials, sound carriers are more subject to damage caused by inadequate handling. The commingling of a technical and scientific formation with historic-philological knowledge (important for the individuation and correct cataloguing of the information contained in audio documents) becomes essential for conservative re-recording operations, going beyond mere analog-to-digital (A/D) transfer: "the development of successful preservation strategies will require the cooperation of computer scientists, data storage experts, data distribution experts, fieldworkers, librarians, and folklorists" [6].

2.1 Cultural content in global networks: the European trend

More than ten years ago, representatives and experts from the European Member States met at Lund in Sweden to discuss the actions that would support coordination and that would add value to massive digitization programmes in ways that would be sustainable over time. The core assumption was that "Europe's cultural and scientific knowledge resources are a unique public asset forming the collective and evolving memory of our diverse societies and providing a solid basis for the development of our digital content industries in a sustainable knowledge society" [7]. Among the points discussed in Lund, there were:

- *the lack of synergies between cultural and new technologies fields*: an increasing need for improved linkages between cultural and new technologies programmes at national and EU level is acknowledged in order to identify priorities and where there is European added value to be gained;
- *the lack of simple, common forms of access for the citizen*: access by the citizen to the different resources, at national and at EU level, is compromised by the lack of common approaches and technical standards as well as by lack of support and systems for multilingual access;
- *obsolescence*: digitization is a costly exercise requiring high investments usually from public funds. There are significant risks to these investments due to the adoption of inappropriate technologies and standards. This can result in creating resources which are quickly obsolete and unusable or which require the investment to be repeated within a short time frame;
- *fragmentation of approach*: digitization activities are highly fragmented, and the absence of a coherent European view of what cultural content has been digitized or of how this content is selected for digitization may result in the potential duplication of resources, effort and investment.

The Lund meeting was followed by a decade of feverish digitization, involving text, images, movies, sound recordings and so on. In 2002, it was estimated that nearly 70% to 80% of documentary heritage in Eastern and Central Europe was inaccessible and in urgent need of preservation [1]. The European Union has proved perfectly loyal to the Lund principles by supporting a large number of research projects, surveys, studies, conferences, festivals and digitization campaigns[2]. To date, most problems among which the approach fragmentation and the format obsolescence are far from being solved, but the European trend to the digitization of cultural content and its availability have fostered new research fields, such as that of Digital Libraries, of Web services and applications, and of Digital Preservation, and new economic fields, such as that of the Cultural Industries and of the Creative Economy.

2.2 Heritage: a vibrant sector of Creative Economy

The multifaceted activities grouped under the umbrella of cultural heritage preservation belong to the "cultural and creative sector", a relevant slice of the European economic pie with a broadband penetration with the scientific-technological sector and in particular with the information and communication technology (ICT) sector[3] (Figure 2.1). Over the past decade, the cultural economic sector has been a leading one, representing about 40% of the world-wide activity in the area of creative goods and services [9], employing a total of 6,576,558 persons, equivalent to the 2.71% of the European labour market [10]: according to a recent European study [11], the whole cultural/creative sector is in total twice as large as the automobile sector, with remarkable growth figures of about 20% over five years. Even after the recent and ongoing economic crisis, which provoked a drop in global demand and a contraction of 12% in international trade, world exports of creative goods and services continued to grow, reaching €592 billion in 2008 – more than double their 2002 level [12].
An accurate estimate of the impact of the cultural and creative sector on the European economy is hard to assess, because it has direct/quantifiable effects and indirect/non-quantifiable effects:

- *primary economic impact*: measures direct contribution to the economy, using GDP and employment figures;
- *second economic impact*: measures indirect quantifiable contribution, as activities in the creative industries induce spin-offs in other sectors (multiplier effect);
- *tertiary economic impact*: measures direct yet less quantifiable contributions resulting from innovations in the creative industries that spill over into other sectors;

[2] CASPAR (`http://www.casparpreserves.eu/`) on digital preservation; POFADEAM (`http://www.ipem.ugent.be/node/19`) on the preservation of ethnic music archives; PREMIS (`http://www.loc.gov/standards/premis/`) on metadata for preservation; PRESTO (`http://presto.joanneum.ac.at/index.asp`) and its extension PRESTOSPACE (`http://www.prestospace.org/`) on the digital preservation of audiovisual collections. Examples of national projects, not funded directly by the EU: REVIVAL (see Section 11.1), Gra.fo (see Section 11.2) and TRANSISTOR (`http://transistor.ciant.cz/2013/`) on preservation techniques and methodologies for digital audiovisual works. All of the web pages have been last visited on 24th March, 2013.

[3] The term "creative economy" appeared in 2001 in John Howkins' book about the relationship between creativity and economics [8].

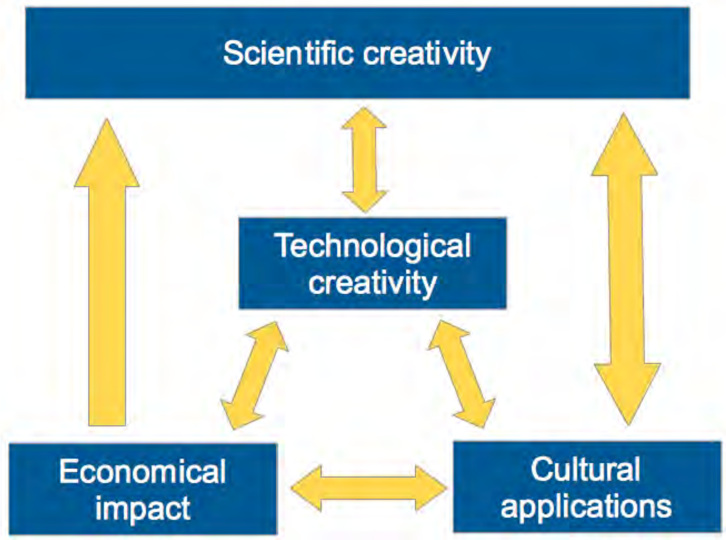


Fig. 2.1: *Creativity* is defined in a cross-sector and multidisciplinary way, mixing elements of artistic creativity, economical and technological innovation. In this scheme, technological creativity is considered as a process of interactions and spill-over effects between different processes in the fields of science, economy and culture. Adapted from [11, p. 42].

- *quaternary economic impact*: measures indirect, non-quantifiable contributions to quality of life, education and cultural identity [12].

Figure 2.2 represents the UNCTAD classification of creative industries (source [12, p. 14]), which is divided into four broad groups: heritage, arts, media and functional creations. These groups are in turn divided into nine subgroups. Cultural heritage is identified as the origin of all forms of arts and the soul of cultural and creative industries. It is the starting point of the classification. The preservation of audio documents and the devising of novel access services and tools for audio archives are rooted in the heritage group, but span over other groups such as new media, audiovisuals, creative services and performing arts. In particular, the preservation of audio documents is a multidisciplinary meta-activity, the aim of which is not to produce goods but rather cultural services produced on large collections of digital multimedia.

2.3 Sound and Music Computing

From a scientific-technological perspective, cultural heritage belongs to the area of Sound and Music Computing (SMC), category H.5.5 of the ACM Computing Classification System [Information Interfaces and Presentation (HCI)]. This research area is defined in [13] as the evolution of Music Informatics and Computer Music. Today SMC approaches the whole sound and music communication chain, including the non-musical related activities (interface design, access tools, ...; Figure 2.3); it aims at understanding, modeling and generating sound and

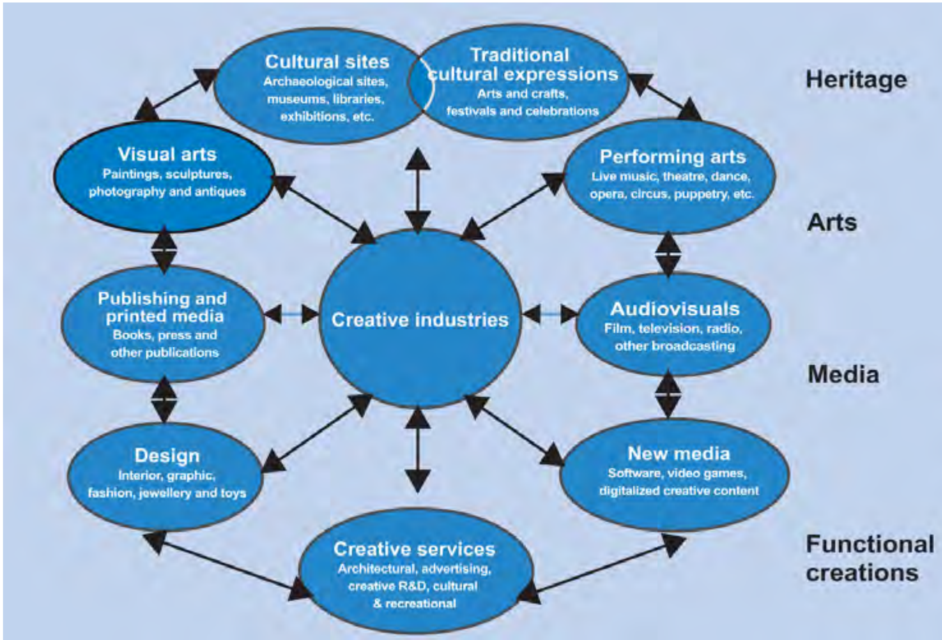


Fig. 2.2: Creative industries comprise four large groups, taking into account their distinct characteristics. The connections between specific sectors of these groups (heritage, arts, media and functional creations) are reported in this scheme (source [12, p. 14]).

music through computational approaches. SMC is a highly multidisciplinary research area, the academic subjects of which relate to music (composition, performance, musicology), science and technology (physics, mathematics, engineering) and psychology (including psychoacoustics, experimental psychology and neurosciences). Its approach and its methodologies are empirically-based and modeling-based, drawing upon advanced tools for measuring and processing information.

The main fields of application for SMC are:

- Digital music instruments
- Music production
- Music information retrieval
- Digital music libraries
- Interactive multimedia systems
- Auditory interfaces
- Augmented action and perception

The area of Digital musical libraries "places particular emphasis on preservation, conservation and archiving and the integration of musical audio content and metadata descriptions, with a focus on flexible access. Applications range from large distributed libraries to mobile access platforms."

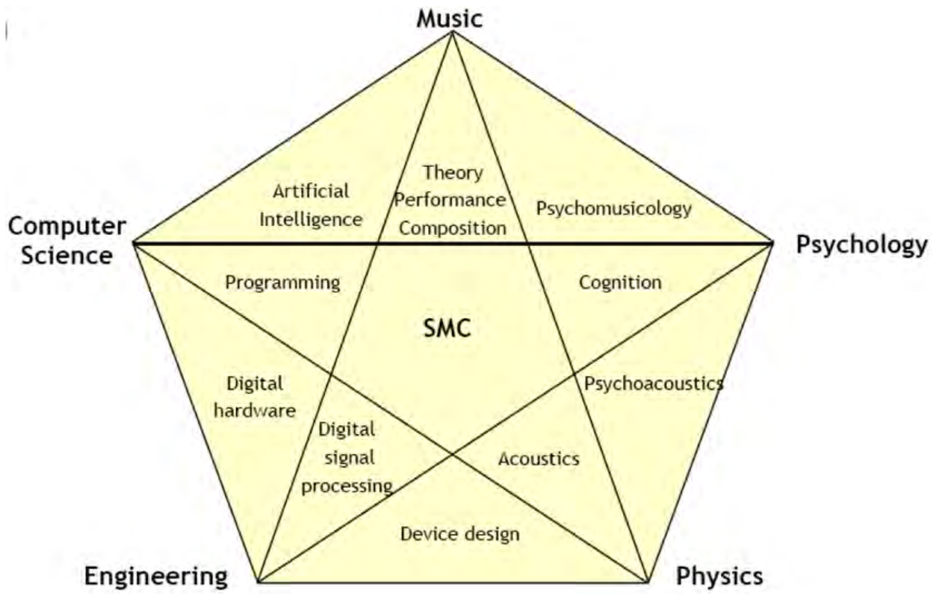


Fig. 2.3: Schematic organization of the disciplines involved in the research area of Sound and Music Computing (adaptated from [14]). Music tops the scheme and it constitues its guiding thread.

2.4 Scenario

Although the intent of the methodology for preservation is to be general, some of its aspects are addressed to a specific type of archives. While all archives face common problems such as obsolescence and degradation of the carriers, some problems depend on the archive size, its history, its policies. The archive of the Arena di Verona is representative for a type of archive that is most often found in Europe (with few exceptions, such as the British Library or the *Institut National Audiovisuel* in Paris), as opposed to the the type of archive found in North America and in Australia. The main difference between the two resides in the fact that archives tend to be big and centralized in younger countries such as the US, Canada, Australia, while there are many, small to medium size archives in Europe. The reasons are obviously historical, but the consequences are manyfold: the fundings for archival services including preservation are fragmented in the European scenario, preventing economies of scale. The creation of a network of shared resources (documents, equipment, personnel, infrastructures) is obstructed by the lack of coordination at political and technical level: these archives cannot afford technological transfer autonomously, nor in-house software development. When necessary, the choices come down to commercial closed software systems, hardly ever designed on requisites that match the archives needs. The strong point of the present work consists in the fact that an original scientific methodology has been defined and applied in archives with the characteristics and problems typical of the European scenario. In this sense, the achievements of the REVIVAL project discussed in the article (the working environment, the software tools, the chemical analyses, the number of digitized documents, ...) are proportioned to this scenario and to the resources available for institutions such as the archive of the Arena di Verona as well as for many others such as European foundations, theatres, private collections, radio broadcastings.

2.5 Structure of the work

The thesis is organized in five parts. Part one explores the field of preservation with a focus on ethics and philology, reporting the positions of the most authoritative representatives within the international archival community with respect to the cultural dilemma of supporting preservation. In the light of these positions, the author proposes her own methodology for preservation, and details an operational protocol reflecting the theoretical principles. Part two describes the original software system that the author has developed with the aim of achieving a greater control over the quality of the preservation process, supporting and automatizing its related activities. Part three reports the results of chemical, mechanical and audio analyses that have been conducted in order to advance the understanding of one of the most common restoration methods for magnetic tapes: thermal treatment. Part four describes the research projects within the scope of which most of the work presented herein has been carried out. The archives involved have proved an invaluable testbed for the definition of the methodology, allowing the author to perfect the procedures in the light of the problems of real-world archives. Finally, part five opens a window on an advanced research field in the preservation area, focused on interactive multimedia installations. Sound is one of the elements that contributes to the creation of the artistic experience, and every aspect of audio preservation is comprised in this field, with the additional problems of dealing with multiple media and with real-time interaction. Included in the substantial appendix closing this work is a summary of the symptoms and signs of degradations affecting different types of audio media, obtained by crossing several sources and aligning overlapping/contradicting definitions.

Part I

Methodology and operational protocol

3

The preservation of audio documents

"Il XX secolo lascia ai suoi protagonisti il particolare privilegio storico di aver sommato la più elevata capacità distruttiva e costruttiva che l'umanità abbia conosciuto dalle sue origini."[1] [15, p. 27]

In the field of audio documents, "preservation is the total sum of the steps necessary to ensure the permanent accessibility – forever – of documentary heritage" [1] represented by the documents. It is mainly finalized at slowing the process of degradation that inevitably affects all audio carriers, and at copying the information stored on the carriers onto new carriers, in order to prolong its life expectancy (LE) and enable wider access.

Intangibility distinguishes audio documents from other cultural materials: because of the the dichotomy between the physical restoration of the carrier and the far more complex "restoration of the experience".

This Chapter presents the most significant positions of the thirty-years long debate that built around the preservation of audio documents. The ethics of preservation is discussed from the viewpoint of the multiple motivations for going digital, which result in different choices on the operational level (see Section 3.1).

3.1 Main reasons for digitization

The fact that digitization is the current best solution to the problem of carriers degradation has been gradually accepted by the international community. To date it is widely understood, yet the reasons for "going digital" can differ depending on the archive characteristics, size and policies. Being aware of these reasons is of paramount importance: "Be clear why you are embarking on a digitization

[1] English translation: "The Twentieth century leaves to its main characters the historical privilege of having ammassed the greatest destructive and constructive capability that human kind has known since its origins."

project: the purpose will determine the process and the costs" [16, p. 7]. This Section presents the main reasons accounted by some authoritative sources in the field.

The first reason for digitization according to [16, pp. 11–13] can be enhanced access to materials that were previously unavailable or only partially/locally available. Digitization, in this sense, is part of the democratic considerations promoted by archives, making public records more widely accessible. Access can be permitted to the metadata and/or to the data, enabling/extending the availability to support educational and outreach projects, or a defined stock of research material. Digitization may also be aimed at implementing the "virtual re-unification" of collections and holdings from a single original location or creator now widely scattered, or at creating a single point of access to documentation from different institutions concerning a special subject.
A second reason for "going digital" is to promote and to facilitate the access. The main purpose is to enable the use of material (original manuscripts and archives, maps, museum artifacts, rare books, ...) that cannot be consulted in its original form other than by visiting its specific repository, because it has been damaged or because it is easier and more productive to access without computer enhancement tools like OCR (Optical Character Recognition) or text encoding for converted texts.
Preservation appears as the third possible reason for starting a digitization campaign, mainly in presence of endangered or damaged source materials: in this case, "the main purpose is to create accurate reproductions of the originals on a long-lasting medium and not to select materials according to demand. These reproductions need to satisfy both users of today and future potential users, and must therefore both be of high quality and possess a physical stability that can be maintained over time" [16, p. 12].

Easily said than done: choosing a "long-lasting medium" is always the result of a compromise, like most things in the field of preservation. Besides, it is not specified what the requirements to "satisfy both users of today and future potential users" are, or what "high quality" means with respect to the audio format. However, the same source itemizes the reasons just described as follows [16, pp. 6-7]:

- To increase access: this is the most obvious and primary reason, where there is thought to be a high demand from users and the library or archive has the desire to improve access to a specific collection;
- To improve services to an expanding user's group by providing enhanced access to the institution's resources with respect to education and long life learning;
- To reduce the handling and use of fragile or heavily used original material and create a "back up" copy for endangered material such as brittle books or documents;
- To give the institution opportunities for the development of its technical infrastructure and staff skill capacity;
- From a desire to develop collaborative resources, sharing partnerships with other institutions to create virtual collections and increase worldwide access;
- To seek partnerships with other institutions to capitalize on the economic advantages of a shared approach;

(a) Technical equipment (b) Audio documents

Fig. 3.1: (a) Technical equipment for recording and for amplification at the audio laboratory of the Fondazione Arena di Verona; (b) open-reel tapes of the Fondazione Arena di Verona archive (see Section 11.1).

- To take advantage of financial opportunities, for example the likelihood of securing funding to implement a programme, or of a particular project being able to generate significant income.

Other reasons for embarking on a digitization project are accounted in [17, p. 81]: "some institutions wish to open up their collections to a wider audience and see digitization and the Internet as a method of achieving this desired aim. Other institutions see digitization as a way of providing access to delicate documents without damaging them. A third group has documents that are approaching the end of their life and digitization thus offers a method of preserving the information for future generations."

These lists show that the reasons for "going digital" may vary and sometimes overlap. Preservation never appears to be the first item on the lists, however the author believes that it should, an that it should be seen as a preliminary step to the realization of any other objective. Final users access audio resources that are the result of a processing chain which usually starts from a digital preservation master, so even when the ultimate goal is access, it makes sense to have a preservation master that is aligned with the highest standards and that is aware of the philological questions of accuracy and authenticity. The quality of the audio resources (in the sense of reliability, accuracy and faithfulness to the original), whatever their purpose may be, depends on the quality of the preservation master (preservation copy), which is the sole depositary of the true history of transmission of the document itself. And "putting long-term preservation at risk in order to satisfy short-term access demand is always a temptation, and sometimes a political necessity, but it is a risk that should be avoided if possible" [1, p. 14].

3.2 The ethics of preservation: a debate thirty years long

The problems related to the degradation of audio documents have implications that impact aspects other than the technical-operative one. Undoubtedly the most important are the philological and the ethical ones, which are described in the next Subsections from the point of view of the evolution of the historical debate in the international archival community.
It is worth noting that, in the Eighties/Nineties of the 20th Century, expert associations were still concerned about the use of digital recording technology and digital storage media for long-term preservation ([18, 19]). They recommended re-recording of endangered materials on analogue magnetic tapes, because of: a) rapid change and improvement of the technology, and thus rapid obsolescence of hardware, digital format and storage media; b) lack of consensus regarding sample rate, bit depth and record format for sound archiving; c) questionable stability and durability of the storage media. The digitization was considered primarily a method of providing access to rare, endangered, or distant materials – not a permanent solution for preservation. Smith, still in 1999, suggested that digitization should be considered a means for access, not preservation – "at least not yet" [20].
It is well-known that preserving the carriers and maintaining the dedicated equipment for their reproduction is hopeless. The audio information stored in obsolete formats and carriers is in risk of disappearing. To this end, the audio preservation community introduced the concept "preserve the content, not the carrier". Audio (and video) preservation must therefore be based on digital copying of contents. Consequently, analogue holdings must be digitized. At the end of the 20th century, the traditional "preserve the original" paradigm shifted to the "distribution is preservation" [6] idea of digitizing the audio content and making it available using digital libraries technology. Now the importance of transferring into the digital domain (active preservation) is clear, namely for carriers in risk of disappearing, respecting the indications of the international archive community [21–25].

For the longest time, the word 'archive' has been suggesting images of shelves and books. It is only recently that audiovisual material, first labeled as *non-book* material (the only way to define it was in contrast with books), earned the right to be stored in a controlled environment, next to the books, and to be regarded as worthy of permanent preservation. However, their inclusion has not been completely painless. It forced the archives to update their storage facilities and to plan radically new access strategies. Multimedia documents encompass a large variety of carriers and formats, and require special equipment to access their content. Whereas traditional media and tools remained in the possession of artists and curators, the multimedia technical and technological load has definitely reduced the autonomy of these cultural actors [26]. Traditional criteria for conservation – a document's originality, longevity and inherent economic value – are not applicable to multimedia documents. Archivists were faced with unprecedented problems that transcended their field of expertise, aggravated by the complex nature of multimedia documents and by their content, which cannot be accessed without mediation technology.

In the last thirty years, the awareness for the preservation of audio documents has increased, allowing them in the definition of cultural heritage. At the same time, the debate on the ethics of preservation got more lively and the tools to act the preservation practices have become richer. More recently, audio recordings have been recognized as an important documentary source for scientific research in the fields of linguistics, history, sociology, musicology and other disciplines. Their dignity has been equaled to that traditionally reserved to bibliographic sources, revealing once more the centrality of philological problems such as the authenticity and the authority of the documents.

Approaching the archival reality from a viewpoint of the methodological research and of the scientific reflection, the author has identified some critical situations in the management of the processes involved in the preservation of the audio patrimony. They have tried to propose effective solutions using original software tools, the design of which required (i) a reflection on the relevant characteristics of each type of carrier and (ii) the subsequent definition of a metadata set that meets the requirements of the methodology proposed by the author in the Chapter 4 as well as the requirements expressed by the archives. In order to do so, the author has considered the documentation produced by previous research projects [27–29] and by some of the most authoritative archives in Europe [30]. All of the tools described in this article are open source and accessible in the 'software' section of [31]. Promoting the circulation of these tools is a priority in the author's agenda because it implies the circulation of the methodological principles that lie behind them; this is especially addressed to medium and small archives that belong to that category of cultural institutions suffering from scarcity of fundings, of personnel and of technical/technological competences for preservation.
From the viewpoint of the scientific research, these tools fall within the scope of the area of *cultural interfaces*. The element of innovation consists in the adoption of a systemic approach to the development of software tools for quality control in the management of semi-automatized procedures for the creation and the description of digital archives for preservation, for the sharing of the information and for the maintenance of their integrity over time. In other words, for the automatic control of concurrent processes.
In fact, the great majority of the operations that characterize the archival routines are highly repetitive, and those involved in the active preservation of audio documents are no exception. As a consequence, the amount of time spent for the processing and the management of electronic files is considerable, and the well known pathologies of attention related to repetitive activities and/or low level tasks may induce the human operator to introduce errors which have a cascade effect on the workflow, causing the malfunctioning of the algorithms that check the internal consistence of the archive and the algorithms for information retrieval. Also for the long-term maintenance of the archive adequate tools are required, as on the one hand the periodical control of every single documents is not sustainable and on the other hand a sample check is not satisfactory.
In particular, the tools developed by the author: (a) reduce the duration of restoration/re-mediation sessions, (b) dramatically reduce the time necessary to create the access copies, and (c) they introduce a set of redundant automatized

(a) Open-reel tapes

(b) Acetate tape being played

Fig. 3.2: (a) Open-reel tapes stored in the office of a researcher in linguistics at the University of Padova. A significant dust deposit is visible on the cases. The tapes have been listed in an inventory and transported from Padova to Pisa in order to digitize them at the laboratory of the Scuola Normale Superiore (see Section 11.2); (b) an acetate open-reel tape playing on a TEAC 4-tracks recorder at the laboratory for audio preservation of the Fondazione Arena di Verona (see Section 11.1).

controls that ensure data integrity. PSKit PreservationPanel has been used for the preservation of audio documents in several projects described in Chapter 11.

3.2.1 "Two Legitimate Directions"

The journal article that started it all in 1980 bore the signature of William Storm, at that time Assistant Director of the Thomas A. Edison Re-recording Laboratory Syracuse University Libraries [32]. The article was posing the problem of standardizing the procedures for audio restoration for the very first time, and it became famous for the number of controversies it stimulated.
Storm individuated two legitimate directions, two types of re-recording which are suitable from the archival point of view: 1) the sound preservation of audio history, and 2) the sound preservation of an artist.

The first type of re-recording (Type I) represents a level of reproduction defined "as the perpetuation of the sound of an original recording as it was initially reproduced and heard by the people of the era." [32]. Storm's contribution aimed at shifting the archivist's interest from the simple collecting of audio carriers to the information contained in the recording, and at highlighting the double documentary value of re-recording by proposing an audio-history sound preservation: on the one hand, he wanted to offer a historically faithful reproduction of the original audio recording by extracting the sound content according to the historical conditions and technology of the era in which it was produced; on the other hand, he wanted to document the quality of sound reception offered by the recording and reproducing systems of the time. These two instances, conceptually joined in a single type of re-recording, had induced Storm to prescribe the use of original replay equipment. The aim of history preservation "is to first hear how records originally sounded to the general public".

The second type of re-recording (Type II) was presented by Storm as a further stage of audio restoration, as a more ambitious research objective, conceived as a coherent development of Type I: "The knowledge acquired through audio-history preservation provides the sound engineer with a logical place to begin the next step – the search for the true sound of an artist". Type II is then characterized by the use of "playback equipment other than that originally intended so long as the researcher proves that the process is objective, valid, and verifiable" [32], with the intent of obtaining "the live sound of original performers", transcending the limits of a historically faithful reproduction of the recording.

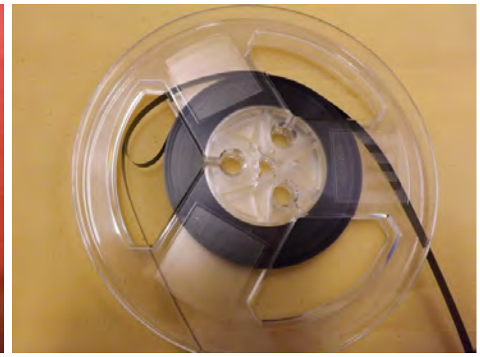
3.2.2 "To Save History, Not Rewrite It"

The Guide [25] commissioned by UNESCO reports the philosophical approach *save history, not rewrite it*. The audio section is clearly influenced by the new formulations made by Dietrich Schüller. Schüller's works [24] move from a different methodological point of view, "which is to analyse what the original carrier represents, technically and artistically, and to start from that analysis in defining what the various aims of re-recording may be" [24]. Regarding the reconstruction of the history of music perception Schüller states: "The only case where the use of original equipment is justified is in the exotic aim to reconstruct the sound of a historical recording as it was heard originally". Instead he points directly towards defining a procedure which guarantees the re-recording of the signal's best quality by limiting the audio processing to the minimum. Having set aside the general philosophical themes, Schüller goes on to an accurate investigation of signal alterations which he classifies in two categories: intentional and unintentional. The former include recording, equalization, and noise reduction systems, while the latter are further divided into two groups: the ones caused by the imperfection of the recording technique of the time, resulting in various distortions and the ones caused by misalignment of the recording equipment, for example, wrong speed, deviation from the vertical cutting angle in cylinders or misalignment of the recording in magnetic tape [25].

The choice whether or not to compensate for these alterations reveals different re-recording strategies: "historical faithfulness can refer to various levels: Type A the recording as it was heard in its time, which is equivalent to Storm's Type I presented in the previous section; Type B the recording as it has been produced, precisely equalized for intentional recording equalizations, compensated for eventual errors causedby misaligned recording equipment and replayed on modern equipment to minimize replay distortions" [25].

Type B re-recording defines a historically faithful level of reproduction that, from a strictly preservative point of view, is preliminary to any further possible processing of the signal. These compensations use knowledge which is external to the audio signal; therefore, even in the operations provided for by Type B, there is a certain margin of interpretation because a historical acquaintance with the document is called into question alongside with technical-scientific knowledge. For instance, to

(a) Cracked CD



(b) Tape folding over

Fig. 3.3: (a) Cracked Compact Disc. A crack is a "break without physical separation" [33, Appenix C, p. 2] (see also Appendix B); (b) open-reel tape affected by *cinching*: "the wrinkling, or folding over, of tape on itself in a loose tape pack. This may occur when a loose tape pack is stopped suddenly, causing outer tape layers to slip past inner layers, which in turn causes a buckling of tape in the region of the slip" [34, p. 21]. See also Appendix B.

individuate the equalization curves of magnetic tapes or to determine the rotation speed of a record. Most of the information provided by Type B is retrievable from the history of audio technology, while other information is instead experimentally inferable with a certain degree of precision. The re-recording work can thus be carried out with a good degree of objectivity and represents an optimal level within which the standard for a *preservation copy* (see Section 4.2.1) can be defined.
After having established an operational criterion for preservative re-recordings, based on stable procedures and derived from an objective knowledge of the degradations, Schüller individuated a third level of historically faithful reproduction, type C: "The recording as produced, but with additional compensation for recording imperfections caused by the recording technique of the time" [24]. While the compensations of type B are commonly accepted and must – as Schüller writes – be carried out, in type C they have to do with the area of equalizations "used to compensate for non-linear frequency response, caused by imperfect historical recording equipment and to eliminate rumble, needle noise, or tape hiss" [24]. These are operations which elude standard operational criteria and must therefore be rigorously documented by the restorer, who must write out accurate reports in which he specifies both the equipment and systems used as well as all the restoration phases.

3.2.3 "Secondary Information": the History of the Audio Document Transmission

The studies of George Brock-Nannestad [35] are in line with the modeling of the degradations through reverse engineering. In these studies he focused on the A/D conversion of acoustic recordings (thus recordings made before 1925) and, in particular, the strong line spectrum in the recording transfer function and unknown

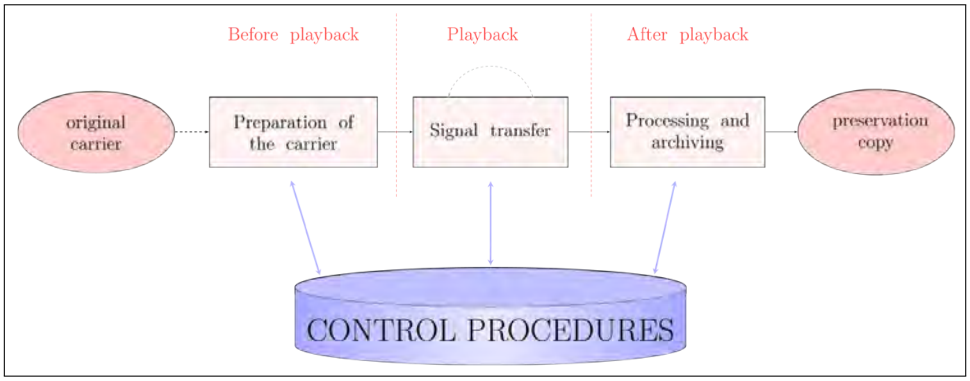


Fig. 3.4: Scheme of the re-mediation process, in which three distinct steps can be observed, as well as the set of control procedures applied during the workflow. Each step is articulated in procedures and sub-procedures.

recording speed. Brock-Nannestad goes back to the first studies in the acoustics of sound reproduction and to the scientific works of Dayton C. Miller [36], whom we must recall as the first to attempt to retrieve the true sound once it had been recorded. In order to be consistent and have scientific value, the re-recording work requires a complete integration between the historical-critical knowledge which is external to the signal and the objective knowledge which can be inferred by examining the carrier and the degradations highlighted by the analysis of the signal.

3.3 Preservation: passive and active strategies

The preservation of audio documents is divided in *passive* and *active*: the first aims at defending the medium from external agents without altering its structure, while the second involves data transfer onto new media. Passive preservation is further divided into indirect and direct: indirect passive preservation does not physically involve the audio document, but it involves preventative strategies that span from fire detection/suppression systems to disaster preparedness, including personnel training, environmental monitoring, and even political/legislative actions for the safeguard of cultural heritage. Indirect passive preservation is to be intended in a very broad sense, and the reason is that in a general perspective it becomes clear that documentary heritage is part of life and part of society, and it is influenced in various degree from many factors that are apparently far from the archives walls. Also the education of the general public, starting from the school system, influences the preservation of documentary heritage in the long run, because it modifies the perception that the value of the cultural patrimony holds in society, which is translated in economical support for preservation, access and fruition. Direct passive preservation is concretely focused on the documents, and it is generally carried out inside the archive. The documents are treated (cleaning, repairing, restoration) without altering their structure and composition. Direct passive preservation is also a preliminary step for active preservation (see the step

Carrier	Period	Composition	Stocks
cylinder – recordable	1886-1950s	Wax	300,000
cylinder – replicated	1902-1929	Wax and Nitrocellulose with plaster ("Blue Amberol")	1,500,000
coarse groove disc – replicated	1887-1960	Mineral powders bound by organic binder ("shellac")	10,000,000
coarse and microgroove discs – recordable ("instantaneous discs")	1930-1950s	Acetate or nitrate cellulose coating on aluminum (or glass, steel, card)	3,000,000
microgroove disc ("vinyl") - replicated	1948-	Polyvinyl chloride - polyacetate co-polymer	30,000,000

Table 3.1: Types of analogue mechanical carriers

'Optimization of the carrier' in the operative protocol in Chapter 5).
Active preservation allows us to copy, handle and store the audio documents in virtual spaces that can be remotely accessed by large communities. It consists in the *re-mediation*, or trans-mediation, of the acoustic information onto another medium. The methodology for preservation proposed in this work mainly addressed this aspect of the preservation chain. If the audio medium from which the signal is extracted uses an analogue recording technique, and the medium onto which the signal is re-mediated uses a digital technique, then the process can be referred to as *digitization*. The term 're-mediation' should be used in all other cases. However, the term 'digitization' is widely (and improperly) employed to describe active preservation in general, and sometimes the author accepts this habit for practical reasons in this work too. So, digitization is *necessary* to prevent the documents from degrading to the point where the information they store is not accessible anymore, and it is *desirable* because it allows to distribute them on a wide scale thanks to the digital technology. The next Section presents some aspects of passive preservation, while Chapter 4 details the methodology for preservation developed by the author, which is mainly focused on the re-mediation of the audio documents.

3.3.1 Passive preservation

The old maxim that "prevention is better than cure" is widely accepted as a truism for documentary heritage. Practices and techniques that slow down deterioration and potential handling damage are far better and cheaper than any recovery process [1]. The way audio media degrade depends on their chemical composition and is therefore specific for each type of medium. The process of degradation cannot be avoided – it can nevertheless be slowed down with adequate storage and handling – and with time it may compromise the readability of the document. This can be considered an *internal* factor, as opposed to external factors that threaten all types of media regardless of their composition and condition, such as natural disasters (flood, fire, earthquake and other calamities) or man-made disasters (looting, accident or war) [1]. In order to carry out an effective indirect passive preservation of audio documents, it is necessary to understand both internal and externals factors of threat, and to achieve a trade-off between ideal requirements, actual resources and costs. [37] contains a discussion on the external factors, while the next Subsections summarize some media-specific external factors and the main internal factors of degradation related to passive preservation for the most common types of audio media: mechanical carriers, magnetic tapes, optical discs and magneto-optical carriers. A comprehensive list of symptoms and signs of degradation for each type of medium is annexed in Appendix B of this work.

3.3.1.1 Mechanical Carriers

The common factor with this group of documents is the method of recording the information, which is obtained by means of a groove cut into the surface by a stylus modulated by the sound, either directly in the case of acoustic recordings or by electronic amplifiers. Mechanical carriers include: phonograph cylinders; coarse groove gramophone, instantaneous and vinyl discs. Table 3.1 summarizes the types of these carriers [38–43].

The main causes of deterioration are related to the instability of mechanical carriers and can be summarized as [38–40, 42]:

1. **Humidity**. Humidity, as with all other data carriers, is a most dangerous factor. While shellac and vinyl discs are less prone to hydrolytic instability, most kinds of instantaneous discs are extremely endangered by hydrolysis. Additionally, all mechanical carriers may be affected by fungus growth which occurs at humidity levels above 65% RH.
2. **Temperature** Elevated temperatures beyond 40 degrees Celsius are dangerous, especially for vinyl discs and wax cylinders. Otherwise the temperature determines the speed of chemical reactions like hydrolysis and should therefore be kept reasonably low and, most importantly, stable to avoid unnecessary dimensional changes.
3. **Mechanical Deformation**. Mechanical integrity is of the greatest importance for this kind of carriers. It is imperative that scratches and other deformation caused by careless operation of replay equipment are avoided. The groove that carries the recorded information must be kept in an undistorted condition. While shellac discs are very fragile, instantaneous and vinyl discs are more likely to be bent by improper storage. Generally, all mechanical discs should be shelved vertically. The only exceptions are some soft variants of instantaneous discs.
4. **Dust and Dirt**. Dust and dirt of all kinds will deviate the pick-up stylus from its proper path causing audible cracks, clicks and broadband noise. Fingerprints are an ideal adhesive for foreign matter. A dust-free environment and cleanliness is, therefore, essential. For some examples on the effects on audio signals, see Figures 3.5 and 3.6.

3.3.1.2 Magnetic Tapes

The basic principles for recording signals on a magnetic medium were set out in a paper by Oberlin Smith in 1880. The idea was not taken any further until

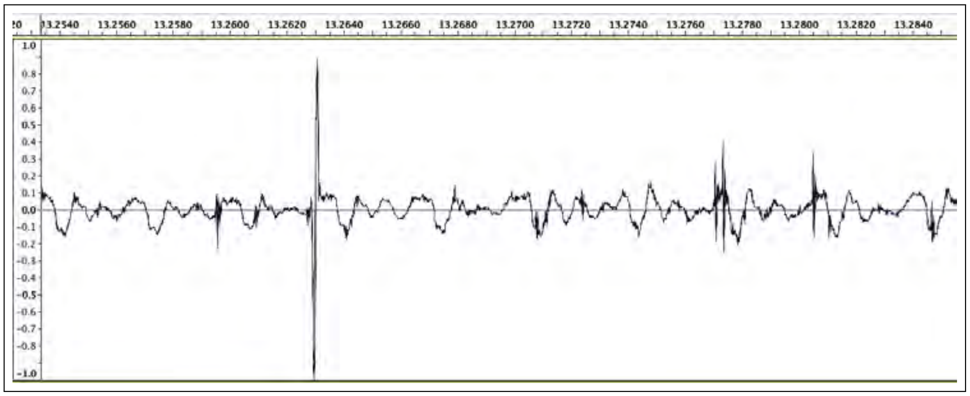


Fig. 3.5: The Figure shows an example of impulsive noise ("click") in the waveform of an audio signal extracted from a 78 rpm shellac disc. It is clearly visible at second 13.263. Such disturbance can be caused by a speck of dust in a disc groove. Time (seconds) is shown on the x-axis, amplitude (normalized) is shown on the y-axis.

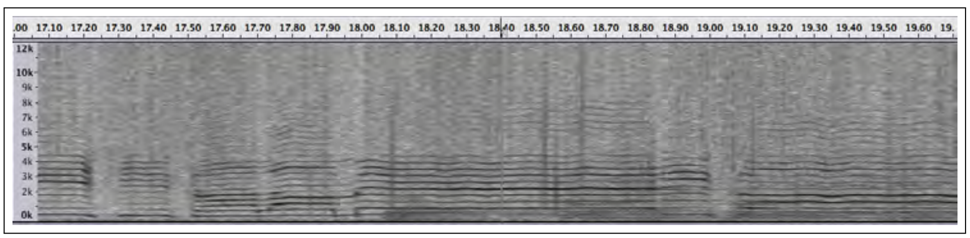


Fig. 3.6: The Figure shows an example of broadband noise and of impulsive noise in a spectrogram of an audio signal extracted from a 78 rpm shellac disc. Broadband noise is due to the granular nature of the material and its degradation over time. Time (seconds) is shown on the x-axis, frequency (Hertz) is shown on the y-axis. The shades of grey color show the amplitude: broadband noise is visible throughout the excerpt from the grey background (in contrast with the darker harmonic frequencies clearly visible up to ~5 kHz); impulsive noises correspond to the vertical lines at seconds 18.08, 18.53 and 18.63.

Valdemar Poulsen developed his wire recording system in 1898. Magnetic tape was developed in Germany in the mid 1930's to record and store sounds. The use of tape for sound recording did not become widespread, however, until the 1950's. Magnetic tape can be either reel to reel or in cassettes. Table 3.2 summarizes some types of these carriers.
The main causes of deterioration are related to the instability of magnetic tape carriers and can be summarized as [38, 40, 42, 44–46]:

1. **Humidity**. Humidity is the most dangerous environmental factor. Water is the agent of the main chemical deterioration process of polymers: hydrolysis. Additionally, high humidity values (above 65% RH) encourage fungus growth,

Period	Type of recording	Composition
1935-1960	Analogue	base: cellulose acetate magnetic pigment: Fe_2O_3 formats: open reel
1944-1960	Analogue	base: PVC magnetic pigment: Fe_2O_3 formats: open reel
1959-	Analogue	base: polyester magnetic pigment: Fe_2O_3 formats: open reel, compact cassette IEC I
1969-	Analogue/Digital	base: polyester magnetic pigment: CrO_2 formats: compact cassette IEC II, DCC
1976-1980	Analogue	base: polyester magnetic pigment: SLH Ferro (blue tabs, Type I) and FeCr (red tabs, Type II) formats: Elcaset
1979-	Analogue/Digital	base: polyester magnetic pigment: metal particle formats: compact cassette IEC IV, R-DAT

Table 3.2: Types of magnetic tape carriers.

which literally eats up the pigment layer of magnetic tapes and floppy disks[2] and also disturbs, if not prevents, proper reading of information.

2. **Temperature**. Temperature, coupled with relative humidity, is responsible for dimensional changes of carriers, which is a particular problem for high density tape formats. Temperature also determines the speed of chemical processes: the higher the temperature, the faster a chemical reaction (e.g., hydrolysis). It is also important to consider the direct effect of temperature and of relative humidity on the magnetic particles, but this behavior cannot be generalized because it depends on (i) relative humidity; and (ii) the type of iron oxide employed by tape manufacturers, which is often not documented[3].

---

[2] Floppy disks are one of the most used supports to store audio documents in the field of electronic music in the 80s and 90s of the last century. The composers usually saved in floppy disks some short sound objects, synthesized at low sampling Hertz ($8 - 15$kHz). The study of this musical excerpt is very important from a musicologist point of view. For instance, the Archive of the Centro di Sonologia Computazionale (CSC, University of Padova, Italy: `http://csc.dei.unipd.it/`) has hundreds of floppy disks: it is unquestionably an outstanding testimony of the musical history in the 1980s and 1990s.

[3] In 2011 the author started a collaboration with the Department of Industrial Engineering – chemical sector of the University of Padova, in order to exploit the knowledge and the techniques of chemistry and of materials science, which are scarce but much needed in the preservation field. A number of analyses are currently under processing in order to gain control of parameters such as temperature and relative humidity in relation with optimized storage environment conditions and carriers degradation. The analyses comprise: Fourier Transform InfraRed (FTIR) Spectroscopic analysis in

	temperature	±/24h	±/year	RH	±/24h	±/year
preservation storage	5°C $< t <$ 10°C	±1°C	±2°C	30%	±5%	±5%
access storage	about 20°C	±1°C	±2°C	40%	±5%	±5

Table 3.3: Recommended climatic storage parameters for mechanical and for magnetic tapes.

3. **Mechanical Integrity**. Mechanical integrity is a much underrated factor in the accessibility of data recorded on magnetic media: even slight deformations may cause severe deficiencies in the playback process. Most careful handling has to be exercised, along with regular professional maintenance of replay equipment, which, in case of malfunctioning, can destroy delicate carriers such as R-DAT very quickly. With all tape formats, it is most important to obtain an absolutely flat surface of the tape pack to prevent damage to the tape edges which serve as mechanical references in the replay of many high density formats. All forms of tape should be stored upright.
4. **Dust and Dirt**. Dust and dirt prevents the intimate contact of replay heads to the medium which is essential for the correct access to the information especially with high density carriers. The higher the data density, the more cleanliness has to be observed. Even particles of cigarette smoke are big enough to hide information on modern magnetic formats. Also pollution caused by industrial smog can accelerate chemical deterioration. The effective prevention of dust is an indispensable measure for the proper preservation of magnetic media.
5. **Magnetic Stray Fields**. Magnetic stray fields are the natural enemy of magnetically recorded information. Sources of dangerous fields include dynamic microphones, loudspeakers and headsets. Also the simple magnets used for magnetic notice boards possess magnetic fields of dangerous magnitudes. By their nature, analogue audio recordings, including audio tracks on video tapes, are the most sensitive to magnetic stray fields.

Among the others, some effects can be:

- "drop out" (i.e. the magnetic material fall off the tape);
- "print-through" (i.e. a condition where low frequency signals on one tape winding imprint themselves on the immediately adjacent tape windings);
- "stretch" (i.e. the actual permanent stretching of the polyester cause by too tightly spooling the tape with noticeable pitch dropping).

Table 3.3 shows the correct parameters for the passive preservation of mechanical carriers and of magnetic tapes [39, 40, 42, 47].

3.3.1.3 Optical discs

Optical disc recording technologies are based on the encoding of binary data in the form of *pits* and *lands* on one of the disc's surfaces. When read, pits and lands

ATR, ThermoGravimetric Analysis (TGA), Scanning Electronic Microscopy (SEM), Acetone extraction test, Acidity test and X-Ray Diffraction.

Carrier	Period	Type of recording	Composition
CD	1981-	Digital	base : polycarbonate reflective layer: aluminium, varnish, inks
CD-Recordable	1992-	Digital	base: polycarbonate reflective layer: gold, silver, varnish, inks
CD-Rewritable	1996-	Digital	base: polycarbonate reflective layer: varnish, inks
SACD	1999-	Digital	base: polycarbonate reflective layer: silver coating: lacquer
DVDA	2000-	Digital	base: polycarbonate inner layer: aluminium outer semi-reflective layer: gold coating: lacquer

Table 3.4: Types of optical discs [48].

reflect the laser light projected along the data path: pits correspond to the binary value of 0, due to lack of reflection, and lands correspond to the binary value of 1, due to a reflection. The beam of light is emitted by a laser diode, usually in an optical disc drive which spins the disc at speeds of about 200 to 4000 rpm or more, depending on the drive type, on the disc format, and on the distance of the read head from the center of the disc. The most common optical audio carriers include Compact Discs (CDs, with a diameter of 12 centimeters), Mini CDs (with a diameter of 8 centimeters) and LaserDiscs (LDs), besides the variants super audio CD (SACD) and Digital Versatile Discs Audio (DVDA) (see Table 3.4).
Digital information is pressed into a polycarbonate base, coated with a light reflective layer usually made of aluminum, however gold and silver are also used. A transparent lacquer is placed over the reflective surface in order to protect it. Most optical discs do not have an integrated protective casing and therefore they are easily subject to scratches, fingerprints and other environmental problems, described in Appendix C of [33] and in [34, 49, 50].

1. **Discoloration (includes Hazing, Bronzing and Oxidation)**. A type of corrosion that affects the reflective layer, manifesting as a change in color on the surface. It may be caused by aging or by temperature problems at the time the discs were pressed. It usually starts at the edge of the disc and slowly works its way towards the center.
2. **Mold**. "Mold usually takes the form of white or grey patches on the surface, with a characteristic [fuzzy] structure visible under low-power magnification." [33] The onset of mold is related to the humidity rate in the storage environment, and on the presence of other carriers affected by mold in the same environment.
3. **Mechanical Integrity**. Mechanical integrity is a fundamental factor in the accessibility of the data recorded on digital optical media. Unlike in mechanical carriers and, to some extent, in magnetic tapes, where localized damage does

	temperature	±/24h	±/year	RH	±/24h	±/year
preservation storage	about 20°C	±1°C	±3°C	40%	±5%	±5%

Table 3.5: Recommended climatic storage parameters for optical media.

not prevent access to other parts of the carrier, the loss of a set of bits prevents that the rest of them are correctly read. Plus, due to the functioning of the error correction algorithms, it is hard to predict when the error rate will trespass the capacity of the algorithms to compensate such errors, and the carrier will be suddenly irrecuperable. Mechanical integrity involves damage ranging from scratches of various size and depth, to cracks (breaks without physical separation), chips (missing small pieces, usually from the edge of the disc) and breaks (he disc has broken into distinct parts).

Table 3.5 shows the recommended climatic access storage parameters for optical discs [48].
The behavior of digital optical media in their physical decay appears to reflect their "binary" nature: a disc will be either playable or unplayable, with very little difference in between (compared to the corruptions that can affect magnetic tapes and that result in many levels of seriousness). When a disc is corrupted but still playable, the extracted signal will be often characterized by impulsive noises, sometimes intermitted with entire sets of consecutive missing samples. Since monitoring during the process of signal extraction is not provided for this type of carriers (see Subsection 5.1.1), it is mandatory to validate the data (either automatically or manually) before storing it in a preservation copy, as the extraction might terminate successfully but the extracted signal might nevertheless be corrupted.

3.3.1.4 Magneto-optical carriers

Sony announced the MiniDisc (MD) audio format to appear in 1992, promising a combination of CD clarity with cassette convenience. Despite the expectations, MiniDiscs did not do very well on the market, and were eventually overshadowed by solid state memory audio recorders. Altogether the format survived two decades: Sony announced that the development of MD devices will be halted in March 2013.
The data is memorized in two steps: a laser heats one of the sides of the disc, making the material in the disc susceptible to a magnetic field, and on the other side, a magnetic head alters the polarity of the heated area. Then the data is accessed with the laser alone: taking advantage of the magneto-optic Kerr effect (MOKE), the player senses the polarization of the reflected light and is able to read the binary values.

Table 3.6 reports some manufacturing details about pre-recorded ("replicated") and recordable MiniDiscs [48].
With regards to degradation, MiniDiscs are mainly threatened by dust and dirt deposits especially within the housing, and in general they share the same problems of optical discs.

Carrier	**Period**	**Type of recording**	**Composition**
MD replicated	1992-2013	Digital	base : polycarbonate reflective layer: aluminium, varnish
MD recordable	1992-2013	Digital	base: polycarbonate magneto-optical layer: ferromagnetic material reflective layer: aluminum

Table 3.6: Types of MiniDiscs [48].

4

A methodology for preservation

> *In the past restoration was performed by artists of the same discipline. The main objective of the effort was to improve the aesthetic appearance and conceal the fact that the article was damaged and repaired. [...] Their repair procedures were secretive and the restoration went undocumented. Secret recipes and procedures were used and were only passed to others through apprenticeships. Often restorers added their own touch and made changes they thought were appropriate without considering the original intent of the artist.* [51, p. 12]

This Chapter presents the methodology for the preservation of audio documents proposed by the author. The methodology builds on the previous work carried out since the 1990s at the Centro di Sonologia Computazionale (CSC), Department of Information Engineering of the University of Padova. The concepts of *preservation copy* and *access copy*, inherited from the work at CSC, have been evolved by the author during her work with the archives of the Fondazione Arena di Verona and of the Scuola Normale Superiore di Pisa, which have been precious testbeds for the assessment of the working methods.
The methodology is divided in three main stages: preliminary activities, the remediation of audio documents, and the preparation for access. The protocol that translates the methodology into the operational level is described in the next Chapter.

4.1 Preliminary activities

Preservation is "both labour intensive and expensive" [16, p. 7]: dealing with delicate documents of high cultural value, it requires resources (in terms of equipment, infrastructure and trained personnel) and a good coordination. It does not coincide with the digitization of the audio materials, as is often thought. "It is not simply a case of buying some equipment, connecting it and starting work" [17, p. 81]: political, ethical, methodological and logistical-operative choices must be made in order to define a preservation plan that takes into account (i) the objective of the operation, (ii) the budget extent and (iii) the eventual time frame limitations. On top of this, the long-term storage and the access systems must be prepared. The next Subsection reports some cues for reflection proposed by some authoritative sources in the archival field.

4.1.1 "Before you start, ask yourself"

The main aspects to consider before starting the digitization can be expressed in the form of direct questions or checklists. "Before you start, ask yourself" is the title of the list proposed by the International Federation of Library Associations and Institutions (IFLA) in [16, p. 7]:

1. Is the project?
   - 1.1 User driven: high demand for (enhanced) access
   - 1.2 Opportunity driven: money available so we can do something
   - 1.3 Preservation driven: high demand on fragile objects
   - 1.4 Revenue driven: we might make some money from it
2. Do we have
   - 2.1 The money
   - 2.2 The skills
   - 2.3 The capacity
   - 2.4 The technical infrastructure
3. Carry out
   - 3.1 Benchmarking study
   - 3.2 Copyright study
   - 3.3 Feasibility study
   - 3.4 Technical pilot study

Some cues are also proposed by George Boston[1] in [17, p. 81]:

4. Are digital copies to be made for access or preservation or both?
5. What prioritization of the making of the digital copies is to be applied? Are endangered documents to be digitized first or is priority to be given to those in highest demand?
6. What speed of access is required? Do the anticipated demands on the service require the very fast access offered by hard disc arrays (a few seconds), the medium speed access of tape drives (a few minutes) or the slow access of carriers housed on a traditional library shelf (a few hours)?
7. Is access only required at workstations within the institution or is the service to be offered "beyond the walls"?

Note that some points of the different lists could be assimilated:
– point 1 and point 4: both refer to the objective of the digitization (which is detailed in Subsection 3.1); – point 1.3 and point 5: both address the question of the criteria for selecting the documents and for establishing a priority for digitization

[1] Member of the Technical Committee of the International Association of Sound and Audiovisual Archives (IASA), Member of the Audio Engineering Society (AES), and Rapporteur of the Sub-Committee on Technology (SCoT) for the Memory of the World Programme (UNESCO).

(a) Equipment maintenance (b) Damaged magnetic tape

Fig. 4.1: (a) Cleaning the audio heads of a reel-to-reel recorder before starting a new re-mediation session at the laboratory for the preservation of audio documents of the Fondazione Arena di Verona; (b) magnetic tape with a spotted backcoat shedding syndrome (see also Appendix B).

(which are detailed in Subsection 4.1.2).

In the light of these considerations, the author wishes to propose a summary of the aspects to consider in the preliminary phase of a digitization project, including some additional points basing on her experience:

1. Objective of the digitization [points 1 and 4];
2. The number, the type and the condition of audio documents (requiring survey and diagnostic tools);
3. The availability of functioning technical equipment, compatible with the recording formats of the documents (problem: sometimes the recording format can only be determined by playing the documents. Is the equipment available? Where? Are there experts capable of discerning the formats? What if the document is damaged and requires restoration to be played?) [point 2.4 expanded];
4. Are there limitations to the project's time frame? [specification of point 3.3];
5. Who will actually perform the job? Where? [point 2.2-4];
6. Long-term storage system for the maintenance of the digital archive of preservation copies (related to point 6);
7. Long-term storage for the physical source documents, which must be maintained for future comparison with the digital copies or for another digitization[2];
8. Copyright issues on the digitized material [point 3.2].

The next Subsection explores the criteria for the selection of the documents, and the priority assigned to the documents during the re-mediation process.

[2] "Many institutions have regretted the premature destruction of originals after making copies that proved to be inferior." [1, p. 13]

4.1.2 Criteria for selection

Before the re-mediation process starts, it is necessary to define a preservation schedule: "A clearly defined hierarchy of priorities for digitizing is imperative to avoid, for example, stable materials being transferred first, while in the meantime unstable materials deteriorate to the point where they become irretrievable" [52, p. 4]. The prioritization depends on the number of documents, on their state of preservation and on the archive priorities/policies. The varying ratio between the size of the collection and the resources available may determine wether an archive is able to digitize its entire holding or not. Other factors also come into play: for example, an archive may decide that some document are not worth preserving according to the archive's internal policy (there is no right from wrong in this field: it is a matter of deliberate decisions, which nonetheless should be clear, declared and taken the responsibility of).

The preservation schedule is usually defined after a study of the characteristics and of the state of preservation of the documents is done, because the information acquired have a substantial weigh in planning the next steps. Determining a satisfactory schedule is not straightforward and always requires a compromise, as the criteria to consider are often in contrast. It is interesting to observe that the criteria suggested by the main institutions in the field have are almost opposite to each other:

IFLA (International Federation of Library Associations and Institutions) [16]

1. Content: intellectual value of materials, their historical, scientific and cultural significance (unique sources must have priority);
2. Demand: priority is given to materials in constant demand;
3. Condition: fragile and damaged unique materials (restoration procedures may be needed before the transfer).

IASA (International Association of Sound and Audiovisual Archives) [52, p. 5] and [53, p. 10]

1. Documents in immediate risk / recordings on endangered media;
2. Documents who are part of an obsolete or commercially unsupported system;
3. Documents in regular demand.

It is clear that the definition of the criteria for selection is an arbitrary choice, and a mandatory one, the responsibility of which belongs to the stakeholders, i.e. the archival institutions. Generally, the author's preference is a trade-off between the IFLA and the IASA positions:

1. Documents in immediate risk / recordings on endangered media;
2. Demand: priority is given to materials in constant demand;
3. Documents who are part of an obsolete or commercially unsupported system.

Once the preservation schedule is planned, the re-mediation process can start.

4.2 Active preservation

A central concept in the operational protocol proposed in this work is the *preservation copy* of an audio document. Before describing the activities involved in the active preservation, a better definition of preservation copy is provided.

4.2.1 Preservation Copy

A preservation copy consists in an organized data set that groups all the information represented by the source document. According to the International Association of Sound and Audiovisual Archives (IASA), a *preservation copy* (or archive copy) is "the artifact designated to be stored and maintained as the preservation master. [. . .] Such a designation means that the item is used only under exceptional circumstances[3]" [54]. Restoration, when referred to a preservation copy, is only allowed if it is intended to optimize the physical condition of the carrier before signal extraction (no restoration on the audio signal is allowed, e.g., denoise, declick, . . .). In the author's view, only the intentional alterations should be compensated (e.g., correct equalization of the re-recording system and decoding of any possible intentional signal processing interventions). As has been said in Subection 3.2.2, Schüller suggests that also unintentional alterations are compensated at a preservation copy level. Differing from this position, the author believes that unintentional alterations should not be compensated at this level, since they *witness the true history of the transmission of the audio document*, representing the so-called "secondary information" introduced in Subsection 3.2.3[4].

A preservation copy is obviously a different artifact than the document of origin, so to be called a "preservation master" – according to the IASA definition [33] – it must minimize the loss of information represented by the document of origin (audio and non-audio data), and it must report an exhaustive documentation of the

[3] Audio carriers, especially modern high density formats, are vulnerable by their very nature. In addition, there is always the risk of accidental damage through improper handling, malfunctioning equipment or disaster. A possible strategy is the creation of *first-level access copies*, low quality copies of preservation copies that can serve as an adjunct to the catalogue, to help researchers decide what documents they wish to study. An copy of average/good quality may be acceptable for access *in situ* of the original. Relying on copies (online or locally) to reduce the frequency of access to the physical original will reduce the stress on the original and help its preservation. A clear policy about the classes of researchers that are allowed access to physical originals – particularly fragile ones – will also help the documents survival. It is clearly impossible to totally restrict the access to originals, but most users can carry out their research using good quality access copies [38].

[4] For example: bias frequency (the addition of an inaudible high-frequency signal to the audio signal. Bias increases the signal quality of audio recordings pushing the signal into the linear zone of the tape's transfer function [55]) or broadband impulsive noise (approximately ranging from 100Hz to 100kHz, it can be caused by electrostatic discharges, by imperfections of the electrical/electronic circuits, or by other damage of electrical-chemical-mechanical nature). Both fall outside the frequency range of the primary information (desired signal), and this is why the re-recording must be carried out at the highest standards available.

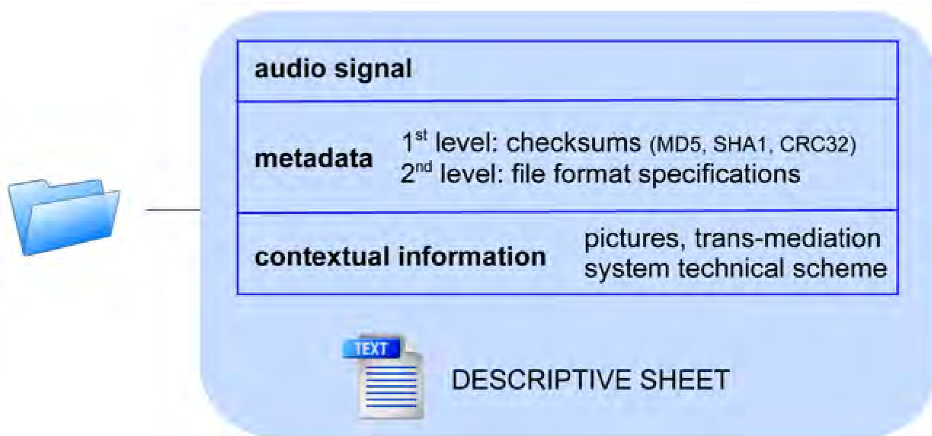


Fig. 4.2: Logical representation of the elements contained in a preservation copy.

document provenance, of the data transfer and of the transfer system. During the re-mediation process, every part of the physical original document – multimedia in itself, because it consists of audio, images (label, case, carrier corruptions, . . .), text (accompanying material), smell (mould, vinegar odor, etc.) – is converted into a digital file, which results in an *unimedia* document: a fusion of different media in a single flow of bits [56]. What cannot be directly represented in a digital form (i.e., smell), is thoroughly documented in the descriptive sheet. Figure 4.2 shows the logical structure of a preservation copy: it includes (a) a descriptive sheet listing all of the files in the preservation copy, the provenance of the document, the details about each audio file and the venue of the transfer along with the person responsible for the creation of the copy; (b) the audio signal; (c) first level metadata:[5] the checksum of the audio files (in this work, three types of checksum are considered, according to the international guidelines: MD5, SHA-1 and CRC32); second level metadata: technical specifications of the file formats included in the preservation copy (bwf, pdf, . . .); (d) photographical documentation of the carrier, its case and the accompanying material, and a technical sheet describing the transfer system. The purpose of providing a preservation copy with this documentation meets the requirement expressed in [58], that all compensations and processing, if applied, are "based on the capacity for precise counteraction" (which means

[5] In a preservation copy, a distinction is made between *metadata* and *contextual information*. Metadata indicates the content-dependent information that can be automatically extracted from the audio signal; contextual information is the additional content-independent information, such as a photographical documentation of the carrier case and the accompanying material [57]. Two levels of metadata are also found (see Figure 4.2): the first is represented by metadata that were extracted directly from the audio signal contained in the preservation copy; the second is represented by the documentation of the file formats contained in the preservation copy (audio signal and contextual information, i.e., text, still images, . . .).

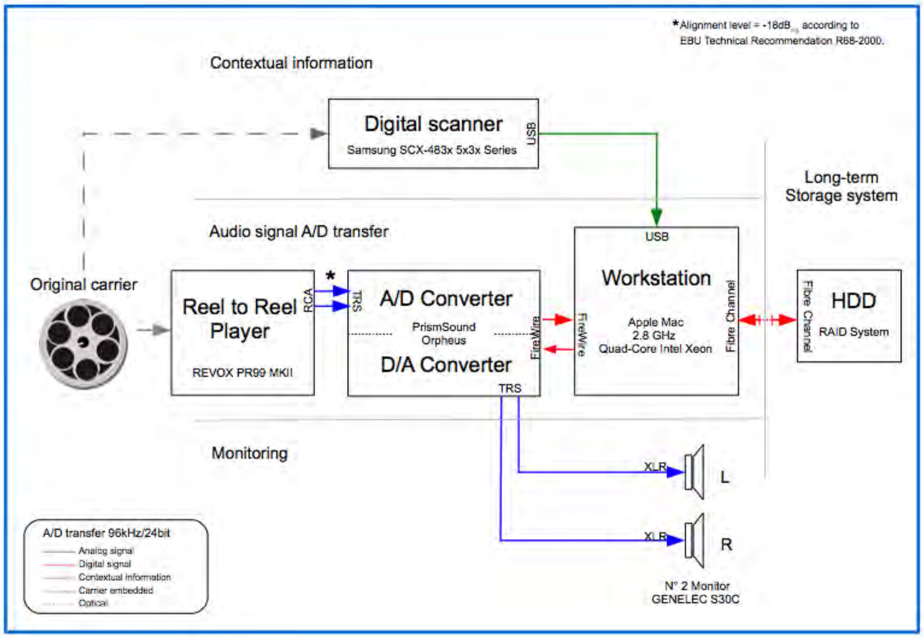


Fig. 4.3: Example of a transfer scheme included in a preservation copy (contextual information).

reversibility of each operation and, consequently, capacity to trace the original characteristics/values that were modified).

4.2.1.1 Format for the Audio Files

According to the precept *the worse the signal, the higher the resolution*[6], the audio signal should be stored in the preservation copy using the Broadcast Wave Format, sampled at least at 96 kHz with a 24 bit resolution (for digital source documents, such as Compact Discs and Digital Audio Tapes, the sampling frequency and resolution of the preservation copy can equal the original). It is advisable to use the monophonic format, where each recording track is equivalent to a different file with Pulse Code Modulation representation [53, 59]. For further details on Broadcast Wave Format refer to [60, 61].

[6] George Brock-Nannestad (October 2007): personal communication to the author. The statement bases on the fact that the characterization of the documents with a low quality useful signal usually relies on its corruptions, which are generally spread on a broad band. Therefore a high resolution is needed in order to capture as much information about the corruptions.

4.2.1.2 Video Shooting and Photographic Documents

The information reported on edition containers, labels and other attachments should be stored with the preservation copy as a static image, as well as clearly visible carrier corruptions (two examples are given in Figure 4.4).
A video of the carrier during playback – synchronized with the audio signal – ensures the preservation of eventual information on the carrier, especially open-reel tapes (physical conditions, presence of intentional alterations, corruptions, graphical signs). The video recording offers:

1. Information related to magnetic tape assembly operations and corruptions of the carrier (disc, cylinder or tape), which are indispensable to distinguish the intentional from the unintentional alterations during the restoration process [21, 62, 63].
2. A description of the irregularities in the playback speed of analogue recordings (wow and flutter[7]): in discs, a spindle hole not precisely centered and/or the warping of the disc cause a pitch variation; in tape recorders, an irregular tape motion during playback (a change in the angular velocity of the capstan, or dragging of the tape within an audio cassette housing) cause changes in frequency. From the video, it is possible to locate automatically the imperfections occurred during the A/D transfer [57] and to distinguish them from the alterations already present in the recording, thus increasing the information about the signal, useful for restoration.
3. Instructions for the performance of the piece (in particular in the electroacoustic music for tape): from the video analysis, some prints of the tape can be displayed; they represent either the synchronization of the score or the indication of particular sound events.

The video file should be stored with the preservation copy. The selected resolution and the compression factor must at least allow to locate the signs and corruptions of the carrier. In the author's experience, a 320x240 pixels resolution video with medium quality DivX compression met this requirement.

4.2.1.3 Descriptive sheet

A preservation copy is meant to be self-explicated. It should provide all the information needed to access, read and interpret correctly its content in twenty or a hundred years from now. Apart from the technical specifications of the file formats, this aim is achieved with the inclusion of a descriptive sheet, which proves useful also in case the logical structure of the archive is modified and some documents get misplaced. A descriptive sheet is divided in four sections:

[7] Wow and flutter are audio distortions perceived as an undesired frequency modulation in the range of [64]: i) wow from 0.5 Hz to 6 Hz, ii) flutter from 6 Hz to 100 Hz. The distortions are introduced to a signal by an irregular velocity of the analogue medium. As the irregularities can originate from various mechanisms, the resulting parasitic frequency modulations can range from periodic to accidental, having different instantaneous values.

(a) (b)

Fig. 4.4: (a) Example of one of the set of images included in the preservation copy of a Compact Cassette. Each element should be clearly visible in all its details, so usually a preservation copy contains from four to eight images. It is recommended that at least one includes the carrier with all its accompanying material – especially if these are not listed somewhere else in the textual documetation. Below the document's signature, a small ruler can be observed: according to the recommendation of the Italian Ministry of Cultural Heritage [65], this simple object conveys the real proportions of the depicted elements; (b) Serious corruption of an optical disc: this image should be stored in the discs' preservation copy in order to add information about the artifacts of the audio signal.

1. A complete list of the elements included and their relative path;
2. Description of the preservation copy (general info and audio metadata for each audio file);
3. Description of the source document (provenance, recording format, . . .);
4. Description of the video recording, if present.

4.2.1.4 Data Integrity Verification

It is widely accepted that, for both technical and economic reasons, the preservation of audio documents relies upon transfer to, and storage in, the digital domain. However, digital files and carriers are not immune from format obsolescence and physical degradation. Quite the opposite: the pace at which technology advances makes each new "generation" shorter, and a minor physical corruption can make all the information inaccessible (unlike analogue carriers, where a scratch on the surface of a phonographic disc does not prevent the access to other parts of it). In this sense, digital files and carriers show weaknesses that are even more dangerous than the analogue ones, because "digital information can be lost – without warning – at any time" [66]. Such evidence calls for safety strategies. The most straightforward is having multiple copies of the documents, so that if one is corrupted or erased, another is available. The slogan "one copy is no copy" [66] expresses this principle: a minimum of two copies must be available at all stages of the transfer and archiving process. Fortunately, the act of copying digital files does not incur the loss of fidelity inherent in analogue copying, so two or twenty copies do not deteriorate the files quality. However, a corrupted file might be copied several times, and the error(s) would not show until the file is being read, which is too late. A possible solution is to extract and to save the documents' checksum and to verify them periodically. This ensures data integrity during the preservation workflow, or during storage or transmission. Our methodology provides that three different types of checksum of the audio files are extracted (MD5, SHA-1 and CRC32)[8]. According to the preservation best practices expressed in [2], the methodology proposed by the author provides that the checksum values are stored within the preservation copy (in the descriptive sheet and in an XML file) as well as in the database, with backup copies kept in multiple physical locations. This avoids susceptibility to a single point of failure in the system or other disasters.

Related concepts to that of preservation copy, are the concepts of first-level access copy and second-level access copy.

4.2.2 First-level access copies

When preservation is the goal, the job ends when the long-term archive of preservation copies is created. If access is the goal, other documents, with special characteristics, will have to be derived from the preservation copies, which are *not* meant for access.
First-level access copies are not subject to strict limitation for file formats and other characteristics as much as preservation copies. Their main function is to enable *access* to the content of the preservation copies, which are imperatively "used only under exceptional circumstances" [33], and that are usually stored in places other than the archive or/and on carriers with slow access (for example, tape drive for low-term storage). In first-level access copies, the duration, the number and the order of the tracks should remain unaltered with respect to the preservation copy. At this level, restoration is permitted, such as the application of de-hiss and de-noise filters, mainly for enhancing the Sound-to-Noise Ratio (SNR) and the intelligibility.

4.2.3 Second-level access copies

By definition, first-level access copies are unaltered with respect to preservation copies in the number and in the duration of audio files (which include silence). The purpose of a second-level access copy, by contrast, is to provide easy access to the *content*, meaning that between the first-level and the second-level access copy there is a shift in the approach to the document: first-level access copies are strictly about preservation, second-level access copies are about the content, which requires interpretation.

[8] The terms "checksum" and "message digest" are commonly used interchangeably. However, the term "checksum" is more correctly used for the product of a cyclical redundancy check (CRC32), whereas the term "message digest" refers to the result of a cryptographic hash function (MD5, SHA-1).

The format of second-level access copies is flexible: this is easily understood when the importance of the preservation copies is clear. If there is a preservation master that meets all the requirements discussed in this Chapter, numberless versions of the recording can be made without losing the objective knowledge about the source document, ensuring reliability, accuracy and philological authenticity. The dichotomy between carrier and content (i.e., artifact and information) distinguishes audio recordings from other cultural materials such as sculptures and paintings: in these cases, preservation and restoration are addressed to the object representing the cultural good, the meaning of which cannot be separated from the physical expression [67]. Conversely this separation can be performed in audio recordings, allowing for multiple restorations (interpretations) without altering the document of origin directly.
A second-level access copy is an audio digital resource, derived from downsampling, cutting or processing, according to one's needs, audio files that come from the archive of preservation copies. Examples are: (i) an opera in MP3 format, from which the silent portions of the tape have been eliminated, and that was split in tracks matching the scenes according to the score (at this stage the knowledge about the content, musically speaking, is equally important than the audio-technical expertise); and (ii) a Compact Disc with a collection of tracks requested by the ballet for rehearsals in a specific order and of specific length.

The definition of two levels for access copies is original to the author's work. In the methodology inherited by the previous research projects there was one type of document simply called 'access copy', which corresponds to the first-level access copy described in the paragraphs above. The process of preparation for access (i.e., cataloguing) in the methodology had not been formalized yet, with the implicit assumption that the public would access down-sampled versions of the preservation copies, without any further processing (i.e., interpretation).
It is not mandatory to create both first- and second-level access copies. Depending on the institution's needs and on the type of access it aims at providing to its public, the creation of first-level access copies might be sufficient. In the author's belief, however, second-level access copies constitute a more consistent collection of resources: after all, preservation copies are meant for long-term archiving, and first-level access copies are but their down-sampled versions, while second-level access copies are *conceptually* different, being conceived from a different viewpoint (i.e., the content) – although their descendance from first-level access copies is clearly maintained. In the author's opinion, the creation of flexible tools and arbitrarily sophisticated services for access would build better on a collection of second-level access copies (the user would not need any reference to levels: to him/her, they would simply be 'audio resources'). Second-level access copies allow a finer-grained description of the content, and the consistency of the collection would be reflected in a cleaner organization of the metadata.
There are some cases where second-level access copies might not be necessary: for example, where the audio material has already been intentionally organized in a "content-oriented" way according to the medium length/capacity (e.g., collection of compositions of electronic music, where each audio document contains a finite set of compositions and the blank tape has been removed). It appears clear that in

these case second-level access copies are not necessary because the re-organization of the sound material would not alter significantly the structure of the first-level access copies (in terms of length, sequence of events, omitted parts).

4.2.4 Methodological funding principles

"Media archiving must be transformed into an active process" [68, p. 107], meaning that watching over audio documents sitting on the shelves is not an effective strategy against the collective memories fade out. In order to transfer the audio content from an old tape or an old record onto new media that are supported by an adequate maintenance system, and eventually to the internet by means of applications developed on purpose, it is necessary to extract the audio signal from the source carrier and to document every piece of information that comes with the document. During this process, the history of the transmission of the document can be lost, and the documentary unity can be easily violated, with the result that the digital copy of the tape or record is not trustable in terms of authenticity, and that very likely it does not meet the highest standards for the audio format in the preservation field.

Reliability, accuracy and authenticity need to be a primary concern in long-term preservation. Today, the authenticity of digital materials is difficult, if not impossible, to prove [69]. One digital document without certain provenance can compromise the reliability of the entire archive, nullifying the digitization campaign with incalculable loss of time, money and even cultural materials (in case the originals became unaccessible). Documenting the process that generated the preservation copy is particularly important in the audio field, because the medium from which the signal was extracted might be irrecoverable – in case of advanced degradation, with subsequent impossibility of future comparisons to determine a document's authenticity.

Despite the large attention that digitization and audio archives have received in the last decades, the author believes that not enough attention has been paid to quality control procedures, as she first pointed out in [70]. A fervid debate on the ethics of preservation, restoration and re-recording was started in 1980 with the "Proposal for the establishment of international re-recording standards" by William Storm [32] (Chapter 3): as the debate went along, it stayed crystal clear that the fundamentals of the practice of preservation were:

- "accurate, verifiable, and objective" procedures [32, p. 35]
- measurements based on an ideally objective knowledge
- modern playback equipment, fully compliant with the format specific parameters of the recordings
- a careful documentation of all measures employed and of each manipulation applied (ensure reversibility) [58].

All of these actions are directed to fight a common enemy: the *falsification of history*, which is the problem of "authenticity" by another name.
Factor et al. [71] introduce the key-concept that authenticity cannot be evaluated

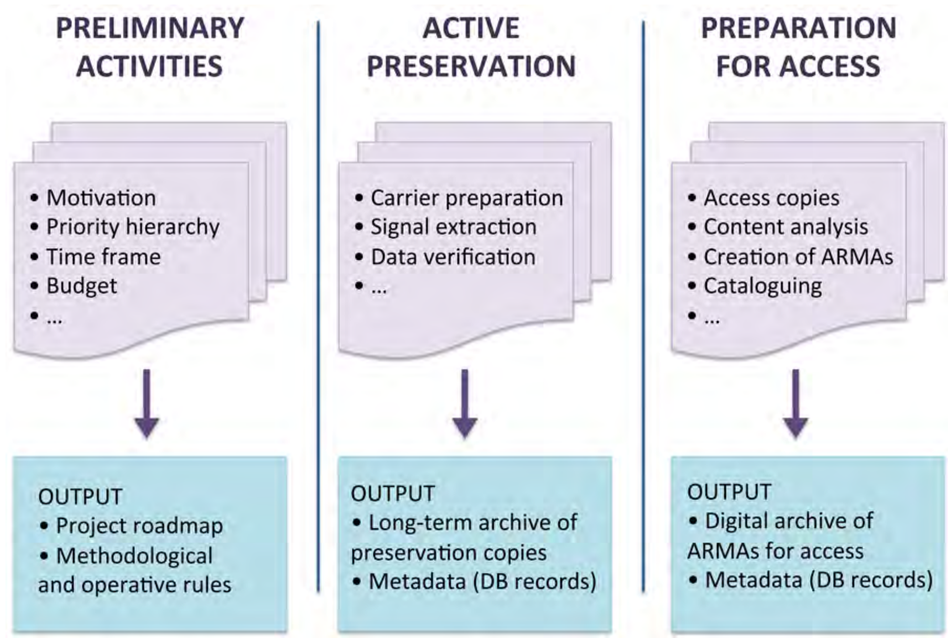


Fig. 4.5: The scheme summarizes the main phases involved in the process of preservation of audio documents: the preliminary activities are intended to be preliminary to the phase of active preservation, the core of the scheme. The preparation for access is the sum of the steps preliminary to the realization of the hardware infrastructure and the software services for access.

by means of a boolean flag, but it is rather the *result of a process*, and never limited to the resource itself but extended to the information/document/record system [72].

During the phase of active preservation, the faithfulness to the source document mainly depends on a number of technical-related issued must be carefully controlled. These include: the equipment calibration, the sound levels, the applications of correct audio formats. Section 5.1 describes each action involved in this phase and details some of them with the aid of flowcharts and visual material.

4.3 Preparation for access

"Permanent access is the goal of preservation: without this, preservation has no purpose except as an end in itself" [4, p. 14]. Although active preservation is a challenging endeavor, in order to achieve a set of deliverable audio resources additional steps must be planned. In particular, a shift in the approach is required at this stage. So far the attention has been focused on the historical faithfulness of the document, while now it is time to consider what the documents mean within their context, why is the community interested in them. With the completion of

preservation copies the process of active preservation has come to an end, and here the cataloguing process start. Competences other than the technical-audio-related are necessary, and they depend precisely on the content of the recordings.
The cataloguing staff is in charge of the description of the contents, which practically involves a re-organization of the audio materials, producing new audio files that have no relation with the preservation copy – and do not need to, because the relation is documented in the project database. The output of this phase will be an archive of second-level access copies. Only at the end of this procedure it is possible to build the applications for [remote] access and to develop more or less sophisticated access strategies. Figure 4.5 summarizes the stages described in this Chapter.

5

Operational protocol

The methodology presented in the previous Chapter provides a conceptual framework for the preservation of audio documents, and expresses some of the ethical principles still debated by the international archival community as discussed in Chapter 3. However, the ultimate goal of preservation is to actually bring the recordings back to the community, which requires that the conceptual framework is translated into an operational protocol. Somehow the value of the methodology is tested in this phase: its principles and requirements must be compatible with the real world, meaning that there must be effective solutions to plan a preservation of real archives that is both theoretically sound and financially sustainable at the same time. The documents that have been regarded as the bearers of historical and cultural values are now considered in their materiality, and consequently treated according to their physical-chemical specificities. This Chapter describes the protocol defined by the author, basing on the methodology as well as on the personal experience with the archives she has collaborated with during several financed research projects (see Chapter 11).

5.1 Active preservation

The *re-mediation process* (already shown in Figure 3.4) is composed by the totality of the steps from the evaluation of the state of preservation of the source document to the completion of a preservation copy. This is the core of the preservation process, but it can take place only when the preliminary activities have been solved (see Section 4.1). This Section describes the process of active preservation, assuming there is a laboratory equipped for the task, and that the audio documents have been selected and shipped to the laboratory already.

This process is divided in three main blocks (before playback, playback and after playback), each of which is articulated in procedures and sub-procedures. The output of each procedure or sub-procedure is either data, a report or a different state of the system. The complete sequence is formalized as follows:

1. **Preparation of the carrier**

1.1. Physical documentation
  1.1.1. Photographic documentation
  1.1.2. Scanned images
  1.1.3. Data validation
1.2. Visual inspection
1.3. Chemical analysis
1.4. Optimization of the carrier
2. **Signal transfer**
2.1. Analysis of the recording format/parameters
2.2. System setup
  2.2.1. Replay equipment (e.g., reel-to-reel tape recorder)
  2.2.2. Re-mediation equipment (converter, acquisition software, monitoring, ...)
2.3. Monitoring
2.4. Data validation
2.5. Archival of the source carrier
3. **Data processing and archival**
3.1. Metadata extraction
3.2. Completion of the preservative copy

The input of the re-mediation process is an audio document, and the expected output is its preservation copy – along with the source document ready to be stored again[1].
If each step is carried out according to the protocol, the preservation copy will fulfill the requirements of accuracy, reliability and philological authenticity [69]. Authenticity is, in fact, the *result of a process*, it cannot be evaluated by means of a boolean flag, and it is never limited to the document itself but extended to the information/document/record system [71].

Each step of the protocol is represented by a flowchart, each block of which represents an atomic task, eventually expanded in a separate flowchart. Descriptions and comments are as exhaustive as possible, in order to minimize aleatory choices, and exceptions are managed. In the next paragraphs a sample flowchart is shown.

5.1.1 Preparation of the carrier

The first thing to do when an audio document enters the re-mediation process is to document its physical condition, in order to know what was its state before any restoration was performed (step 1.1, see Algorithm 5.1). The photographical

[1] After the re-mediation process, the carrier's condition should normally be better than before, thanks to the restoration to optimize its performance – except for the carriers with a very poor starting condition: these might not endure one/multiple playback sessions, and be no longer readable after the process (for these, the optimization of the carrier before playback is crucial since there is only one chance to extract the best signal). In general, source documents should be kept for future comparisons and for other purposes that depend on the evolution of technology and that cannot be predicted to date. "Discarding an original, no matter how many copies have been made, should never be undertaken lightly." [1, p. 13]

(a) Bad focus (b) Bad light

Fig. 5.1: Examples of unsuitable photographical documentation, hardly detectable on the small screen of the camera. A visual control by the operator is required.

documentation (1.1.1, flowchart in Figure 5.3) includes the carrier, its housing, the cover, the case/box and any accompanying material. At choice, some of these may be acquired by means of a scanner to enhance intelligibility (1.1.2). The photographical documentation needs to be validated by the operator (1.1.3, in order to discard hazy or dark pictures like in Figure 5.1) before moving to the next step, aimed at detecting major sign of degradation of the physical carrier (step 1.2), such as dirt/dust deposits, mold, tear/breaks, ...
Figure 5.2 shows the flowchart associated to this procedure. Each block is extensively commented, and different comments are provided for each carrier type. When possible, visual documentation is provided, such as pictures and short demo movies. As an example, here are the instructions of the block 'Clean with soft cloth' for the carrier type Compact Cassette:
– Step 1. If dust is visible on the housing of the cassette, clean the housing before taking care of the tape. When the housing is free from dust, rewind the cassette.
– Step 2. Flip the cassette over to whichever side is completely rewound. The rewound side will show all of the tape coiled on the left coil, and the right coil will be empty.
– Step 3. Insert a pencil into the left spool, then place a soft microfiber cleaning cloth on top of the tape. Twist the pencil to the right while slightly pressing down on the tape with the cloth. Stop after 10 to 30 turns and see if dust deposits are visible on the tape or on the cloth. If so, keep twisting the pencil to the right while slightly pressing down on the tape with the cloth until all of the tape has coiled up in the right spool. Move the cloth every 30 to 50 turns in order to keep the tape in contact with a clean surface. Conversely, if there is no dust on the tape, it does not need to be rewound by hand.
The preparatory step terminates with the optimization of the physical carrier (step 1.4), achieved through specific restorative actions, in order to maximize its performance condition. The purpose of the optimization is to enable the extraction of the best signal possible. This is of vital importance for carriers in a poor state of preservation that might not endure multiple playback sessions.

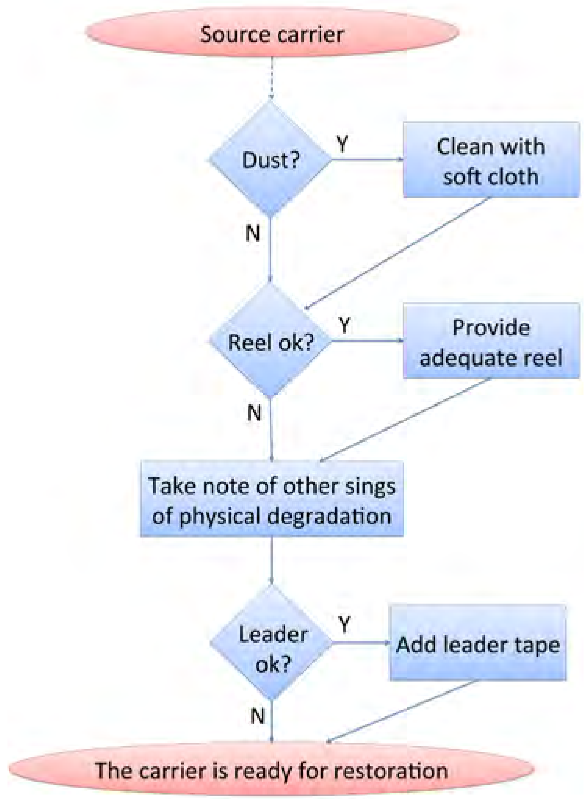


Fig. 5.2: Flowchart of the step 1.2 Preparation of the carrier → Visual inspection.

5.1.2 Signal transfer

At this point, the carrier is physically ready for playback. However, playback requires some additional information in order to read the carrier correctly. The recording format is specific for each carrier type (step 2.1, flowchart in Figure 5.6): it can be inferred from a direct analysis of the carrier, and from the writings on the cover and on the carrier itself, although often imprecise or missing. The methodology proposed in this article provides that when the noise reduction system is unknown or it is not clear (even after a signal analysis and/or a perceptual test) wether it has been used during the recording, the carrier is played 'flat', without any compensation, and this choice is reported in the preservation copy documentation. The analysis usually requires that the carrier is tested on the reading device, which causes this operation to be particularly delicate. In the tower of Babel of the recording formats, defining the correct ones is not an easy task. Some historical research on the technologies used at the time of the recording may be required. A secondary aim of this test is to detect some symptoms/corruptions that can only be detected when the carrier is played (e.g., sticky shed syndrome for magnetic tapes). These symptoms still regard the physical carrier and should be treated accordingly before proceeding with the signal extraction.

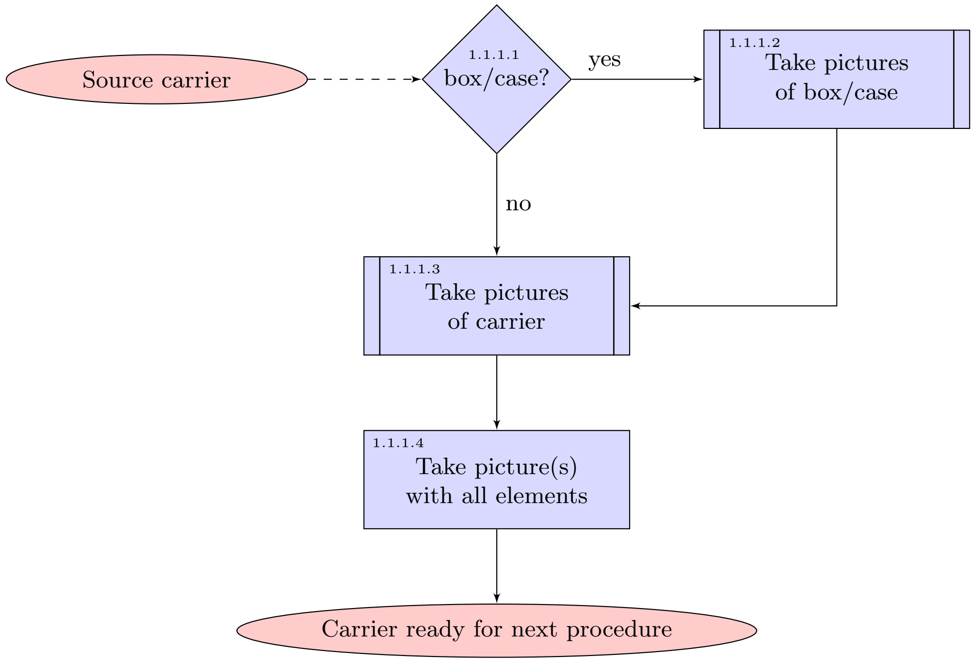


Fig. 5.3: Flowchart of the procedure 1.1.1: Preparation of the carrier → Physical documentation → Photographic documentation. Block 1.1.1.2 is expanded in Figure 5.4. Block 1.1.1.3 is expanded in Figure 5.5.

The definition of the recording format may have involved multiple replay devices: when the format is clear, the best equipment should be (1) selected and (2) adjusted for signal extraction (2.2.1). The same applies to the analog/digital converter and the rest of the re-mediation chain down to the workstation that acquires the data (2.2.2). Some differences may be observed in the procedure depending on the type of carrier, due to the mechanical-chemical-electrical specificities. The methodology presented in this article aims at being general, however detailing the procedure for each type of carrier goes beyond the scope of this work. At a macroscopic level, a partition can be done between carriers with analog or digital signals. The main differences regarding these two groups are that carriers with digital signals do not require a link of the re-mediation chain that is fundamental for carriers with analog signals, the analog/digital converter; that some types of carriers with digital signals are the only exception to monitoring (e.g., CD, audio files, ...); that algorithms for automatic error detection/correction can be used during the digital-to-digital copy.
An important feature of the methodology proposed by the author is that automatic re-recordings with simultaneous use of several systems is impossible, because the protocol requires that each re-recording is monitored by an operator (step 2.3). Every audio document is inherently unstable, and requires the annotation and the description of a number of signal alterations, let alone the supervision of the re-mediation chain (a malfunctioning device can tear, break or crumple the carrier;

Algorithm 5.1 Visual inspection

Require: source physical carrier

```
for all carrier-specific symptoms do check symptom;
    if symptom is present then take adequate remedy and document the intervention
    end if
end for

if carrier is open-reel tape then
    if flange is inadequate then replace flange
    end if
    if leader tape is missing/inadequate then add/replace leader tape
    end if
end if

document other relevant signs of the physical carrier
return restored physical carrier and data (documentation)
```

a reason why an operator must always be ready to intervene). Here is a list of the alterations that can be noted during playback:

- local noise: clicks, pops, signal dropout due to joints or tape degradation;
- global noise: hums, background noise, distortion (periodical or non-periodical);
- alterations produced when the sound was being recorded: electrical noises (clicks, ripples), microphone distortions, blows on the microphone, induction noise;
- signal degradation due to malfunctions of the recording system (i.e., partial tracks deletion).

When the signal extraction is complete, a set of manual and of automatic controls should be applied to the digital waveform (step 2.4). If the resulting audio file is well-formed and compliant with the desired parameters, it can be exported in the format selected for the preservation action (see Subsection 4.2.1.1). At this point, all information has been extracted from the original carrier (from the photographic documentation to the audio signal), and it can exit the re-mediation system (step 2.5). It should never be dismissed before validating the integrity of the preservation copy. As has been said in Section 5.1, discarding a source document should never be undertaken lightly. Only who is the legal owner of the document can take the responsibility of such decision. In general, all the originals exit the re-mediation system in the best condition possible, and ready for long-term storage (e.g., vacuum packing is desirable for magnetic tapes).

5.1.3 Data processing and archival

Audio metadata are of paramount importance in the documentation of the preservation copy (step 3.1). Some of them are known *a priori*, some could be extracted manually, and some can only be extracted with software tools: the best way to go is to extract them all with the assistance of a software tool, that will also re-organize

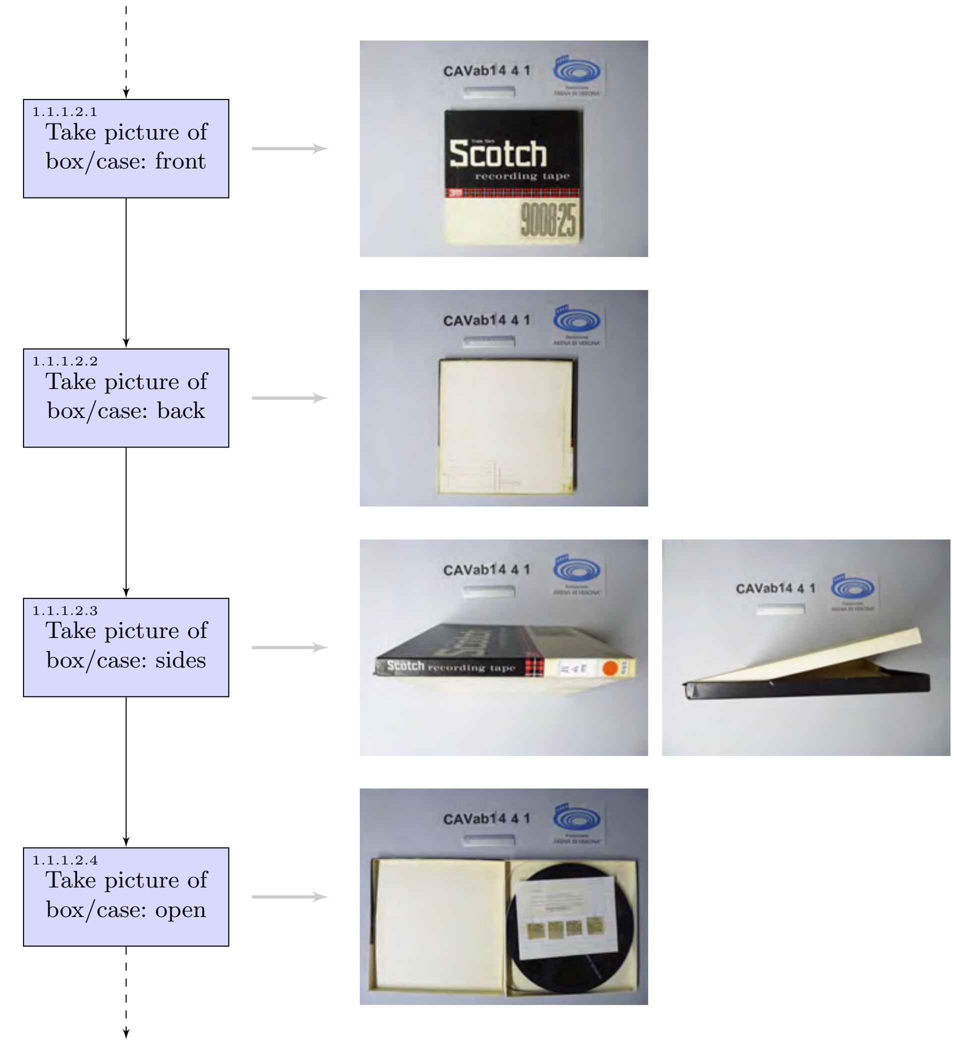


Fig. 5.4: Expanded routine 1.1.1.2 of Figure 5.3, showing the photographical documentation of the carrier's box/case with the support of visual material.

them in the predefined format, e.g., XML (the software PSKit PreservationPanel described in Chapter 6 generates an XML file with a selection of the metadata of the audio tracks contained in a preservation copy and automatically copies it into the correct folder). Finally, in order to complete the preservation copy some more data processing is required (step 3.2): images and schemes should be named and located correctly, and the descriptive sheet should be compiled. At choice, a watermark could be added to images. These operations can be performed manually or with the assistance of software tools (see Chapter 6).

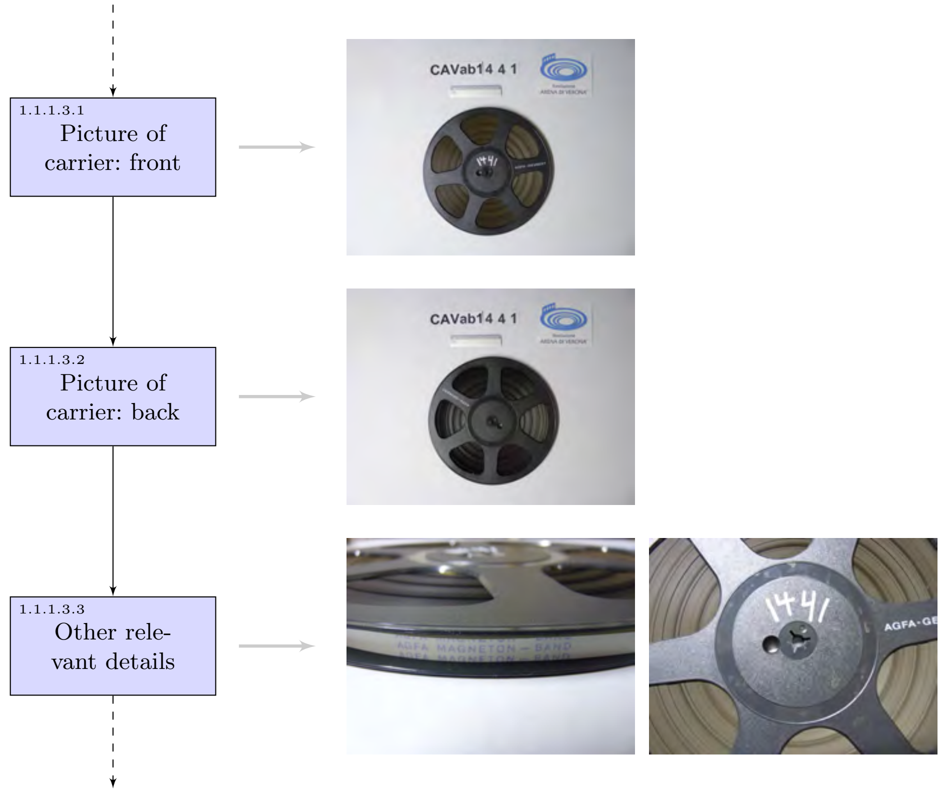


Fig. 5.5: Expanded routine 1.1.1.3 of Figure 5.3, showing the photographical documentation of the audio carrier with the support of visual material.

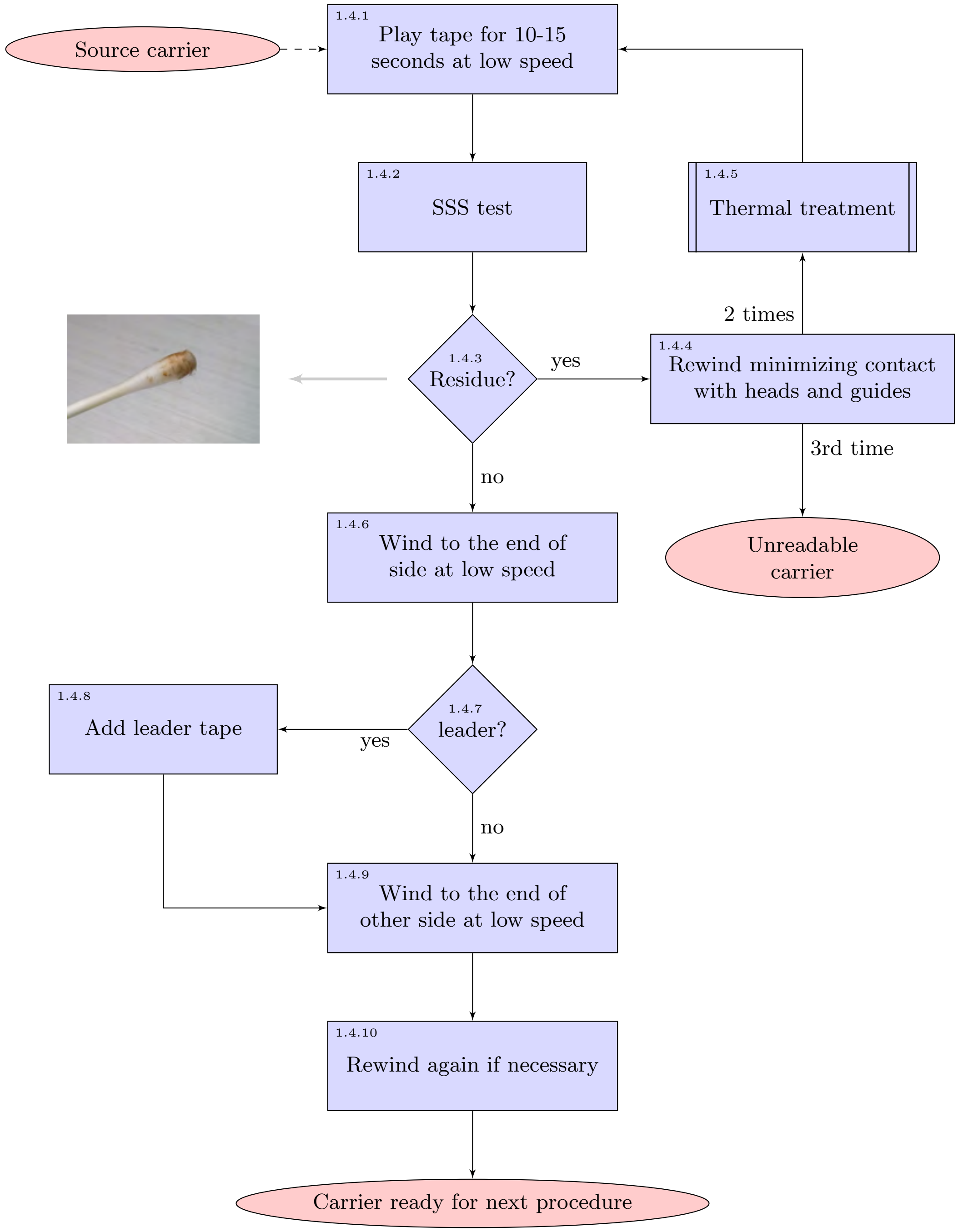


Fig. 5.6: Flowchart of the procedure 2.1: Signal transfer → Analysis of the recording format/parameters. The carrier is placed for the first time on the recorded and played. At this stage the recording format can be determined, and also the presence of SBS-SSSyndrome.

Part II

Software system architecture

6

Preservation Software Kit (PSKit)

Nobody should start to undertake a large project. You start with a small trivial project, and you should never expect it to get large. If you do, you'll just over-design and generally think it is more important than it likely is at that stage. Or worse, you might be scared away by the sheer size of the work you envision. So start small, and think about the details. Don't think about some big picture and fancy design. If it doesn't solve some fairly immediate need, it's almost certainly over-designed. And don't expect people to jump in and help you. That's not how these things work. You need to get something half-way useful first, and then others will say "hey, that almost works for me", and they'll get involved in the project.
Linus Torvalds

Simplicity is the ultimate sophistication.
Leonardo da Vinci

This Chapter describes the software system developed by the author. The purpose of the system is to support the process of active preservation of audio documents, providing control and automation of the procedures involved in the process described in Chapter 5. The software is currently used at the Scuola Normale Superiore di Pisa and at the Centro di Sonologia Computazionale of the University of Padova. Javadoc is available online[1].

6.1 What is PSKit

PSKit is an open-source software system made of independent modules that combine different programming languages and technologies. Its main purpose is to support the process of active preservation of audio documents according to the workflow defined by the protocol described in Chapter 5, which reflects the methodological principles exposed in Chapter 4. Figure 6.1 schematizes the workflow in function of the modules where PSKit is involved: the process starts with the remediation of the audio documents performed by the staff for preservation, and

[1] `http://www.dei.unipd.it/~bressanf/software/javadoc/pskit/`

the output of this process is the long-term archive of preservation copies with the associated records in the database. At this point, active preservation is complete. As has been said before in this work, preservation is not limited to storage, but it is "the sum total of the steps necessary to ensure the permanent accessibility – forever – of documentary heritage" [1, p. 12]. Therefore, additional actions need to be undertaken in order to obtain a collection of second-level access copies starting from the archive of preservation copies (see Sections 4.3). A set of software tools scheduled for automatic execution processes the audio material in order to provide the staff in charge of the description of the contents with data in a suitable format for the task. The cataloguing of the new audio files (second-level access copies) is performed with the aid of a software for the population of the database. The output of the cataloguing is the archive of second-level access copies with the associated records in the database. The entire workflow just described is subject to automatic control and backup procedures.

6.1.1 Motivation

The motivation for developing a software system such as PSKit derives from the scenario presented in Section 2, which shows that in the field of software tools for archival activities related to active preservation of audio documents has mainly been in the hands of private companies, with the result that a scientific guiding line is totally missing. Private companies develop products and sell them on the market: this is what they do and what they have a right doing. This is also precisely why a scientific approach should be introduced in the field of software tools for archival activities related to preservation: because the current state of the art is not scientifically characterized, but is rather a collection of diversified closed commercial products, the worst trait of which is the ignorance of the methodological principles exposed in Chapter 4: primarily, the confusion of the concepts of preservation copy, first-level access copy and second-level access copy (i.e., restoration is almost always carried out on the digitized audio, losing trace of the equivalent of the preservation copy in terms of faithfulness to the original); secondly, the supporting of parallel digitization (while in the methodology exposed in this work, full monitoring is demanded, meaning that one operator can take care of one digitization at a time). An example of this type of products is *AudioInspector*[2], the advertisement of which has been found by the author on the IASA Journal.
PSKit is the first software system that implements the scientific methodology exposed in Chapter 4, and its component PSKit PreservationPanel (PP) is the first software tool that manages the creation of preservation copies in combination with the population of the database.

6.2 Description of the software tools

The software system presented in this Chapter consist in a set of tools that support the re-mediation process. It is open source (GNU GPL v.3) and it includes

[2] `https://www.audioinspector.com/`

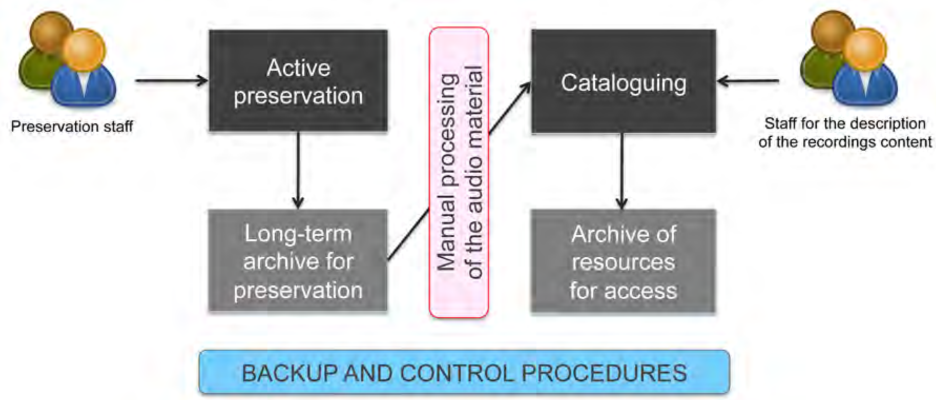


Fig. 6.1: High-level schematization of the preservation workflow from the viewpoint of the software tools.

two Java applications with a graphic user interface (GUI) and a number of shell scripts and Java programs without GUI. All of these elements are integrated in the preservation workflow schematized in Figure 6.1. The users they are destined to are members of the preservation and the cataloguing staff (i.e., trained people involved in the preservation process).

In function of the role played in the workflow, the software tools described in the next Subsections can be grouped in:

1. tools for the active preservation of audio documents;
2. tools for the description of the contents (cataloguing);
3. tools for data monitoring and maintenance;
4. tools for data sharing.

The block on top left in Figure 6.1, reading "active preservation", includes all the steps of the protocol introduced in Section 4.2 and detailed in Section 5.1. It starts with the original document entering the re-mediation chain and it terminates with the preservation copy transferred to the long-term storage system. The archive of preservation copies, represented by the block on bottom left in Figure 6.1, is the expected output. The software tools involved are described in Subsection 6.2.2. At this point, preservation could be considered complete, because the original documents have been safeguarded and the related data and metadata have been organized and stored. But most archives express their mission as to "identify, acquire, and preserve archival material [on grounds of their enduring cultural, historical, or evidentiary value], and to make it available [to the highest standards]". Therefore, preservation should be intended in a broader sense that is not limited to storage: unrestricted access must be made available "forever" – decades or centuries, or long enough to be concerned about the obsolescence of technology" [73].
As a consequence, additional steps are needed in order to obtain an archive of catalogued audio resources ready to be accessed by the general public, starting from

the archive of preservation copies. The main difference between the two stages is the description of the content, which is missing in the preservation copies. The preservation copies are only intended to safeguard the audio document as such, without any relation to its content (symphonies, interview, electro-acoustic music or even silence). But the final users need to search the documents with keywords related to the content (title, author, subject, ...). For this task, solid competences on the content of the recordings are required; in this sense, this represents a variable part of the preservation process, because unlike the first part, which applies to all types archives, this one depends on the area of interest of the recordings: it may be formed by musicologists, anthropologists, linguists, historians, and so on. In this article, a scenario with linguists is considered, i.e. a sound archive of speech documents. Going back to the workflow: the cataloguing staff need to access the audio contained in the preservation copies, which is cumbersome and difficult to share over a network connection[3]. To solve this problem, *first-level access copies* are created (see footnote in Section 4.2.1). These are made available to the cataloguing staff, which in our scenario is geographically distant from the laboratory and need to download the files from the internet in order to process them on their local workstations. These steps are completely automatized, and are described in Subsection 6.2.3 together with other automatized tasks mainly related to backups and data monitoring.

Regardless on the type of the recordings, the relation between the original document, the preservation copy and the first-level access copy is 1:1. This is not true for the relation between the preservation copy/first-level access copy and the audio resources for public fruition (second-level access copy), which are abstract entities independent from the structure of the physical originals. They consist in audio files of varying duration, corresponding to self-concluded acoustic events such as an interview, a song, an intermezzo, and so on. Figure 6.2 shows this situation: while the original documents (represented by Compact Cassettes) and the preservation copies (represented by the folders) coincide, the fruition units (represented by the yellow rectangles) may have an arbitrary relation with the source documents. This is true for all archives, but it is more evident where the recordings have been gathered on the field, such as in a speech archive of linguistics: every inch of tape was used, therefore the recordings are often split on multiple sides, and a side can contain several recordings. The cataloguing staff listens to the digitized audio and re-organizes it by cutting and merging tracks to obtain a new set of audio files. This step is described in Subsection 6.2.4. The expected output is an archive of resources for fruition, represented by the block on bottom right in Figure 6.1. Another important step of the preservation process is complete: the next - and last - is to design and build a (web) access system onto the archive of resources for fruition, to let final users perform searches, retrieve relevant information and listen to the audio. Also the preservation metadata can be made available, but the audio in the preservation copies is not intended for circulation and has no relation whatsoever with the access system.

It is to note that almost every step of the process can be assisted or automatized by software tools, except for the re-organization of the audio material, represented

[3] A stereo audio file with a duration of 48 minutes, a sampling frequency of 96 kHz and a resolution of 24 bit occupies ∼1.5 GB.

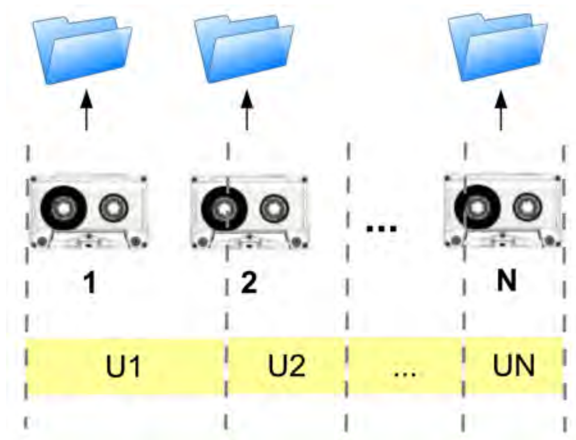


Fig. 6.2: The relation between the audio documents (in the middle) and the preservation copies (on top) is always 1:1. The relation between the latter and the fruition units (U1, U2, . . .) can be complex, which is often the case with archives of recordings gathered on the field for linguistics and ethnomusicological studies.

by the pink rectangle in the middle of Figure 6.1, which must completely be carried out by human operators. Finally, as shown in Figure 6.1, a set of control procedures is always active during the entire process.

From the viewpoint of their function, the software tools can be divided in:

- Working tools
  - Archive alignment (working local archive, mid-/long-term archive on the remote server, backups)
  - Creation and sharing of first-level access copies
  - Database
  - Programs for data ingestion into the database
- Control tools
  - Process monitoring
  - Data verification (mid-/long-term)
  - Backup procedures (database, archives,)
  - Monitoring of the data growth

6.2.1 System infrastructure

The infrastructure of the system is depicted in Figure 6.3, while the technology used to realize the system and required by the system can be summarized as follows:

- Software
  - Java (original software developed by the author)
  - Shell scripting (original software developed by the author)

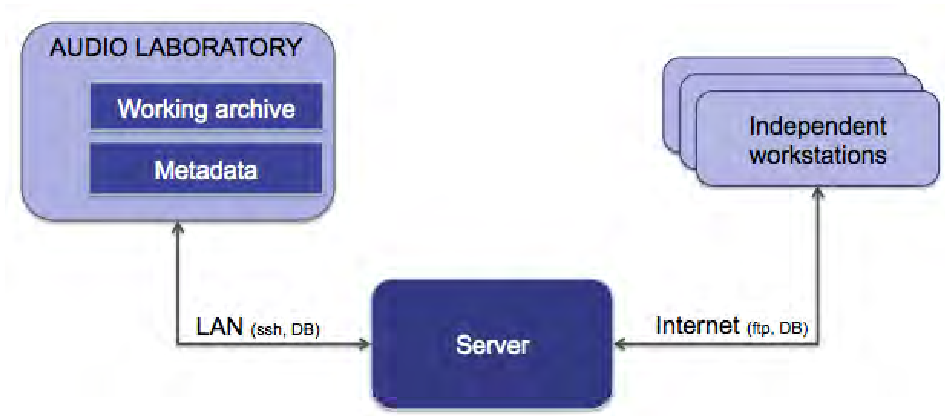


Fig. 6.3: The infrastructure used by the software system. The server hosts: data (archives and backups), database, website, ...

  - JHove[4]
  - MySQL
  - LaTeX (for the compilation of the descriptive sheets included in the preservation copies)
- Hardware
  - Unix server machine
  - Unix or Unix-based workstation
- Additional services required
  - SSH server
  - Web server
  - Network connection

The operations that take place in the audio laboratory, schematized in Figure 6.4, produce two types of data that are cyclically transferred to a server machine, represented by the block in the middle of Figure 6.3: (1) the preservation copies, and (2) the metadata that are stored in the database. The connection between the laboratory environment and the server is preferably a fast local network, since the amount of data to transfer is relevant. Besides the archive of preservation copies, the server hosts: data (archive of access copies and backups), the database and the web pages through which the first-level access copies are made available to the cataloguing staff (see Subsection 6.2.3). Each independent workstation in Figure 6.3 represents a member of the cataloguing staff, working on their personal computers and sending data to the database over an internet connection.

6.2.2 PSKit PreservationPanel

> *The trick is to fix the problem you have, rather than the problem you want.*
> Bram Cohen

[4] `http://sourceforge.net/projects/jhove/` (last visited on March 24th, 2013).

Preservation Software Kit (PSKit) PreservationPanel is an open source software application developed in Java by the author and licensed with the GNU GPL v.3. The Javadoc is available online[5].PreservationPanel counts almost 50,000 lines of code and it has been used since 2011 in the laboratory for audio preservation of the Scuola Normale Superiore di Pisa (see Subection 11.2). In July 2011, the performance of PreservationPanel has been tested: in just three working days, it assisted the creation of 217 preservation copies (analysis, organization, transfer and archival), equal to 430 hours of digitized audio and to 700 GB of storage space – while the digitization of the audio required six months. The amount of preservation copies created until now[6] tops 1200 items, equal to 1350 hours of digitized audio and to 2,4 TB of storage space. Additional modules are currently under development for the Centro di Sonologia Computazionale (CSC) of the Department of Information Engineering of the University of Padova[7].

At a user level, the main functions of PSKit PreservationPanel are:

1. the creation and the maintenance of the archive of preservation copies;
2. data ingestion into the database (see Subsection 6.2.5).

The usefulness of PSKit PreservationPanel is mainly represented by the quality control that it performs on the re-mediation process, managing data and metadata in parallel and thus ensuring a constant alignment between them. It significantly reduces the processing timing, by batch processing some categories of files, and at the same time eases the workload of the operator, by hiding all information that is known *a priori* or derivable. There are redundant controls associated to every step of the workflow carried out by the software. The interface of PSKit PreservationPanel is organized in panels, as can be seen in Figure 6.6).

The panel for the description of single documents (physical original, recording format and preservation copy) is customized for each carrier type. Filters are applied to attributes, that may apply or not to the selected carrier type, resulting in different components on the interface. The introduction of errors is minimized by loading in the components only the valid values for each applicable attribute (it has been scientifically proven that the introduction of errors is an intrinsic factor in low-level and repetitive tasks, such as those involved in the daily archival routines [74]). For audio-specific metadata extraction (panel for batch processing), the author has implemented in their system a modular tool for analysis and validation of digital objects in [digital] preservation programmes developed by JSTOR and Harvard University [75]. The complete set of audio-specific metadata automatically extracted with JHove is listed in Table 6.1.
Other operations supported by PSKit PreservationPanel in the panel for batch processing are: (a) assignment of audio and contextual information files from default temporary folders to the correct preservation copies; (b) creation of XML file with the checksums of the audio files for each preservation copy; (c) creation of descriptive sheet; (d) validation; and (e) transfer to remote server. Figure 6.4

[5] `http://www.dei.unipd.it/~bressanf/software/javadoc/pskit/`
[6] March 24th, 2013.
[7] http://csc.dei.unipd.it/

METADATA	DESCRIPTION
Name*	Name of the audio file contained in the preservation copy including the extension, and without any leading directory components.
Duration*	Duration of the audio file in the format HH:MM:SS.
Size	Size of the audio file in a human readable format, e.g. 874 MB or 1.2 GB.
Extension	Extension of the audio file, e.g. wav.
Format (MIME Type)	The standard recognized name for the format of the audio object.
Encoding	The encoding scheme used when audio digitization occurred for the described audio object. The majority of digital audio recordings will have a value of 'PCM'.
Profile	String obtained with the combination of the values Format and AudioFormat extracted from the header of the audio file. Example: PCMWAVEFORMAT. See the WAVE file format specifications for details.
Number of tracks	Tracks are here intended as channels, therefore a mono recording will have 1 track. This definition have been adopted to resolve the ambiguity of terminology between 'track' (here intended as autonomous audio file, e.g. a CD has 14 tracks) and 'channel' (typical values would be 1, 2, 4 and 8). Note that the metadata 'Signal type' (mono, stereo, ...) is not listed in this table because it is a qualitative evaluation of the operator and it cannot be extracted automatically – nevertheless it is included in the descriptive sheet in the section that describes the physical original. In the author's experience, 'number of tracks', 'number of channels' and 'signal type' are the minimum combination of metadata to describe any type of recording format with no ambiguity whatsoever.
Bitdepth	The number of bits per sample for the audio content of the described audio object. This element describes the actual number of bits of the sample, whereas Word Size describes the number of bytes used to contain the sample.
Sample rate	The sample rate of the audio data for the described audio object.
Byte order	The order in which a sequence of bytes are stored in computer memory. Used to indicate whether the file is in little-endian or big-endian order.
First sample offset	The byte offset of the start of the data chunk which actually contains the waveform data with respect to the beginning of the file.
Compression	Name of the algorithm for data compression applied to the audio file, if any. For preservation copies, it should always be 'none'.
Checksum MD5	A string indicating the checksum signature of the audio object. Example: 8847e21949079bfd4bf0c2bc26ba074a
Checksum CRC32	A string indicating the checksum signature of the audio object. Example: 422f2901
Checksum SHA-1	A string indicating the checksum signature of the audio object. Example: 10a000e21a4c99479b15b852fcb3467b51c08cf5

Table 6.1: Metadata associated to the audio files in the descriptive sheet of a preservation copy. Items marked with a star (*) are not obtained with JHove: the name of the file is given by the user, and the duration of the file is calculated with PSKit PreservationPanel (class MetadatiAudio, private method durataTraccia(File f) that returns a String with the duration in the format HH:MM:SS).

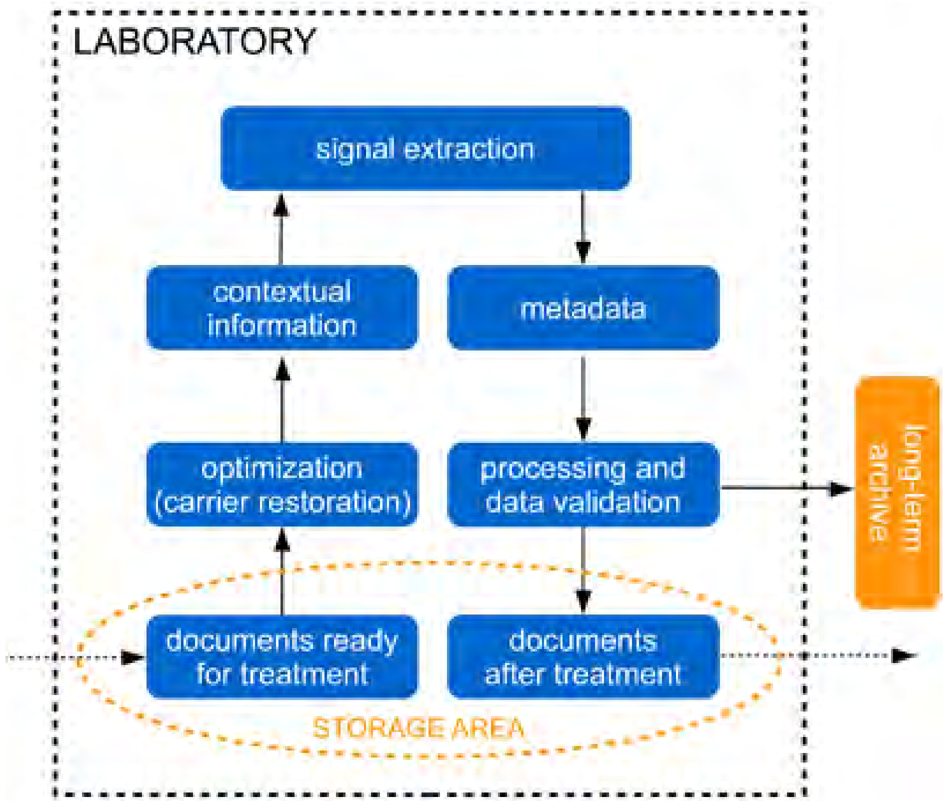


Fig. 6.4: Abstract view of the activities that take place in the preservation laboratory.

schematizes the actions that take place in the laboratory during the process of active preservation and that are assisted by PreservationPanel. More information on PSKit PreservationPanel is available in [76].

6.2.3 Automatic processing

This Subection describes the procedures that take place on the server machine to which the complete preservation copies have been transferred using PSKit PreservationPanel. All of the procedures are automatically executed on a daily-weekly-monthly-yearly basis according to the `crontab` job scheduler configuration(Figure 6.5):

1. DAILY SCHEDULE
   - Creation of first-level access copies
   - Sharing of first-level access copies on a web page with limited access
   - Automatic mail messages to notify the new available audio files
   - Calculation of the total duration of the digitized audio
   - Backup of the audio archive

- Backup of the database
2. WEEKLY SCHEDULE
   - Backup of the website
   - Grouping of daily database backups in compressed archives
3. MONTHLY SCHEDULE
   - Monitoring the new items added to controlled vocabularies in the database
   - Grouping of weekly database backups in compressed archives
4. YEARLY SCHEDULE
   - Grouping of monthly database backups in compressed archives
5. OTHER SERVICES
   - Periodical messages reporting the status of the server machine
   - Possibility to monitor single processes with periodical reports sent via mail

The creation of first-level access copies (item number 1 in the above list) involves a shell script that down-samples the audio in the preservation copies and converts it to a compressed format, adding new metadata to the header. The compressed files are then associated to the photographic documentation, and the resulting object is moved to the archive of first-level access copies. This archive is accessible through a web site with restricted access (item number 1 in the above list). Finally, every morning a script checks if on the previous day there have been new uploaded preservation/access copies, and if so sends a notification mail message with the list of the audio files and link to retrieve them. This way, each member of the cataloguing staff is updated on a daily basis and can access the new documents very quickly, enabling a fast processing chain from active preservation to the archive of preservation copies and to the archive for access.
The system as it has been described in this work uses a redundant Hard Disk Drive array to store the data (archive of preservation copies, access copies, database, ...) in the long-term. The specific problems related to the checking, refreshing and migration technology fall within the scope of the research area of digital preservation (see for example [77]).

6.2.4 Cataloguing

The tool that the members of the cataloguing staff use to populate the database is called PSKit CataloguingPanel, and like PSKit PreservationPanel has been developed in Java during the collaboration with the sound archive of the Scuola Normale Superiore di Pisa (see Subsection 11.2).
Once the audio material has been re-organized and new audio files coinciding with self-concluded acoustic events have been created, the cataloguing staff can proceed with its classification and its description. PSKit CataloguingPanel is essentially an interface for data ingestion, but just like PSKit PreservationPanel it follows an attentive study of the requirements carried out in tight collaboration with the linguistics research team. Long discussions have been made to refine the data model, trying to bridge the gab between two disciplines such as computer science and linguistics: an extended time spent for the collection of the requirements has paid off with the realization of a tool that guides the operator in the workflow making it fast and simple, and at the same time ensures data consistency

```
# m   h   dom  mon  dow   command

# MONITOR DATA GROWTH IN THE DATABASE CONTROLLED VOCABULARIES
  0   7    20   *    *    /script/valore.sh parola peter@pskit.it,tony@pskit.it
  1   7    20   *    *    /script/valore.sh argomento peter@pskit.it,tony@pskit.it
  2   7    20   *    *    /script/valore.sh genere peter@pskit.it,tony@pskit.it

# DATABASE BACKUP
  6   1    *    *    *    /script/db-bck/daily.sh
  12  2    *    *    0    /script/db-bck/weekly.sh
  18  3    *    *    *    /script/db-bck/monthly.sh
  42  4    1    1    *    /script/db-bck/yearly.sh

# AUDIO ARCHIVE BACKUP
  4   4    *    *    *    /script/backup_archivio.sh

# WEBSITE BACKUP
  15  5    *    *    0    /script/backup_sito.sh > /script/backup_sito_log.txt

# CREATE ACCESS COPIES
  30  0    *    *    *    /script/creazione_copie_accesso.sh > /tmp/accesso_log.txt

# NOTIFY ABOUT NEW ACCESS COPIES
  0   8    *    *    *    /script/share_update.sh > /tmp/notifica_log.txt

# CALCULATE TOTAL DURATION OF DIGITIZED AUDIO
  0   7    *    *    *    /script/calcola_durata_audio_batch.sh > audio_report.txt

# RE-CREATE ALL ACCESS COPIES (DISASTER RECOVERY)
# 15  3    7    10   *    /script/recalculateMP3.sh

# MONITOR A PROCESS (SEND PERIODICAL REPORTS VIA MAIL)
# */30 *   *    *    *    /tmp/updateme.sh /tmp/mylog.txt "admin@pskit.it"

# CHECK IF SERVER IS UP AND RUNNING (SEND REPORT VIA MAIL)
  0   */3  *    *    *    /mail/send_mail_periodically.sh

#-------------------------
# *   *    *    *    *
# -   -    -    -    -
# |   |    |    |    |
# |   |    |    |    +----- day of week (0 - 6) (Sunday=0)
# |   |    |    +------- month (1 - 12)
# |   |    +--------- day of month (1 - 31)
# |   +----------- hour (0 - 23)
# +------------- min (0 - 59)
```

Fig. 6.5: Snapshot of the `crontab` file on the server of the project Gra.fo (see Section 11.2), updated to September 19th, 2012.

and minimizes the introduction of errors.
PSKit CataloguingPanel allows to maintain the connection between the new self-concluded audio files coinciding with the catalogued acoustic events, and the source files in the preservation copies that have been used to created them. This connection is crucial because it is the only link between the archive for preservation and the archive for access, i.e. between the preservation metadata and the content descriptions. More details about this relation are provided in the next Subsection.

6.2.5 Database

A database that is designed within the scope of a preservation project must be able to maintain the data, as well as the relation between the data, that belong to

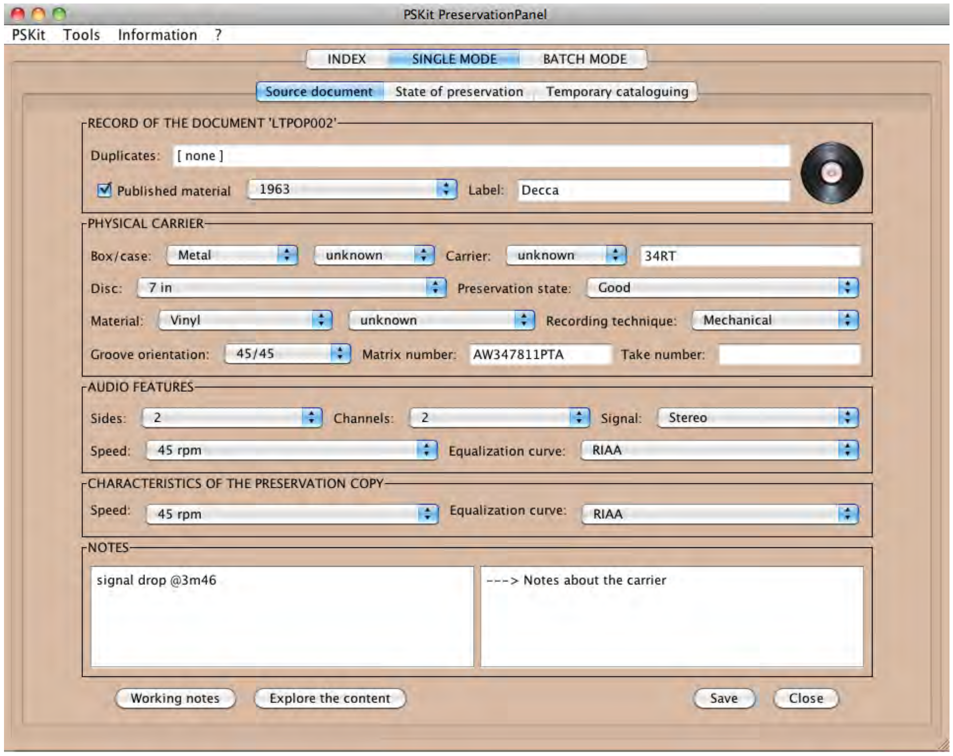


Fig. 6.6: Panel for the description of single documents in PSKit PreservationPanel for the carrier type *phonographic disc*.

two different and opposite aspects of the process: the active preservation of audio documents on the one hand, and the cataloguing of the contents on the other. These aspects are opposite because the first focuses on the document as such, regardless of their content. The metadata produced in this part of the process are mainly technical and audio-specific. The second aspect sacrifices the fidelity to the data structure of the physical original carrier in favor of abstract self-concluded acoustic events that coincide with culturally-mediated interpretations of the audio stream. The metadata produced in this part of the process are content dependent and vary according to the area of interest of the recordings. For example, in the scenario with speech documents of dialectological relevance, the metadata will include the linguistic area, the date of creation and the people involved in the conversation, the topics of the conversation and an abstract of what is being said, in order to provide the final users with as much information as possible.
The database adopted by the software system described in this article was created using the relational model, with Oracle MySQL. Its population is performed by means of the applications described in Subsections 6.2.2 and 6.2.4, which are able to reach the database from a local or a remote network connection. The relation between the preservation copy and the audio files for fruition is maintained by associating the identification number of the source audio files (which contain a

reference to the preservation copy they belong to) to the identification number of the audio files for fruition. Additional information regards the starting/ending time of the re-organized audio, which allows the re-creation of the fruition file in case it gets lost or erased. More generally, the metadata stored in the database allows the reconstruction of every operation performed starting from the preservation copies, which are the ones that should always be safeguarded with the highest care. Thanks to the database design, the final users will be able to retrieve the technical audio-specific data starting from a search by content, and viceversa, meeting the needs of the users interested in the recordings content, those interested in preservation, and the more general public searching the archive out of curiosity and for personal entertainment.

Part III

Chemical analyses on magnetic tapes

7

Motivation and methodology

> *"I often receive questions on baking reels from archivists – how to do it, when to do it, and if it should be done at all. I would not be surprised if there are portions of collections out there that were accidentally destroyed by a well meaning archivist."* [78, p. 24]

This chapter describes the methodology and the results obtained from an experiment and from a number of chemical analyses carried out on magnetic tapes in collaboration with the Department of Industrial Engineering – Chemical sector. The objective of the collaboration was to understand the modifications that affect the tapes when they are treated for one of the most common syndromes observable in this type of medium, SBS-SSS (Soft Binder Syndrome – Sticky Shed Syndrome, see Section B.1 of Appendix B for a definition). The main motivations for the experiment and for the analyses are that: (i) scientific literature on this subject is scarce, and (ii) the documented approaches are currently fragmented, leaving space for improvised treatments with unexpected ill effects on the tapes. The ultimate objective is to define a general protocol for the treatment of magnetic tapes syndromes.

7.1 Introduction

Magnetic tape is an important medium in the capturing of information and has had widespread use in audio, video, and computer applications over the past 60 years. Libraries, archives, museums, government agencies, and commercial organizations have relied on magnetic tape for storing a considerable part of their information. As years go by, the preservation of this information is becoming of increasing concern to society, particularly as the recorded information becomes older and it is frequently of greater value. Magnetic tape has also been widely used by individual consumers to preserve records of personal or entertainment value [21]. It represents the most common type of carrier in sound archives to which the methodology described in this work has been applied, in particular in the form of Open-reel tapes and of Compact Cassettes.

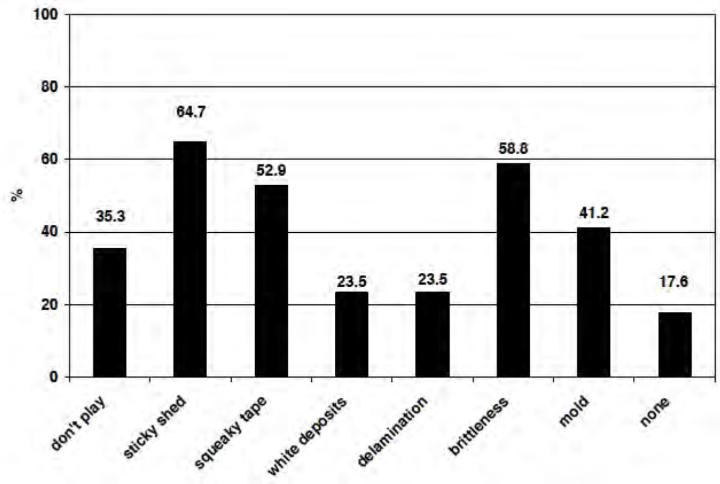


Fig. 7.1: Major manifestations of decay observed in tape collections (x-axis). Percentage of institutions (out of 17 involved) having witnessed each decay manifestation in their collections (y-axis).
Source of the picture: [79, p. 20].

The critical concern is primarily the change in physical properties of the magnetic tape, and not the loss of magnetic characteristics [21]: magnetic tapes have proved to be rather stable in this aspect, and if a significant loss of magnetic characteristics is present, it usually is due to careless exposure to magnetic charges.

To date, a standard specification against which tape life can be evaluated is not available, and neither are standards on the life expectancy of hardware and on the problems associated with hardware wearing out or becoming obsolete [21]. The lack of diagnostic tools forces tape inspection to entirely rely on visual examination and evaluator expertise [79], producing evaluations that are descriptive at best ("in good condition", "some concerns", "obvious decaying", . . .).

The lack of diagnostic tools, of evaluation standards and of effective solutions to the damage caused by physical decay proves to be of paramount importance in the preservation of magnetic tapes. The lack of standards leaves the way open for improvised expedients and home-made solutions (see Section 7.2), without certain knowledge on the ill effects possibly caused to the tape. Figure 7.1 shows the percentage of institutions (museums, libraries and archives) having witnessed some major manifestations of decay in their tape collections. A total of 17 institutions took part to the survey, carried out by the Image Permanence Institute (IPI) at Rochester Institute of Technology, Rochester, New York [79]. A significant proportion of institutions have had experience with tape decay: around 80% have observed various decay manifestations and 35% have been unable to replay materials due to decay.

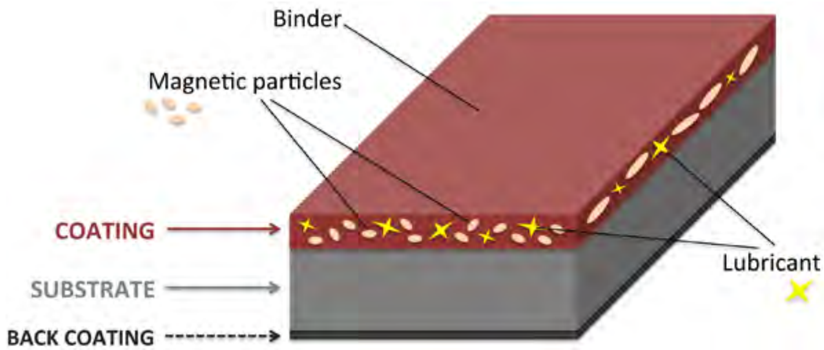


Fig. 7.2: Cross section of a coated magnetic tape. The main elements are the substrate (or base) and the magnetic coating, containing the magnetic particles and the lubricant homogenized in a binder. A typical thickness is 35-40 μm for the substrate and 10-15 μm for the top coating. The back coating is not always present (optional).
Author of the figure: Federica Bressan.

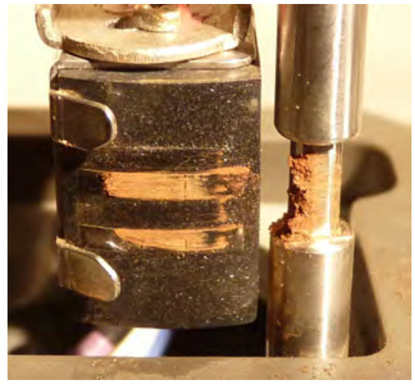
7.2 Thermal treatment of magnetic tapes

Most tape is made by coating the surface of a plastic film base or backing with a paint or "ink" containing magnetic particles homogenized in a binder that adheres to the film and dries by evaporation. Figure7.2 shows a general cross section of a tape. The coating is usually so thin that it is only a small fraction of the overall tape thickness [80, p. 97].
Although the base is magnetically inert, it must meet stringent requirements of thickness, strength, and stability, in order to give a reasonable playing time in a compact reel. A tape about 50 μm thick fills a 18 cm diameter reel with 365 meters of tape, which equals to a half hour at 7.5 inch/s. In addition to the base and binder, most tapes produced since the early 1980s show a back coating that acts as an aid to tape packing on the hub and reel [45].
The degradation of all types of audio carriers is mainly due to their intrinsic chemical instability [66], aggravated by inadequate handling, storage conditions and poor manufacture. The effects of the process of degradation are multiple and carrier-dependent. One of the problems most often observed in magnetic tapes, especially Open-reel tapes, is known as Sticky Shed Syndrome (SSS, see Appendix B for a definition): this is confirmed by the survey in Figure 7.1 (second value from left, "sticky shed"), and also by the author's experience with the archives of the Fondazione Arena di Verona (see Section 11.1 of Chapter 11) and of the Scuola Normale Superiore di Pisa (see Section 11.2 of Chapter 11).

Organic materials are commonly prone to spontaneous chemical decay, and metallic particles in the presence of oxidizing compounds are subject to oxidation [79].

The importance of remedial actions finalized at making audio media playable is revealed within the field of preservation by the number of scientific and non-scientific sources discussing them. But at the same time it shows how the approaches are

(a)



(b)

Fig. 7.3: Detailed views of the audio heads of a reel-to-reel recorder after playing a tape affected by SBS-SSS. Note the colored residue on the heads.
Author of the picture: Federica Bressan. Location: Fondazione Arena di Verona.

fragmented and how seldom the information builds upon scientific knowledge: "baking methods have been refined in diverse studios and labs by many different practitioners, they vary significantly in terms of equipment, temperature, and duration." [81].

After treating a set of tapes, or "baking" them as is often heard, the author has observed that some were not responding to the treatment at all, while others required longer treatments to achieve an improvement. Therefore the author decided to have a deeper insight on thermal treatment, considering that the object of the treatment were unique copies of unpublished performances by artists the calibre of Luciano Pavarotti, for which the risk of collateral damage must be avoided completely.
Despite the popularity of thermal treatment, the material gathered by the author formed a contradictory set of information, from which basically emerged that no-one clearly knows what happens in the incubator. It all started in 1993, with the US Patent assigned to the Ampex Systems Corporation [82] which presented "a method of heat treating magnetic recording media comprising maintaining the magnetic recording media at a sufficiently elevated temperature for a sufficient time to overcome the adverse consequences of undesirable shed, stickiness or squeal". It recommended "a temperature of at least 50 °C for at least 8 hours", however "lower temperatures and/or shorter times can restore media sufficiently to enable playback". The factor that determines the temperature and the duration of the treatment is the state of deterioration of the audio document, but the patent does not provide specific indications to plan adequate treatments. It is generally agreed that the presumed responsible for the sticky syndrome is hydrolysis (*hydro* "water" and *lysis* "separation"), a reaction between the polymers of which the tape is made and water from atmospheric moisture: "when a sufficient number of [polymeric chains] have been hydrolyzed and broken, the binder becomes undesirably

Fig. 7.4: Cotton buds used to remove the sticky residue caused by SBS-SSS from the audio heads of a ree-to-reel recorder. From left to right, the quantity of residue removed increases, making the cotton buds more dirty. Gaining experience by evaluating the quantity of residue helps to plan better treatments for the tapes affected by SBS-SSS. Author of the picture: Federica Bressan. Location: Centro di Sonologia Computazionale (CSC), University of Padova.

weakened due to degeneration of molecular weight" (see also [83]).

The patent curiously refers to its own results as "unexpected"[1] and "surprising"[2], besides admitting that the theory behind it is not ascertained: "*it is believed* that the heat restoration process according to this invention, to some extent, may reverse certain hydrolysis" (italics of the author). According to this "belief", more recent sources claim that thermal treatment is aimed at "removing the moisture that has accumulated in the binder" – although apparently this is only "thought" to happen[3]. Other sources from the archival community admit that the data they possess about thermal treatment "is merely anecdotal and will require further study." [78, p. 24].
Other open questions about the treatment are: the recommendable humidity level in the incubator during the treatment, which is not indicated in any of the sources; the duration of the benefits ("incubating the tape returns the tape to a playable condition for weeks or months after treatment" [84]; "this remedy is temporary; the tape will revert over time." [85]); and the risks involved with the treatment. "Although some report having 20-or-more successful 'bakes', there is no published

[1] "In this invention it has been unexpectedly found that deteriorated magnetic recording media [. . .] can be restored to playable and excellent quality media by heat treatment at a sufficiently elevated temperature for a sufficiently long time [. . .]." [82]

[2] "It has also surprisingly been found that the heat treatment according to this invention can be carried out with the magnetic recording media such as tape in its cassette, on its reel or retained by other tape housings [. . .]." [82]

[3] "*It is commonly thought* that baking a tape will temporarily remove the moisture that has accumulated in the binder" (italics of the author), from `http://en.wikipedia.org/wiki/Sticky-shed_syndrome` (last visited February 12th, 2013).

or documented information on how many times a tape can be baked, cycling back and forth between the sticky-firm-sticky succession before it fails completely or before the signal is distorted or altered beyond use". [45] In fact, there is "little knowledge about how exposure to increased heat may impact the tape artifact itself". [81]

In the author's experience the treatment has generally produced satisfying results, nevertheless within the scope of a scientific methodology a deeper understanding of the reasons why and how the treatment works is required, and the author believes that a deeper understanding will save a lot of documents from the consequences of unaware treatments – in terms of temperature, duration, and equipment (instead of a precision incubator, relatively expensive, "the most common equipment is the American Harvest Snackmaster Pro FD50 Food Dehydrator" [81]; even the home made solution of the hair-dryer-in-a-cardboard-box is said to "work well" [86].
The author's aim is to prevent improvised treatments on precious audio documents, and to achieve a scientific protocol for tape restoration. In order to do this, a set of chemical analyses have been planned in collaboration with the Department of Industrial Engineering (Chemical sector) of the University of Padova. The first step has been the characterization of the tapes, because only a precise knowledge of their properties would provide the understanding of their behavior at varying environmental conditions. Characterizing the tapes has been necessary as most brands and models were unknown or uncertain: very few tapes show the brand/model on the back surface (among the tapes analyzed in this work, only two have been identified by their names, see Figures 8.8(a) and 9.1). This information is usually derived from the reel or the box, although "a tape's box may not be original and may not accurately indicate the type of tape" [79, p. 8].

Eight tape segments have been selected and analyzed with a Fourier Transform InfraRed spectroscopic analysis (FTIR) and a ThermoGravimetric Analysis (TGA). The next Section presents the analytic techniques, while the experimental results are described in Chapter 8 and discussed in Chapter 10.

7.3 Description of the techniques employed

The chemical and mechanical analyses conducted on the samples are described in the next Subsections. The instruments used for the analyses have been made available by the Department of Industrial Engineering of the University of Padova and by the Centro Universitario Grandi Apparecchiature Scientifiche (CUGAS) of the University of Padova.

7.3.1 FTIR Spectroscopic analysis in ATR

7.3.1.1 The technique

Infrared spectroscopy is a widely used technique that for many years has been an important tool for investigating chemical processes and structure. The combination of infrared spectroscopy with the theories of reflection has made advances in

(a) (b)

Fig. 7.5: (a) Equipment used for the FTIR analysis; (b) detail of the tape sample in position during the analysis.
Author of the picture: Federica Bressan. Location: Department of Industrial Engineering (chemical sector), University of Padova.

surface analysis possible. The fundamentals of Attenuated Total Reflection (ATR) spectroscopy are based on the evanescent wave and how it is related to the concept of internal reflection. The concept of internal reflection spectroscopy originates from the fact that radiation propagating in an optically dense medium of refractive index *n1* undergoes total internal reflection at an interface of an adjacent medium of lower optical density (refractive index $n2 < n1$). This wave is termed *evanescent* and is derived from the Latin root *evanescere*, meaning “to tend to vanish or pass away like a vapor”. The above phenomenon occurs only when the angle of incidence exceeds a critical angle Θ_c determined by $\sin \Theta_c = n1/n2$. Samples are examined directly, without preparation. Infrared radiation internally reflects through a crystal (ZeSe Diamond) penetrating the sample by only a few microns. The absorbing / scattering of the light is collected and measured to produce a spectrum which is characteristic for the compound being analyzed.
The instrument used for the analyses is a Nicolet Nexus 5700 (Figure 7.5(a)).

7.3.2 ThermoGravimetric Analysis

7.3.2.1 The technique

Thermogravimetric Analysis (TGA) measures the amount and rate of change in the weight of a material as a function of temperature or time in a controlled atmosphere. Measurements are used primarily to determine the composition of materials and to predict their thermal stability at temperatures up to 1000 °C.The technique can characterize materials that exhibit weight loss or gain due to decomposition, oxidation, or dehydration.
The analysis has been carried out with a linear temperature increase with a rate of 15 °C per minute. The instrument used for the analysis is a TA Instruments SDT 2960 Simultaneous DSC-TGA (Figure 7.6(d)). The analysis has been carried out under nitrogen atmosphere.

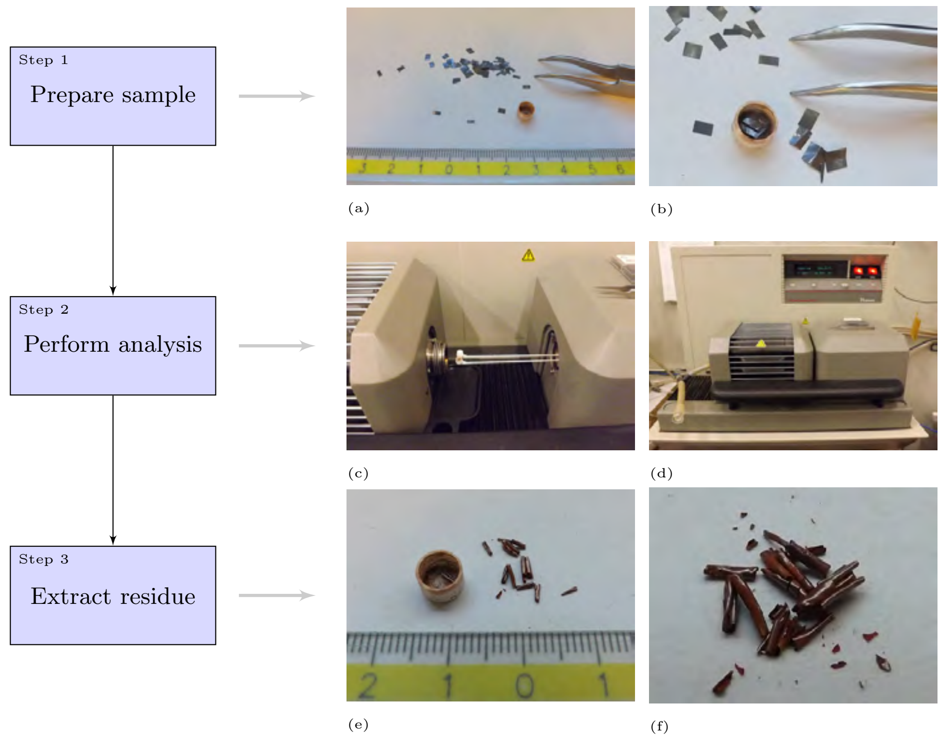


Fig. 7.6: (a) and (b) The tape samples are prepared for the analysis; (c) and (d) the samples are placed in the machine; (e) and (f) when the analysis is over, the residue of the tape samples is removed.
Author of the pictures: Federica Bressan. Location: Department of Industrial Engineering (chemical sector), University of Padova.

7.3.3 Electronic Microscopy

7.3.3.1 The technique

The Scanning Electron Microscope (SEM) is considered to be non-destructive analysis[4]. It uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens which are subsequently collected by a detector. The signals that derive from electron-sample interactions include secondary electrons (that produce SEM images), backscattered electrons (BSE), diffracted backscattered electrons (EBSD), photons (characteristic X-rays), visible

[4] In this field, non-destructive means that the analysis can be repeated on the same sample more than once. But from the viewpoint of audio preservation, this test is destructive because it requires that the sample is prepared (i.e., gold coating), which is an irreversible modification of the tape. The fact alone that a small piece of tape must be cut to obtain the sample (approximately 1 cm) would not make the test destructive.

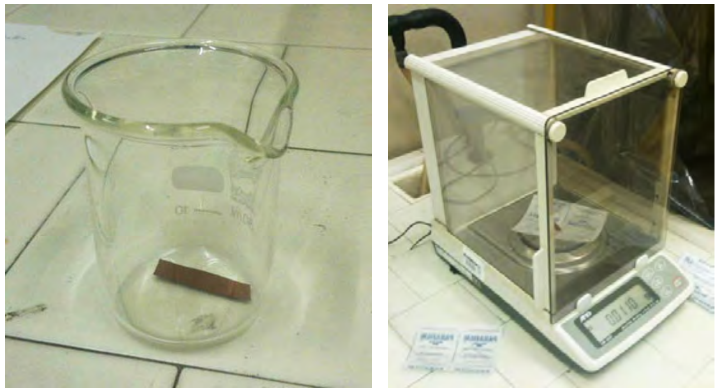
Fig. 7.7: The instrument used for the SEM and ESEM analyses at the Centro Universitario Grandi Apparecchiature Scientifiche (CUGAS) of the University of Padova. Source of the picture: Department of Industrial Engineering (chemical sector), University of Padova. Location: CUGAS.

light (cathodoluminescence–CL), and heat.
These signals reveal information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample or a selected area of the surface of the sample (areas ranging from approximately 1 cm to 5 microns). A 2-dimensional image is generated with magnification ranging from X20 to approximately X30,000 and spatial resolution of 50 to 100 nm.
Samples must be solid and they must fit into the microscope chamber which undergoes into a stable vacuum on the order of 10^{-5} - 10^{-6} torr. (Samples likely to outgas at low pressures are usually analyzed by "low vacuum" and "environmental" SEMs or ESEM).
The instrument used for the analysis is a Philips XL30 TMP Microanalisi XRF-EDS (Figure 7.7).

7.3.4 Acetone extraction test

7.3.4.1 The technique

The acetone extraction test is able to provide valuable information on tape binder stability. The degradation products of the polyurethane binder were found to be soluble in acetone, and the weight percent (wt.%) of extractable was considered to be a measure of the degradation. Tape binder degradation is the result of polymer breakdown that occurs in reaction with humidity (i.e., hydrolysis). Hydrolytic breakdown causes a change in the structure of the polymeric chain, producing low-molecular-weight fragments. These end-fragments are compounds that are mobile and tacky, and they are likely to be extractable in acetone.



(a) (b)

Fig. 7.8: Figure (a) shows a tape sample in the becker ready for incubation; Figure (b) shows the precision weighing balance (0.0001 g) used to weigh the samples before and after incubation.
Author of the pictures: Federica Bressan. Location: Department of Industrial Engineering (chemical sector), University of Padova.

The acetone extraction test was chosen based on its ability to measure an increasing proportion of extractable end-fragments from the polyurethane polymer as binder hydrolysis proceeds. Measuring the percentage of extractable in acetone provides an indication of tape condition and reflects tape playability. Such a measurement indirectly detects the presence of low-molecular-weight products and is a good indicator of either degraded or unstable polyurethane binder. Other tape components, such as lubricants, might also be soluble in acetone, however, and this may alter the results: for this reason, the author has planned a study to analyze the composition of the residue. Since tape formulation may vary in significant ways, it was expected that the wt.% of extractable may also vary from one type of tape to another regardless of the degree of binder hydrolysis. Significant variation due to differences in format, manufacturer, or production batch was expected, besides a number of tape samples that were completely destroyed after the test, preventing any further measure of the weigh. The number of tapes on which the test could not be performed due to this behavior are significant (about half of them): this fact was not reported in the previous study that inspired the one presented by the author [79, p. 25 ff], which makes even more important to find alternative tests, such as the acidity test (extraction in water), which will be performed in the next future precisely on the tapes that degrade completely in acetone.
The year of production and the storage conditions of most tapes analyzed in this work are unknown. The results of the analyses of these tapes are reported in the next Chapter. Conversely, Chapter 9 reports the results obtained on the same tape sample before thermal treatment (sample M) and after treatment (sample N), where more information about the history of the carrier is available (brand, model, origin). It was believed that the difference between the two samples would reflect the condition of the samples during the incubation period. These two samples have

Tape width		% acetone extractable obtained for various extraction times		
		1/2 hour	1 hour	2 hours
3/4 in	Max.	2.4	2.5	2.5
	Min.	2.1	2.3	2.3
	Average	2.2	2.4	2.4
1 in	Max.	1.7	1.8	1.8
	Min.	1.6	1.7	1.8
	Average	1.6	1.7	1.8

Table 7.1: Effect of acetone extraction time on the determination of percent acetone extractable. Average values were calculated based on four measurements for each test. The percent acetone extractable is expressed in wt.% based on the weight loss of the tape sample. Source: [79, p. 26].

also been incubated in hexane for the same time duration (see Subsection 9.4.3). Figure 7.8(a) shows a tape sample ready for the test; Figure 7.8(b) shows the precision weighing balance used to weigh the samples before and after the test.

7.3.4.2 Extraction time

[79] reports that some preliminary tests shows that the wt.% of extractable is influenced by a variety of factors, most notably the duration of the acetone extraction. Thirty-minute immersion in acetone provides repeatable results. Shorter extraction times lead to inconsistent results, and longer extraction times do not significantly increase the amount of extractable compounds. Table 7.1 reports results obtained by [79] on 3/4" and 1" magnetic tape using 30-minute, one-hour, and two-hour extractions in acetone. Average values were determined based upon four evaluations for each extraction time and tape width. It was shown that increasing the duration of acetone extraction beyond 30 minutes did not significantly alter the final results for tapes. The values determined for each set of four measurements conducted on each tape displayed small differences.
Previous works [44] also suggest a 20-minutes extraction time, but in the present study a 30-minute extraction time was adopted.
Based on the preliminary tests, [79] finalized an acetone extraction method for use in the research, which the author replicated herein. The method provides reproducible results within an acceptable range. The data discussed in the following sections were determined following the procedure described in Table 7.2.

7.3.5 Mechanical analysis: Tensile test

7.3.5.1 The technique

This test method covers the determination of tensile properties of plastics in the form of thin sheeting, including film (less than 1.0 mm in thickness). The magnetic tape tested in this work have a total thickness of 0.5 mm (the information, provided by the manufacturer, is reported on the box of the tape, see Figure 9.1(a)).

Step	Description
1. Sample preparation	Sample weight: approx. 0.5 mg. Length of tape sample was based on tape width (e.g., 18" sample for 1" tape, 36" sample for 1/2" tape). Four test samples were prepared for each tape tested.
2. Conditioning	Sample was conditioned to 21°C, 50% RH, for at least one hour.
3. Weighing	Sample was placed in a weighing bottle and weighed on precision scale (±0.0001gram).
4. Acetone extraction	Sample was accordion-folded and immersed in 30 mL of acetone for 30 minutes.
5. Drying	Sample was retrieved and rinsed in acetone. Then, it was placed on filter paper for 15 minutes to drain and to let the acetone evaporate. Sample was placed in dry oven at 50°C for 15 minutes.
6. Conditioning	Sample was conditioned to 21°C, 50% RH, for at least one hour.
7. Reweighing	Sample was placed in a weighing bottle and weighed on precision scale.
8. Calculation	Acetone extractable was expressed in wt.% based on weight loss of sample. Final determination was expressed as average value based on four determinations for each tape tested.

Table 7.2: Acetone extraction method used by [79] for testing magnetic tapes. Source: [79, p. 27].

Tensile properties determined by this test method are of value for the identification and characterization of materials for control and specification purposes. In this work, however, the purpose of this test was to compare the magnetic tape samples before and after thermal treatment.

Three types of tape samples have been tested: two samples of blank tape before treatment, three samples of recorded tape before treatment, three samples of recorded tape after treatment (for a description of the treatment cycle, see Section 9.3). For comparative purposes, the elastic module (E) and the yield strength (σ_s) have been determined. The tensile strength at break and the percent elongation at break have also been determined.
During the preparation of the test, the *Standard test method for tensile properties of thin plastic sheeting* has been considered [87]. For tensile modulus of elasticity determinations, a sample length of 250 mm is considered as standard, however a length as short as 100 mm is accepted. It is recommended that at least five samples are tested from each type (in this case the types of tape are: blank/recorded, before/after treatment). As for the speed of testing (rate of grip separation), 50 mm/min are indicated for initial grip separations of 10 mm ([87, Table 1 at p. 4]. In this work, tape samples of 10 mm have been used. Two samples of blank tape before treatment and three samples of recorded tape respectively before and after treatment have been tested, with a rate of grip separation of 50 mm/min according

to the recommendation. The instrument used is dynamometer Galdabini SUN2500 with a load cell of 25,000N (Figure 7.10).

Figure 7.10 schematizes the three main phases of the test: first the sample is anchored to the grips, then the grips separate until the sample breaks, and finally the sample is removed. Details of the tape samples at different degrees of deformation are visible in Figure 9.6.

It is worth mentioning that a different physical test (*friction test*) is suggested in [79, p. 33], aimed at "detecting the changes in the tape binder over time" and which was inspired by the work of the Eastman Kodak Company on motion-picture films in 1971 [88]. The test involves placing a length of the tape sample on the surface of an inclined plane. A rider is placed on top of the sample strip that has point contact with the surface. The inclined plane is raised until the rider slides. The idea behind this application of the friction test is that binder degradation increases the stickiness of the tape surface, and increased stickiness, in turn, necessitates raising the device plane higher in order to initiate the sliding of the rider. The coefficient of sliding friction was measured as a tangent of the inclined plane to the horizontal. Contrary to the test conducted in the present work, the friction test just described is non-destructive. The author has not been able to try this test yet.

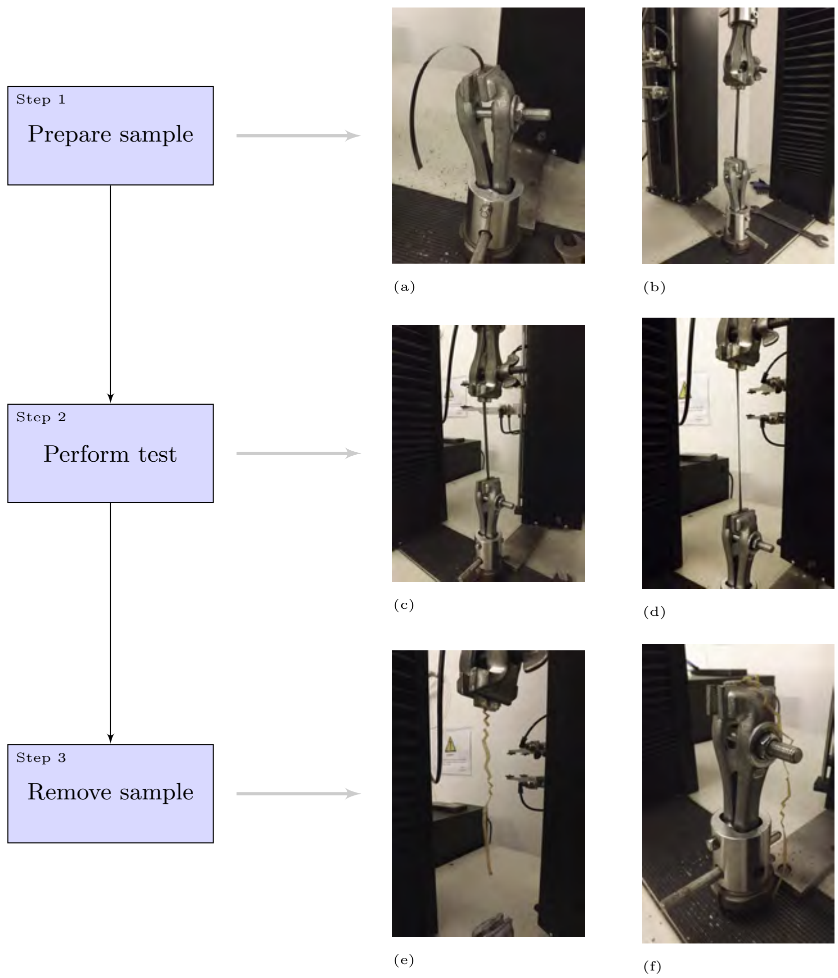


Fig. 7.9: The main phases of a tensile test. Details of the tape samples at different degrees of deformation are visible in Figure 9.6.
Author of the pictures: Federica Bressan. Location: Department of Industrial Engineering (chemical sector), University of Padova.

Fig. 7.10: The instrument used for the tensile test: a dynamometer Galdabini SUN2500 with a load cell of 25,000N.
Author of the picture: Federica Bressan. Location: Department of Industrial Engineering (chemical sector), University of Padova.

8

Characterization of magnetic tapes

This Chapter reports the experimental results of the analyses carried out on ten different samples of magnetic tape. Each sample is presented in a separate section, from Tape A to Tape L. The methodology and the techniques employed have been described in the previous Chapter, while the results are discussed in Chapter 10. The figures that did not fit in the text have been collected in Appendix D. Additional documentation is also available separately[1].

8.1 Tape sample A

Brand: TEAC. Model: unknown.
Both the shiny side of the tape and the matt side are light brown.

8.1.1 FTIR Spectroscopic analysis in ATR

Shiny side

The peaks that correspond to cellulose acetate are visible in the analysis of the shiny side of the tape sample (Figure 8.1(a) shows the spectrum and Figure 8.1(b) shows the identification).

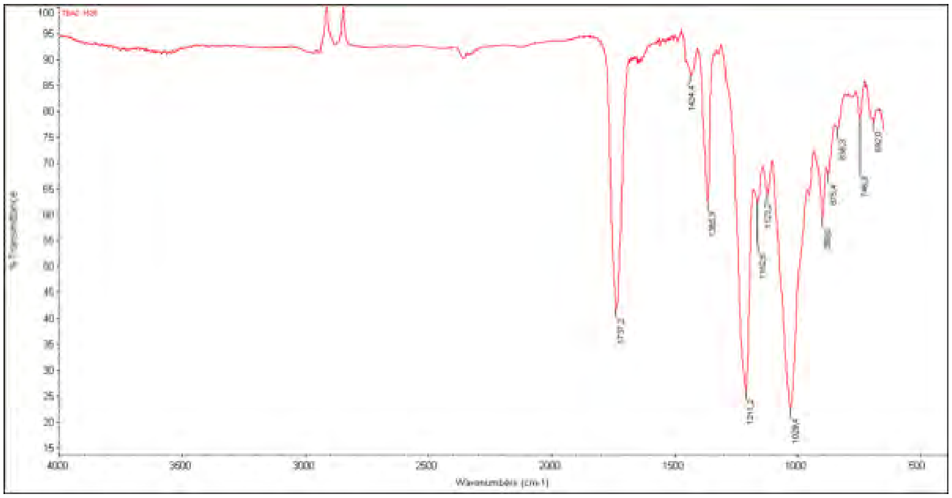
Matt side

The analysis of the matt side of the tape sample shows that the coating of the magnetic coating is a co-polymer (polivynilchloride-vynil alcol or vynil acetate). The absorption at 3266cm^{-1} suggests the presence of water.

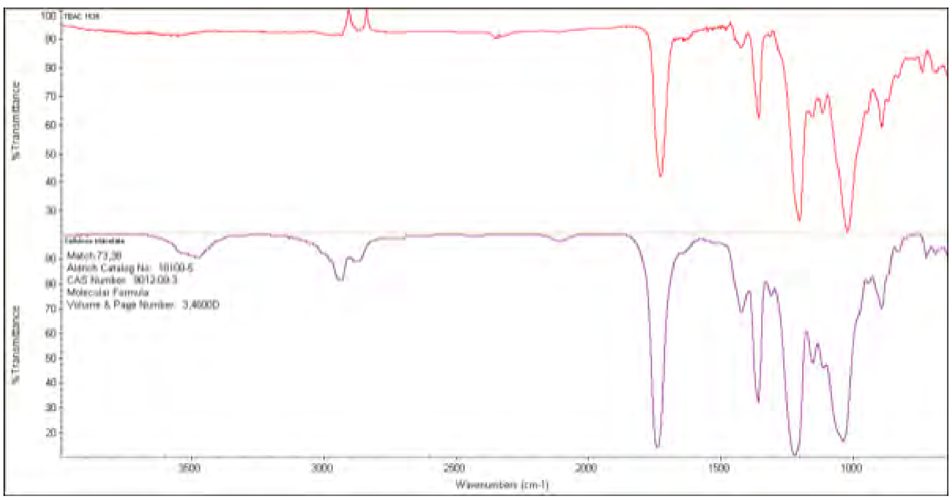
8.1.2 ThermoGravimetric Analysis (TGA)

The analysis shows that below 150 °C, less than 1.5% of the sample weight is lost, reasonably due to the absorption of water. Degradation processes of the polymer occur at 233.96 °C, 290.15 °C, 336.12 °C, 503.89 °C, with a residue of 26.71%.

[1] `http://www.dei.unipd.it/~bressanf/tesi/tesi2013/`



(a) Tape sample A: shiny side



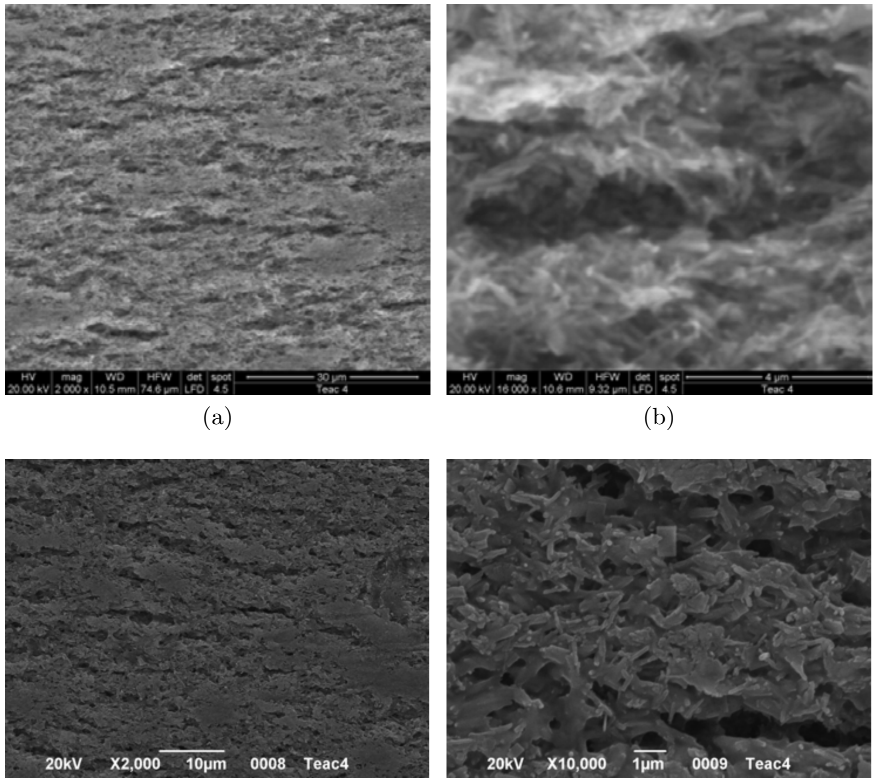
(b) Tape sample A: shiny side identification

Fig. 8.1: Tape sample A: (a) shiny side; (b) shiny side identification.

8.1.3 ESEM

Shiny side

The analysis indicates that the shiny side of the sample is the base of the tape (Figures 8.2(a) and 8.2(b)). The elemental analysis shows the presence of only carbon and oxygen.



(a) (b) (c) (d)

Fig. 8.2: (a) nastro A ESEM; (b) idem; (a) nastro A SEM; (b) idem.

Matt side

The analysis indicates that the matt side of the sample carries the magnetic coating. The magnetic domains are visible with the SEM analysis. The elemental analysis shows the presence of iron oxide in approximatively 1:1 atomic ratio (Fe/O). The analysis also shows the presence of chloride.

8.1.4 SEM

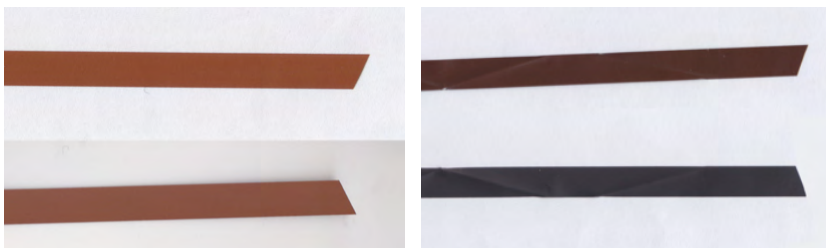
The matt side of the tape is the one with the magnetic coating (Figures 8.2(c) and 8.2(d)).

8.1.5 Acetone Extraction test

The sample is completely destroyed in acetone: the polymer is dissolved and the inorganic part (red-brown) is collected as a powder (Figures 8.3(a) and 8.3(b)).

(a) Tape sample A (b) Tape sample B

Fig. 8.3: Tape sample B: acetone extraction test.



(a) Tape sample B (b) Tape sample C

Fig. 8.4: (a) Sample B: shiny side (top), identified as the base of the tape, and matt side (bottom), with the magnetic coating; (b) Tape sample C: shiny side (top), with the magnetic coating, and matt side (bottom), identified as the base of the tape.

8.2 Tape sample B

Brand: AGFA. Model: unknown.
Both the shiny side of the tape and the matt side are light brown (Figure 8.4(a)).

8.2.1 FTIR Spectroscopic analysis in ATR

Shiny side

The peaks that correspond to cellulose acetate are visible in the analysis of the shiny side of the tape sample.

Matt side

The poor quality of the infrared spectrum does not allow the identification of the material.

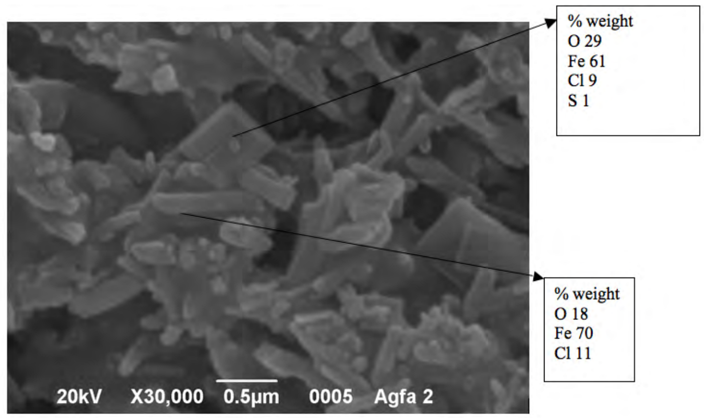


Fig. 8.5: SEM tape sample B.

8.2.2 ThermoGravimetric Analysis (TGA)

The analysis shows that below 150 °C, less than 1% of the sample weight is lost, reasonably due to the absorption of water. Degradation processes of the polymer occur at 230.21 °C, 284.57 °C, 338.93 °C e 602.31 °C, with a residue of 23.92%.

8.2.3 SEM

Crystals in shape of prisms and cubes are visible in some SEM images (Figure 8.5). The analysis shows different compositions: the prismatic crystals contain iron and chloride, while the cubic ones contain a smaller quantity of chloride, but also some sulfur.

8.2.4 ESEM

Shiny side

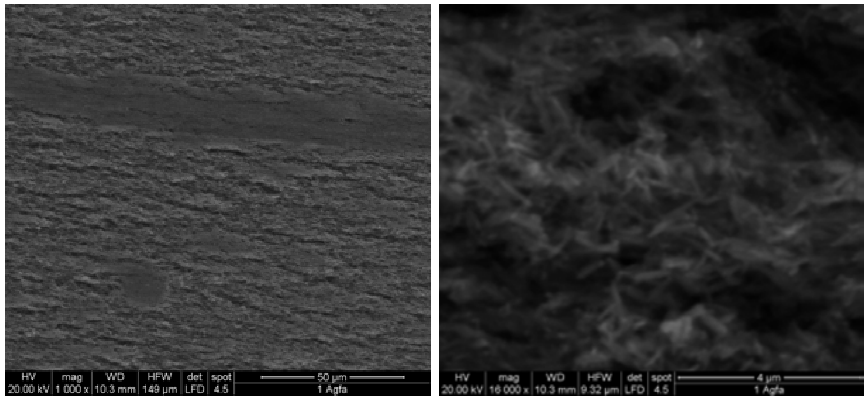
The analysis indicates that the shiny side of the sample is the base of the tape. The elemental analysis shows only the presence of carbon and oxygen.

Matt side

The analysis shows that the matt side of the sample carries the magnetic coating. The magnetic domains are visible with the SEM analysis. The elemental analysis shows the presence of iron oxide in approximatively 6:4 atomic ratio. The analysis also shows the presence of chloride.

8.2.5 Acetone Extraction test

The sample is completely destroyed in acetone: the polymer is dissolved and the inorganic part (red-brown) is collected as a powder.



(a) (b)

Fig. 8.6: (a) and (b): ESEM tape sample B.

8.3 Tape sample C

Brand: MAXELL. Model: unknown.
The shiny side of the tape is dark brown; the matt side is black (Figure 8.4(b)).

8.3.1 FTIR Spectroscopic analysis in ATR

Shiny side

The peaks that correspond to a co-polymer (poly-viny butirrale - vynil alcol - vynil acetate) are visible in the analysis of the shiny side of the tape sample. Apparently a higher content of water (with respect to other samples) is present.

Matt side

Even if the quality of the spectrum is poor, the identification system suggested the material as polyurethane.

8.3.2 ThermoGravimetric Analysis (TGA)

The analysis shows that below 120 °C, less than 1% of the sample weight is lost, reasonably due to the absorption of water. At 142.10 °C a fast degradation occurs. At 322.06 °C, and 429.85 °C other degradation processes occur, with a final residue of 34.07%.

8.3.3 ESEM

Shiny side

The analysis indicates that the shiny side of the sample carries the magnetic coating. The elemental analysis shows only the presence of iron and oxygen, in atomic ratio 1:1 (Fe/O).

Matt side

The analysis indicates that the matt side of the sample is the base of the tape, containing only carbon and oxygen.

8.3.4 Acetone Extraction test

The sample is completely destroyed in acetone: a black film is separated by the brown one. The black film is strongly damaged losing its shape.

8.4 Tape sample D

Brand: TDK. Model: unknown.
The shiny side of the tape is brown; the matt side of the tape is black.

8.4.1 FTIR Spectroscopic analysis in ATR

Shiny side

The peaks that correspond to polyester are visible in the analysis of the shiny side of the tape sample (Figure D.7(a)).

Matt side

The peaks that correspond to polyester are visible in the analysis of the matt side of the tape sample (Figure 8.7(b)).

8.4.2 ThermoGravimetric Analysis (TGA)

The analysis shows that below 149 °C, less than 1% of the sample weight is lost, reasonably due to the absorption of water. At 231.15 °C a fast degradation occurs. At 436.41 °C another degradation process occurs, with a final residue of 35.60%.

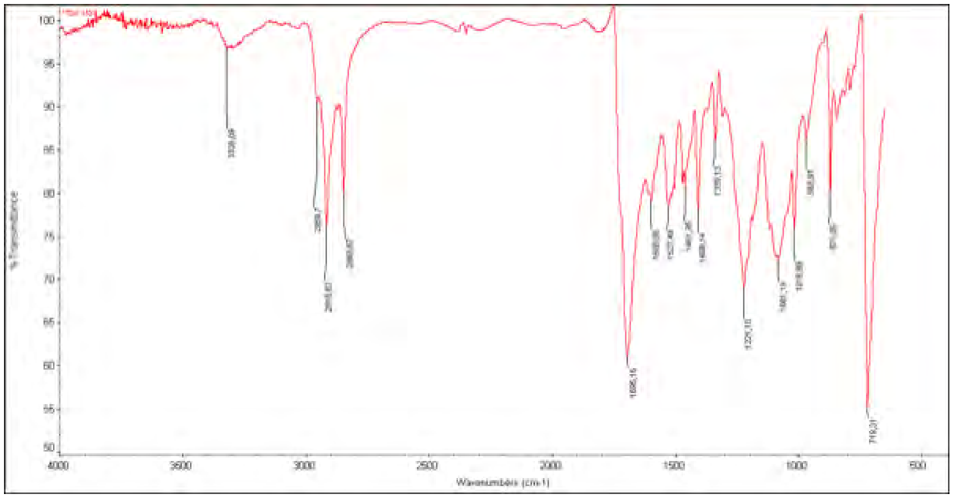
8.4.3 ESEM

Shiny side

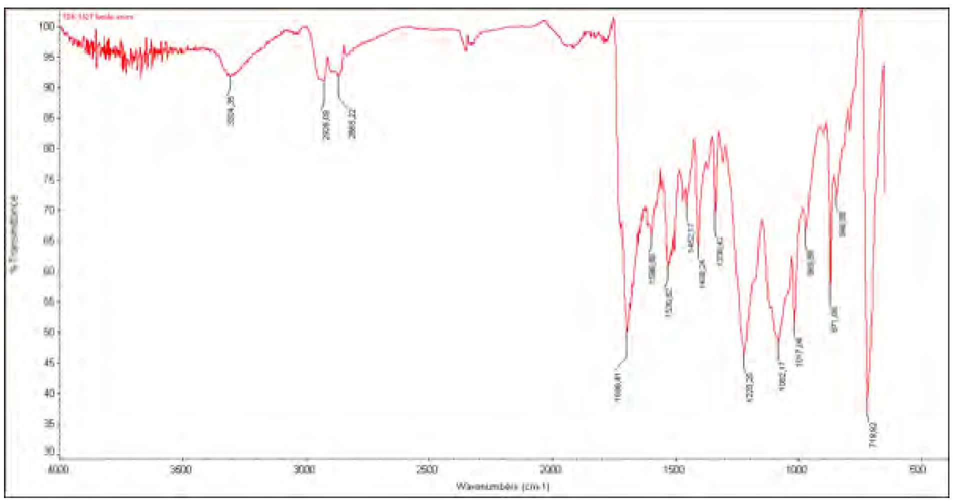
The analysis indicates that the shiny side of the sample carries the magnetic coating. Figure 8.6 shows that the material is not homogeneous. The elemental analysis shows the presence of iron and oxygen, in approximatively 1:1 atomic ratio (Fe/O). The analysis also shows the presence of chloride.

Matt side

The analysis indicates that the matt side of the sample is the base of the tape, containing only carbon and oxygen.



(a) Tape sample D: shiny side

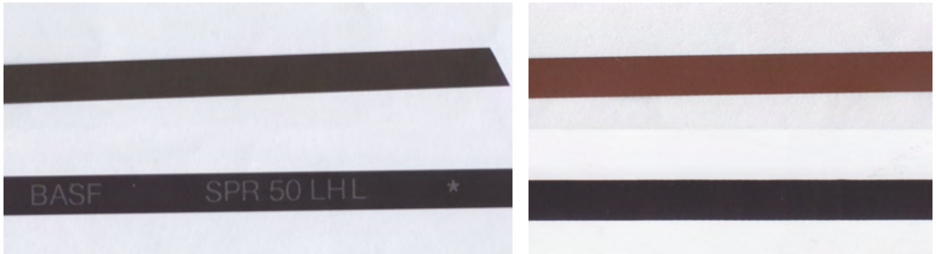


(b) Tape sample D: matt side

Fig. 8.7: Tape sample D: (a) shiny side; (b) shiny side identification.

8.4.4 Acetone Extraction test

The sample is completely destroyed in acetone: a brown powder is formed leaving a dark brown film.



(a) Tape sample E (b) Tape sample F

Fig. 8.8: (a) Sample E: shiny side (top), with the magnetic coating, and matt side (bottom), identified as the base of the tape; (b) Tape sample F: shiny side (top), with the magnetic coating, and matt side (bottom), identified as the base of the tape.

8.5 Tape sample E

Brand: BASF. Model: SPR 50 LHL.
The shiny side of the tape is dark brown; the matt side of the tape is black. The name of the model is printed on the matt side (Figure 8.8(a)).

8.5.1 FTIR Spectroscopic analysis in ATR

Shiny side

The peaks that correspond to plyurethane are visible in the analysis of the shiny side of the tape sample.

Matt side

The poor quality of the spectrum does not allow the identification of the material.

8.5.2 ThermoGravimetric Analysis (TGA)

At 79.31 °C and at 175.85 °C, very fast degradations occur. At 428.38 °C another degradation process occurs, with a final residue of 29.50% (Figure 8.9(a)).

8.5.3 ESEM

Shiny side

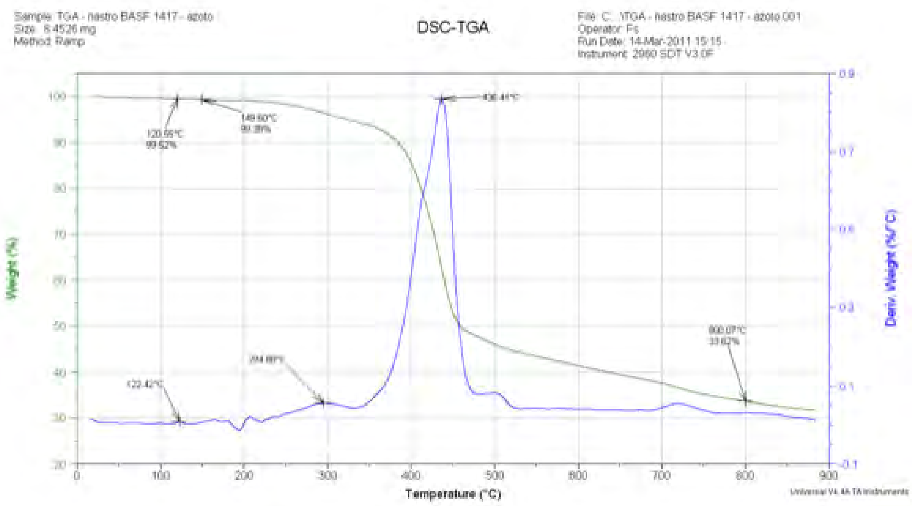
The analysis indicates that the shiny side of the sample carries the magnetic coating. The elemental analysis shows the presence of iron and oxygen, in approximatively 1:1 atomic ratio (Fe/O).

Matt side

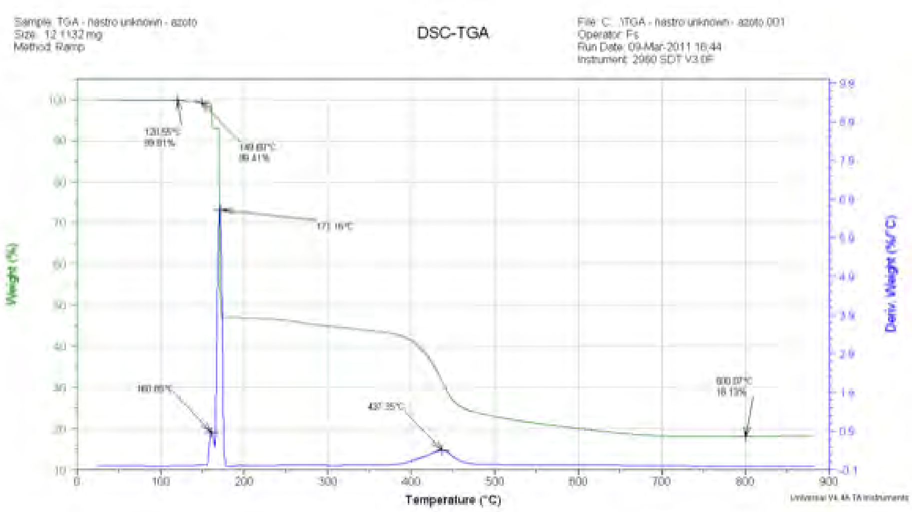
The analysis indicates that the matt side of the sample is the base of the tape, containing only carbon and oxygen.

8.5.4 Acetone Extraction test

The sample is destroyed in acetone: the tape is broken in small parts.



(a) Tape sample E



(b) Tape sample F

Fig. 8.9: (a) Tape sample E; (b) Tape sample F.

(a) Tape sample D

(b) Tape sample E

Fig. 8.10: Acetone extraction test: (a) Tape sample D; (b) Tape sample E.

8.6 Tape sample F

Brand and model: unknown.
The shiny side of the tape is light brown; the matt side is black (Figure 8.8(b)).

8.6.1 FTIR Spectroscopic analysis in ATR

Shiny side

The peaks that correspond to polyurethane are visible in the analysis of the shiny side of the tape sample.

Matt side

The peaks that correspond to polyester (stearate) are visible in the analysis of the matt side of the tape sample.

8.6.2 ThermoGravimetric Analysis (TGA)

At 171.16 °C a very fast degradation occurs. At 437.35 °C another degradation process occurs, with a final residue of 18.13% (Figure 8.9(b)).

8.6.3 ESEM

Shiny side

The analysis indicates that the shiny side of the sample carries the magnetic coating. The elemental analysis shows the presence of iron and oxygen, in approximatively 1:1 atomic ratio (Fe/O), and a small quantity of chloride.

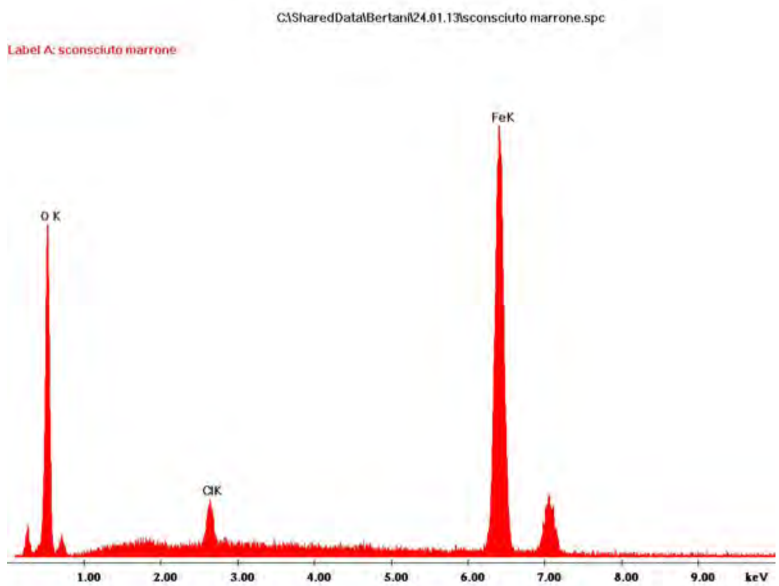


Fig. 8.11: Tape sample F: elemental analysis.

Matt side

The analysis indicates that the matt side of the sample is the base of the tape, containing only carbon and oxygen.

8.6.4 Acetone Extraction test

The sample shows a weight loss of 0.66%.

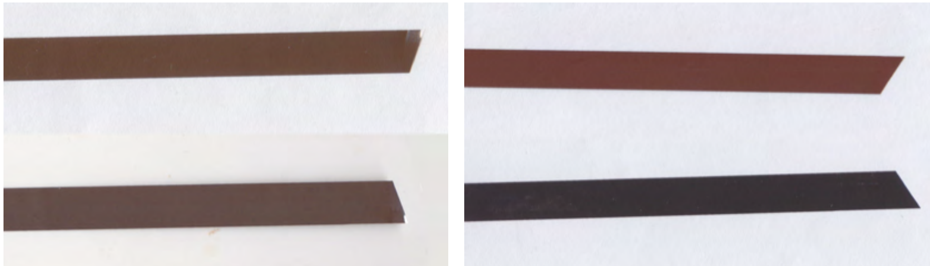
8.7 Tape sample G

Brand: Scotch/3M. Model: unknown.
Both the shiny side of the tape and the matt side is brown (Figure 8.12(a)).

8.7.1 FTIR Spectroscopic analysis in ATR

Shiny side

The peaks that correspond to polyetilenthereftalate (PET) are visible in the analysis of the shiny side of the tape sample.



(a) Tape sample G (b) Tape sample H

Fig. 8.12: (a) Sample G: shiny side (top), identified as the base of the tape, and matt side (bottom), with the magnetic coating; (b) Tape sample H: shiny side (top), with the magnetic coating, and matt side (bottom), identified as the base of the tape.

Matt side

The peaks that correspond to polyurethane are visible in the analysis of the matt side of the tape sample.

8.7.2 ThermoGravimetric Analysis (TGA)

At 152.41 °C a very fast degradation occurs. At 250.83 °C and at 440.16 °C, other degradation processes occur, with a final residue of 31.26%.

8.7.3 ESEM

Shiny side

The analysis indicates that the shiny side of the sample is the base of the tape, containing only carbon and oxygen.

Matt side

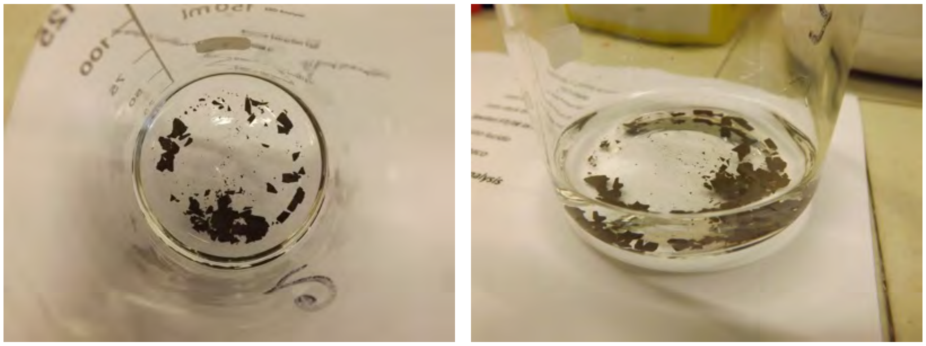
The analysis indicates that the matt side of the sample carries the magnetic coating. The elemental analysis shows the presence of iron and oxygen, in approximatively 1:1 atomic ratio (Fe/O). The analysis also shows the presence of chloride.

8.7.4 Acetone Extraction test

The sample is completely destroyed in acetone: the tape breaks giving small fragments.

8.8 Tape sample H

Brand: BASF. Model: unknown.
The shiny side of the tape is brown; the matt side is black (Figure 8.12(b)).



(a) Tape sample G (b) Tape sample G

Fig. 8.13: Tape sample G: acetone extraction test.

8.8.1 FTIR Spectroscopic analysis in ATR

Shiny side

The peaks that correspond to polyurethane are visible in the analysis of the shiny side of the tape sample.

Matt side

The peaks that correspond to a co-polymer (tetrafluoroethylene - esafluoropropylene (TEFLON100)) are visible in the analysis of the matt side of the tape sample.

8.8.2 ThermoGravimetric Analysis (TGA)

The analysis shows that below 100 °C, less than 1% of the sample weight is lost. At 294.88 °C and 436.41 °C degradation processes occur, with a final residue of 33.62%.

8.8.3 ESEM

Shiny side

The analysis indicates that the shiny side of the sample carries the magnetic coating. The elemental analysis shows the presence of iron and oxygen, in approximatively 1:1 atomic ratio (Fe/O), and a small quantity of chloride.

Matt side

The analysis indicates that the matt side of the sample is the base of the tape, containing only carbon and oxygen. Some grains with different compositions are visible on the surface. The sample shows a weight loss of 2.05%.

8.9 Tape sample I

Brand: unknown. Model: unknown.
The shiny side of the tape is brown; the matt side is black.

8.9.1 FTIR Spectroscopic analysis in ATR

Shiny side

The peaks that correspond to polyurethane are visible in the analysis of the shiny side of the tape sample.

Matt side

The poor quality of the spectrum does not allow the identification of the material..

8.9.2 ESEM

Shiny side

The analysis indicates that the shiny side of the sample carries the magnetic coating. The elemental analysis shows the presence of iron and oxygen, in approximatively 1:1 atomic ratio (Fe/O).

Matt side

The analysis indicates that the matt side of the sample is the base of the tape, containing only carbon and oxygen.

8.9.3 SEM

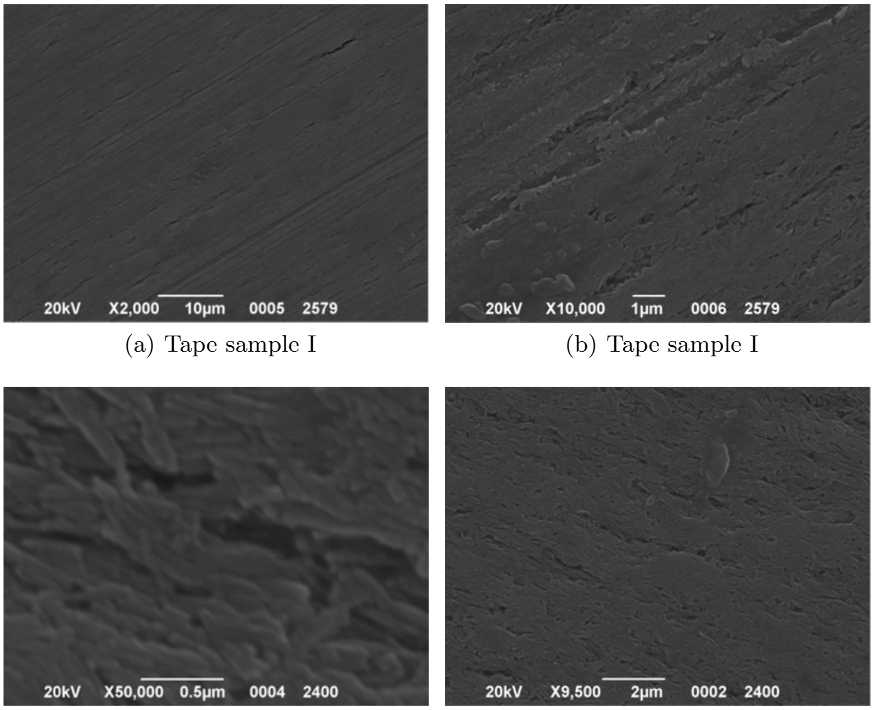
Figures 8.14(a), 8.14(b) and 8.14(c) show the shiny side of the tape with a magnification of X2,000, X10,000 and X50,000.

8.9.4 Acetone Extraction test

The sample shows a weight loss of 6.30%.

Magnetic residue: ESEM

In accordo con la grande perdita di peso del tesi in acetone, during re-play si osserva una perdita di pasta (SBS-SSS), la cui analisi all'ESEM riportata di seguito: nella pasta c' una parte di polimero; ci sono grains of iron oxide. The analysis shows crystals of iron oxide with different atomic ratios.



(a) Tape sample I (b) Tape sample I

(c) Tape sample I (d) Tape sample L

Fig. 8.14: (a), (b) and (c): SEM analysis of the tape sample I; (d) SEM analysis of the tape sample L.

8.10 Tape sample L

Brand: unknown. Model: unknown.
The shiny side of the tape is brown; the matt side is black.

8.10.1 FTIR Spectroscopic analysis in ATR

Shiny side

The peaks that correspond to polyurethane are visible in the analysis of the shiny side of the tape sample.

Matt side

The poor quality of the spectrum does not allow the identification of the material.

8.10.2 ESEM

Shiny side

The analysis indicates that the shiny side of the sample carries the magnetic coating (Figures 8.15(a) and 8.15(b)). The elemental analysis shows the presence of iron and oxygen, in approximatively 1:1 atomic ratio (Fe/O).

Matt side

The analysis indicates that the matt side of the sample is the base of the tape, containing only carbon and oxygen.

8.10.3 SEM

Figure 8.14(d) shows the shiny side of the tape with a magnification of X9,500.

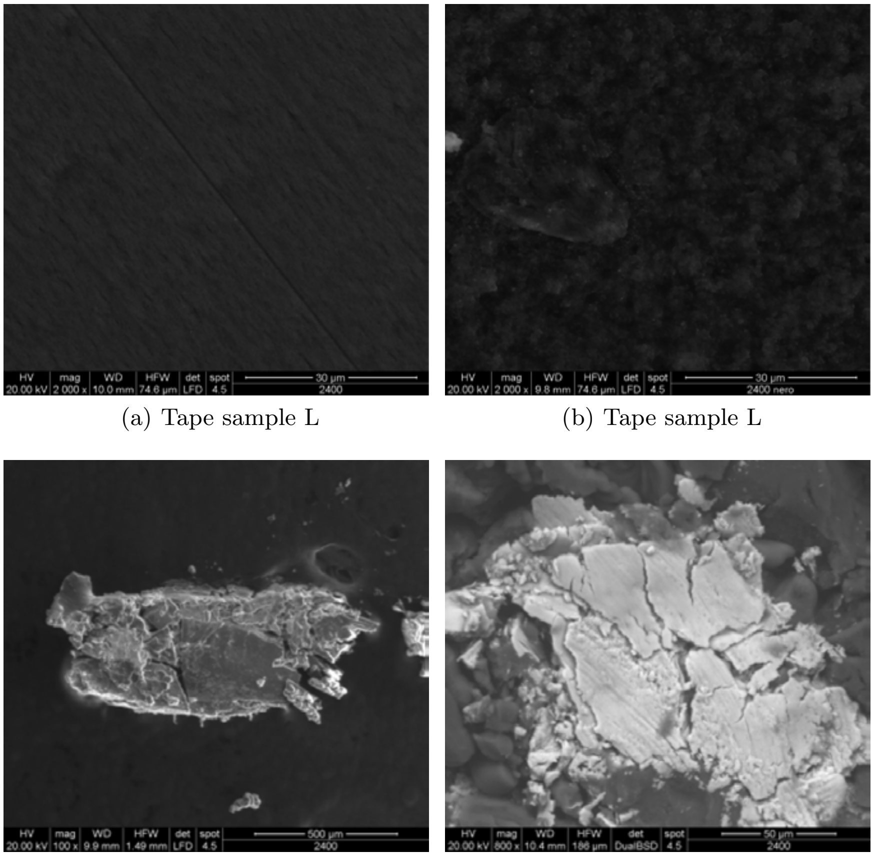
8.10.4 Acetone Extraction test

The sample shows a weight loss of 5.80%.

ESEM: sticky residue

In accordance with the significant loss of weight observed in the acetone extraction test, which indicates a poor condition of the binder, the tape leaves a sticky residue on the recorder during re-play. An ESEM analysis has been conducted on the residue (Figures 8.15(a) and 8.15(b)). The analysis shows crystals of iron oxide with different atomic ratios (Figure 10.5).

The results presented above are discussed in Chapter 10.



(a) Tape sample L

(b) Tape sample L

(c) Residue of tape sample L

(d) Residue of tape sample L

Fig. 8.15: (a) and (b): ESEM of tape sample L; (c) and (d): ESEM of the residue of tape sample L.

9

Analyses of thermally treated tapes

This Chapter describes the methodology and the first results obtained by an experiment finalized at understanding the physical and chemical modifications to which the magnetic tapes are subject during thermal treatment.

9.1 Introduction

In the previous Chapter, the experimental results of the characterization of the tapes have been presented. The characterization provides information about the behavior of the materials of which the tapes are made at varying heat and humidity rate, or under mechanical stress. This information is useful because it helps formulating hypotheses on what to expect when a tape is thermally treated. The experiment described in this Chapter is necessary to the definition of a scientific protocol for the restoration of magnetic tapes affected by SBS-SS Syndrome. It consists in audio and chemical analyses conducted on the same tape samples before and after treatment. The next Section describes the materials used in the experiment, Section 9.3 details the method used, while the experimental results are presented in Section 9.4 (Subsection 9.4.1 and 9.4.2 for the audio signal analyses, and Subsection 9.4.3 for the chemical analyses). The results are discussed in Chapter 10.

9.2 Materials

The tape used for the experiment is a Maxell UD 50-60 (Figure 9.1) borrowed from the archive of the Centro di Sonologia Computazionale. The tape was probably bought over ten years ago[1], but it has been kept in a sealed cardboard box with other brand new tapes, in its original container.
Four saw-tooth signals have been synthesized with fundamental frequencies at 110 Hz, 220 Hz, 440 Hz, 880 Hz, with a duration of 20 seconds each, and with a normalized amplitude of 0.8. The test signal is included in the supplementary material

[1] The experiment has been carried out over December 2012 and February 2013.

(a) (b)

Fig. 9.1: The tape used in the experiment, a Maxell UD 50-60.

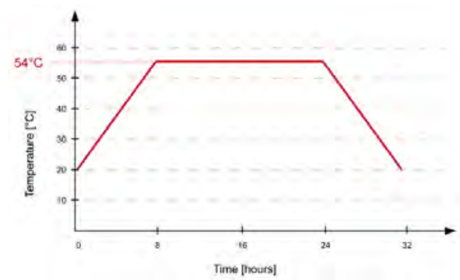
of this work[2].
The signal has been recorded on the tape with a Revox PR99. The same machine has been used to read the tape. The signal has been converted with a Prism Orpheus and acquired with the free wave editor Audacity on a Mac Pro (2.8 GHz Quad Core Intel Xeon, RAM 8 GB, 1066 MHz DDR3) at the Centro di Sonologia Computazionale.
The tape samples have been thermally treated with a precision incubator (Memmert INP 400, in Figure 9.2(a)). The spectrum of the audio signal has been generated with the Audacity analysis tools, while the audio features have been extracted with the Matlab MIRToolBox. For a description of the instruments and of the techniques used for the mechanical-chemical analyses, please see Section 7.3.

9.3 Method

The test signal has been recorded on the blank tape. Then the tape has been replayed and the audio digitized, generating two audio files: one from the blank part of the tape and one with the test signal. After this, the tape has been physically split: a sample of blank tape and a sample of the tape with the test signal have been stored for the chemical analyses, while the rest of the tape has been thermally treated. The fan of the incubator has been kept open (50% in a scale from 0 to 100), and the cycle has been programmed as follows: a starting ramp of 8 hours to go from ambience temperature to 54 °C, 48 hours plateau, another ramp of 8 hours to go from 54 °C back to ambience temperature. The cycle lasted a total of 64 hours. Figure 9.2(b) shows the profile of this treatment cycle, with a different duration.
When the treatment was complete, the tape has been re-played again and the audio digitized, generating two more audio files: one from the blank part of the tape and one with the test signal. This procedure has been repeated twice, in order

[2] `http://www.dei.unipd.it/~bressanf/tesi/tesi2013/`

(a) Precision incubator



(b) Treatment cycle

Fig. 9.2: (a) The precision incubator used for the thermal treatment of magnetic tapes: a Memmert INP 400 with natural convection; (b) typical cycle for a thermal treatment of magnetic tapes.

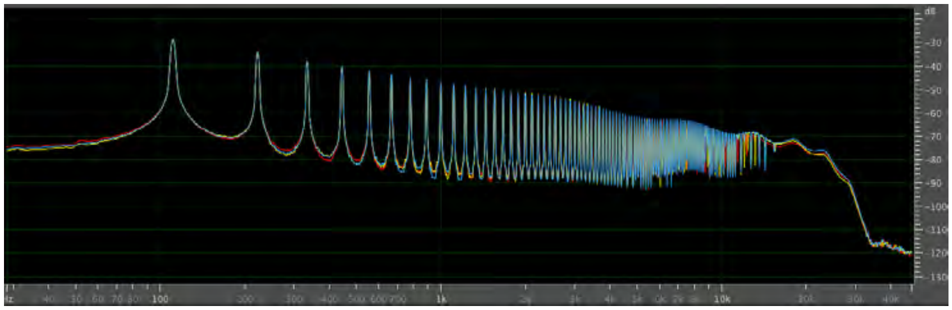
to have two versions of the same tape sample digitized after treatment. A total of four tape samples have been produced:

- 2 before treatment: blank tape and recorded tape (with test signal)
- 2 after treatment: blank tape and recorded tape (with test signal)

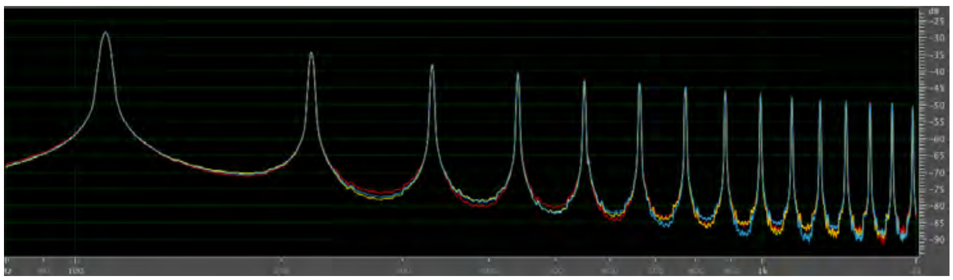
corresponding to a total of six audio files:

- 2 before treatment: blank tape and recorded tape (with test signal)
- 4 after treatment: 2 blank tape (take 1 and take 2) and 2 recorded tape (with test signal) (take 1 and take 2)

The digitized audio was ready to be analyzed, while the tape samples were sent to the Department of Industrial Engineering in order to proceed with the chemical analyses.
After listening to the files, the audio files of the blank tape samples have been discarded because the differences between before and after treatment were imperceptible, therefore the audio features extracted with MIRToolBox would not be significant. The audio analyses have been carried out on three audio files: before treatment and after treatment (take 1 and take 2).
All tape samples have been chemically analyzed, but similarly to the audio part of the experiment, blank tapes have discarded and the only data reported in the experimental section of this Chapter regards the samples with the test signal. The samples have been labeled Tape M (before treatment) and Tape N (after treatment).



(a) Spectrum of the audio samples before and after treatment



(b) Detail of the spectrum

Fig. 9.3: Comparison of the audio signal spectra. Colors: blue indicates the signal extracted from tape before the treatment, yellow and magenta indicate the signal extracted from the tape after the treatment (respectively take 1 and take 2).

9.4 Experimental results

9.4.1 Spectrum of the signal

The spectrum of the audio files has been calculated by means of an FFT with a Blackman-Harris window and a size of 65,536 samples. Figure 9.3(a) shows the comparison between the files, while Figure 9.3(b) shows a detail of it.

9.4.2 Audio features

The following set of audio features has been selected from the Matlab MIRToolBox:
• *RMS* takes into account the global energy of the signal, computed as the root average of the square of the amplitude (Root Mean Square) [89, p. 1593].
• *Centroid* is the first moment of the spectral amplitude. It is related with the impression of "brightness"of a sound [90], because a high centroid value means that the sound energy is concentrated at the higher frequencies.
• *Spread* is the standard deviation of the spectral amplitude.
• *Skewness* is the third standardized moment, i.e. the ratio between the third central moment of the spectral amplitude and the standard deviation raised to the third power. It is related to the symmetry of the spectral envelope. A symmetrical distribution has a coefficient of skewness of zero. A positive coefficient of skewness

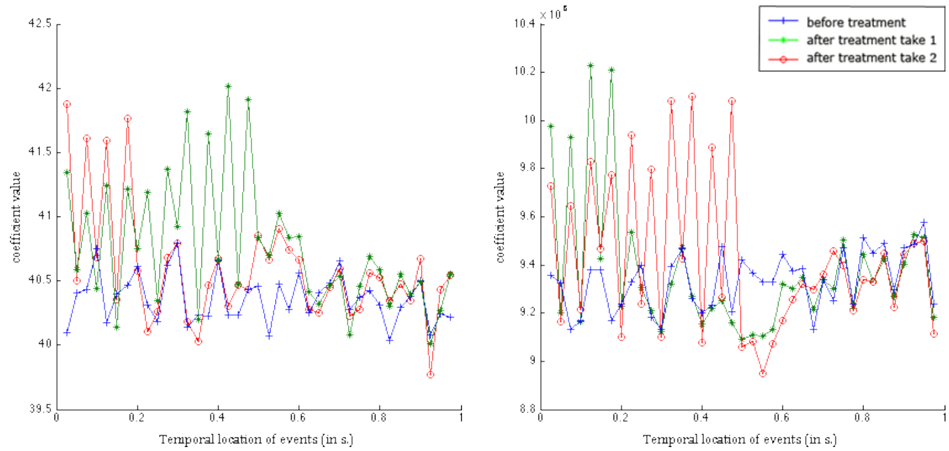
Features		Before	After: T1	After: T2
dynamics.rms	mean	0.9987	0.9991	0.9989
	std	0.0286	0.0257	0.0276
spectral.centroid	mean	5.4681e+03	5.5164e+03	5.4805e+03
	std	139.3696	149.1016	151.9717
spectral.spread	mean	40.3647	40.7611	40.5892
	std	0.1889	0.5068	0.4503
spectral.skeweness	mean	9.3341e+06	9.4216e+06	9.3711e+06
	std	1.2021e+05	3.1639e+05	2.7774e+05
spectral.brightness	mean	0.5433	0.5440	0.5428
	std	0.0074	0.0076	0.0077
spectral.rolloff85	mean	1.3695e+04	1.3810e+04	1.3729e+04
	std	346.2345	379.8534	365.7089
spectral.rolloff95	mean	2.1572e+04	2.1690e+04	2.1624e+04
	std	212.0853	237.0967	255.6722
spectral.roughness	mean	9.5087e+04	9.5360e+04	9.5081e+04
	std	3.3087e+03	4.4374e+03	3.6459e+03
spectral.irregularity	mean	0.3128	0.2226	0.2678
	std	0.2564	0.1638	0.2186

Table 9.1: Column 'Before': values of the signal digitized from the tape before thermal treatment. Columns 'After': values of the signal digitized from the tape after thermal treatment (take 1 and take 2).

indicates that the distribution exhibits a concentration of mass toward the left and along tail to the right, whereas a negative value generally indicates the opposite.
• *Brightness* measures the amount of energy above the frequency of 1500Hz.The result is expressed as a number between 0 and 1.
• *Rolloff85* is the frequency such that the 85% of the total energy is contained below that frequency. It is related, as the previous and the following feature, to the "brightness" of the sound.
• *Rolloff95* is the frequency such that the 95% of the total energy is contained below that frequency [91, pp. 1003-1004].
• *Roughness* is calculated starting from the results of Plomp and Levelt [92], that proposed an estimation of the dissonance degree between two sinusoids, depending on the ratio of their frequency. The total roughness for a complex sound can be calculated by computing the peaks of the spectrum, and taking the average of all the dissonance between all possible pairs of peaks [93].
• *Irregularity* refers to the irregularity of the spectrum is the degree of variation of the successive peaks of the spectrum [94].

These features have been chosen because previous works showed that they effectively highlight the differences between different takes of an audio recording [91].

1) The features have been calculated for each frame of the audio files. Two significant results are reported in Figures 9.4(a) and 9.4(a), while the others have been collected in Appendix E).
2) The mean and the standard deviation of the three audio files have been calcu-



(a) Audio feature: spread

(b) Audio feature: skewness

Fig. 9.4: Comparison of the features SPREAD (a) and SKEWNESS (b) of the audio files. Colors: blue indicates the signal extracted from tape before the treatment, green and red indicate the signal extracted from the tape after the treatment (respectively take 1 and take 2).

lated for each feature. The results are summarized in Table 9.1.
3) A comparison between the spectra of the first frame of the three audio files has also been compared (Figure 10.1).

9.4.3 Chemical analyses

9.4.3.1 Tape sample M: before treatment

Brand: MAXELL. Model: UD 50-60.
Both the shiny side of the tape and the matt side are brown.

FTIR Spectroscopic analysis in ATR: Shiny side The peaks that correspond to PET are visible in the analysis of the reflective side of the tape sample.
Matt side The analysis indicates that this side of the tape sample is made of polyester.

ThermoGravimetric Analysis (TGA): The analysis shows that below 150 °C, less than 0.5% of the sample weight is lost. At 274.26 °C and 442.03 °C degradation processes occur, with a final residue of about 30%.

ESEM: Shiny side Figure D.44(b) shows the dimension of some magnetic crystals. The analysis indicates that the shiny side of the sample carries the magnetic coating. The elemental analysis shows the presence of iron and oxygen, in approximatively 1:1 atomic ratio (Fe/O), and a small quantity of chloride (Figure D.46).
Matt side The analysis indicates that the matt side of the sample is the substrate of the tape, containing only carbon and oxygen.

(a) (b)

Fig. 9.5: Figure (a) shows a detail of the tape samples in the flasks, ready for incubation; Figure (b) shows the flasks sealed with parafilm, with acetone on the left and hexane on the right.

Acetone Extraction test: The sample shows a weight loss of 1.90%. Figure 9.5(a) shows a detail of the samples ready for incubation.

Hexane Extraction test: No modification has been observed in the samples after incubation.
Figure 9.5(b) shows the samples in incubation (acetone left and hexane right).

Mechanical analysis: The curve shows the tape backing's strength when subjected to a constant rate of elongation. The sample reached an elongation of 139.2% before failing. The threshold of the acceptable deformation, equal to 5%, corresponds to a stress between 60 and 75 MPa (Figure 10.6). After 5%, the tape is considered useless because the magnetic coating starts detaching from the substrate.
Figure 9.6 shows a tape at different degrees of deformation.

9.4.3.2 Tape sample N: after treatment

Brand: MAXELL. Model: UD 50-60.
Both the shiny side of the tape and the matt side are brown.

FTIR Spectroscopic analysis in ATR: Shiny side – The peaks that correspond to PET are visible in the analysis of the shiny side of the tape sample.
Matt side The analysis indicates that this side of the tape sample is made of polyester.

ThermoGravimetric Analysis (TGA): The analysis shows that below 150 °C, about 0.1% of the sample weight is lost. At 266.76 °C and 440.16 °C degradation processes occur, with a final residue of about 30%.

Tape sample		E (MPa)	σ_S (MPa)	σ_R (MPa)	ϵ_R (%)
Before treatment	Sample 1	1651	106.2	80.2	136.9
	Sample 2	1614	105.9	86.3	143.7
	Sample 3	1554	107.4	77.5	136.8
	Average	1606	106.5	81.3	139.2
After treatment	Sample 1	1596	106.7	93.3 6	142.7
	Sample 2	1733	105.7	88.1	138.8
	Sample 3	1704	106.8	88.4	134.8
	Average	1678	106.4	89.9	138.8

Table 9.2: The Table shows the results obtained with the tensile test on the tape samples. Three samples for each type of tape (recorded, before and after treatment) have been tested. The columns represent the elastic module (E), the yield strength (σ_S), the tensile strength at break (σ_R) and the percent elongation at break (%). For the values associated to the blank tape before treatment, please see Table D.1 in Appendix D.

ESEM: Shiny side The analysis indicates that the shiny side of the sample carries the magnetic coating. The elemental analysis shows the presence of iron and oxygen, in approximatively 1:1 atomic ratio (Fe/O), and a small quantity of chloride (Figure D.48).
Matt side: The analysis indicates that the matt side of the sample is the substrate of the tape, containing only carbon and oxygen.

Acetone Extraction test: The sample shows a weight loss of 1.50%. Figure 9.5(a) shows a detail of the samples ready for incubation.

Hexane Extraction test: No modification has been observed in the samples after incubation. Figure 9.5(b) shows the samples in incubation (acetone left and hexane right).

Mechanical analysis: The sample reached an elongation of 138.8% before failing. The sample reached an elongation of 139.2% before failing. The threshold of the acceptable deformation, equal to 5%, corresponds to a stress between 60 and 75 MPa (Figure 10.6). After 5%, the tape is considered useless because the magnetic coating starts detaching from the substrate.
Figure 9.6 shows a tape at different degrees of deformation.

The results presented above are discussed in the next Chapter.

Fig. 9.6: Different degrees of deformation of a magnetic tape during a tensile test.

10

Discussion

This Chapter discusses the results of the audio and chemical analyses presented in Chapters 8 and 9.

10.1 Discussion

The results of the exploratory experiment described in Chapter 9 do not show any significant modification in the audio signal nor in the tape samples before and after the treatment, as will be discussed in the next paragraphs. It is an important and interesting observation, because it proves that thermal treatment does not alter the mechanical and chemical properties of the tapes (true at least for the tapes with a characterization similar to that used in the experiment: PET (shiny side) and polyester (matt side)).

The audio analyses did not return any significant difference between the audio signal and the tape samples before and after the treatment. The differences between the audio signal digitized before the treatment and one of the audio signals digitized after the treatment (take 1) has the same order of magnitude of the audio signals digitized after the treatment (take 1 and take 2). Therefore they can be attributed to the inevitable fluctuations of the analogue replay system.
Observing the means (Table 9.1), some values are very close to each other while others are not (for example, 'skewness' (9.3341e+06, 9.4216e+06, 9.3711e+06) and 'spread' (40.3647, 40.7611, 40.5892)). In order to verify if the differences were statistically significant, an analysis of variance (ANOVA) has been carried out. The *p value* calculated for each feature has always been greater than 0.05. Therefore it was drawn that there are no significant differences in the audio features calculated before and after the treatment.
Observing the graphics in Figures 9.4(a) e 9.4(b), some differences are more evident, for example in the values of the first frames. In order to understand the reason why the values differ that way, the spectrum of a single frame has been calculated (Figure 10.1 shows the spectrum of the first frame of the three audio signals). Again it can be noted that the difference between the audio signal digitized before the treatment and one of the audio signals digitized after the

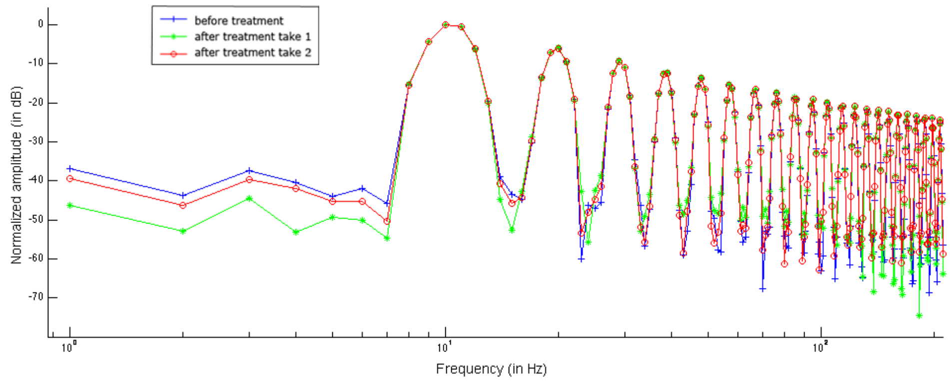


Fig. 10.1: Comparison of the spectrum of the first frame of the three audio files. Colors: blue indicates the signal extracted from tape before the treatment, green and red indicate the signal extracted from the tape after the treatment (respectively take 1 and take 2).

treatment (take 1) has the same order of magnitude of the audio signals digitized after the treatment (take 1 and take 2). Therefore they can be attributed to the inevitable fluctuations of the analogue replay system: "the interaction of the differential reel-supplied forces and the friction force between tape and heads can lead to irregularities in the uniformity of motion across the heads, because of the friction between the heads and the oxide tape surface" [95, p. 34].
The most likely hypothesis is that the differences observed in the calculation of the features frame by frame can be considered measurement noise [96,97], and not related to the thermal treatment.

For what concerns the chemical analyses, most results confirm the absence of a significant difference between the tapes tested before and after treatment. However, some interesting considerations can be made.
First of all, the scientific literature does not report previous works where magnetic tapes have been analyzed by means of the electronic microscopy. The ESEM allows to determine which side of the tape carries the magnetic coating, which is not always easy to do with a visual inspection: the tape sides come in different colors (from light brown to black) and often with a shiny side and a matt side, but either can carry the magnetic coating. For example, both sides of the tape samples M and N are brown and shiny, and the only way to determine which one is the magnetizable side is to trust the winding on the reel (if the tape is correctly wound, the magnetizable side is the one looking in, because of the way reels are mounted on the recorder, like shown in Figure 10.2(a), as opposed to Compact Cassette recorders in Figure 10.2(b)). Secondly, the ESEM allows to analyze (i) the morphology of the tape, including damages of mechanical origin (gouges and hollows, like in Figures 8.15(a) and D.40(a)), and (ii) the distribution of the magnetic material on the tape surface. Table 10.1 shows the percent weight and the percent atomic of tape samples M and N.
The ESEM does not require the preparation of the samples (e.g., gold coating), but the SEM analysis (which does) reaches a greater magnification and allows to

Tape sample	Element	Wt %	At %
Before treatment	C K	8.09	20.81
	O K	19.63	37.91
	ClK	4.03	3.51
	FeK	68.26	37.77
After treatment	C K	8.68	21.68
	O K	20.63	38.67
	ClK	5.46	4.62
	FeK	65.23	35.03

Table 10.1: The Table shows the weight precent and the atomic percent of tape samples M (before treatment) and N (after treatment).

observe the different crystalline structures of the magnetic particles, like in tape sample B (Figure 8.5). Different structures suggest the presence of different types of iron oxides, corresponding to different chemical and magnetic properties. The types of iron oxides are at least four:

1. wüstite (FeO), crystallized in cubes;
2. magnetite (Fe_3O_4), crystallizes in octahedra;
3. hematite (αFe_2O_3), crystallizes in the rhombohedral system;
4. maghemite (γFe_2O_3), crystallizes in the tetragonal system;

Figure 8.5 suggests the presence of two different types of iron oxide, since two different shapes are observed. In order to determine them accurately, future work might include an X-Ray Diffraction (XRD) analysis: the differences among the types of iron oxide is significant to the study on magnetic tapes in that it involves aging (behavior in time) and reactivity to water (hydrolysis).

The combination of electronic microscopy and the FTIR in ATR allows to determine the chemical nature of the tape substrate, of the binder and of the magnetic material. The FTIR technique is fast, non-destructive, relatively inexpensive, and it allows to recognize acetate tapes, the degradation of which is more accentuate and, most importantly, should never undergo thermal treatment. Acetates are thermolabile, and they would be irreversibly damaged. The most common rule of thumb to recognize acetate and polyester-based tapes is to "hold the tape up to the light and observe whether it appears translucent or opaque. If it appears translucent, it is acetate. If it appears opaque, it is polyester" [81]. Another source claims that tapes are "easy to identify: hold the tape pack up to a strong light and look through the pack itself. Acetate-based tapes are translucent, and light may be seen through the layers. Polyester tapes are opaque and no light is visible through the tape pack" [34, p. 5]. The characterization of the tape samples in Chapter 8 has proven that this rule of thumb might be deceiving: in fact the FTIR spectroscopic analysis in ATR of tape samples A and B has revealed that their shiny side is made of cellulose acetate, despite their appearance which is not translucent. A "well meaning archivist" [78, p. 24] (with a reference to the quotation at the beginning of Chapter 7) failing to recognize the tape's material could destroy the tape in the well meaning attempt of restoring it by means of thermal treatment.

(a) Reel-to-reel recorder (b) Compact Cassette recorder

Fig. 10.2: Figures show the position of the audio heads with respect to the tape. In reel-to-reel recorders (a), the tape runs *below* the heads, meaning that the magnetizable side of the tape is the one looking in (with respect to the reel). Conversely, in Compact Cassette recorders, the tape runs *above* the audio heads, meaning that the magnetizable side of the tape is the one looking out (with respect to the housing).

The importance characterizing the tapes should be self-evident at this point, as well as the importance of defining shared protocols for storing and handling tapes within preservation/restoration programmes.
The contribution of materials science and chemistry is much needed in this field, where the main actors are archivists and cultural operators, with a limited technical-scientific knowledge of audio media. In this sense, the Austrian Mediathek is an emblematic example of the shockingly low level of expertise owned by the leaders of a preservation project addressing a collection of over 40,000 audio documents: a set of tapes was found to be affected by Stycky Shed Syndrome, and the authors report that they "were quite shocked" when they first noticed it. "Nobody really knew how to deal with it so we started researching on the Internet" [98, p. 42]. Needless to say, "the repeatedly given answer in online discussion forums about tape machines and magnetic tapes leads in one special direction: baking!". Being a precision incubator too expensive, and wisely not trusting suggestions from a colleague about creative solutions[1], the Austrian team decided to buy a food dehydrator from a Swiss producer for 150€. Tight budgets and limited time frames are a common problem for many archival institutions, and it is easily understood why makeshifts are often preferred to more adequate solutions. An idea that has been expressed in Chapter 2 of this work is that archives form coordinated networks aimed at sharing knowledge and resources, which would certainly help on the methodological and on the financial side[2]. As for the lost battle against time: involving a team of experts from the beginning of preservation projects ensures that no surprises are found along the way, such as that reported by the authors at the Austrian Mediathek, who learnt about Sticky Shed Syndrome clearly to late

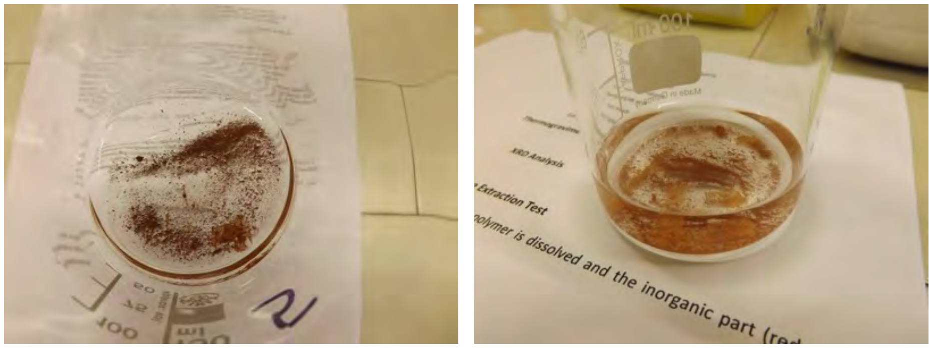
[1] "One archivist even told us about a baking contraption made out of a cardboard box, a hair dryer and a sugar thermometer." [98, p. 42]

[2] A precision incubator costs about 2,500€(source: statement of account of a recent research project in which the author was involved).

Sample	Brand	Shiny side	Matt side
Tape A	TEAC	cellulose acetate	polyvynil chloride - vynil alcohol
Tape B	AGFA	cellulose acetate	not identified[a]
Tape C	MAXELL	co-polymer (poly-vinyl butirrale - vinyl alcohol - vinyl acetate)	poliurethane
Tape D	TDK	polyester	polyester
Tape E	BASF	polyurethane	not identified[a]
Tape F	unknown	polyurethane	polyester (stearate)
Tape G	3M	PET	polyurethane
Tape H	BASF	polyurethane	co-polymer (tetra-fuoloethylene - esafluoropropylene (TEFLON 100))
Tape I	unknown	polyurethane	not identified[a]
Tape L	unknown	polyurethane	not identified[a]
Tape M	Maxell	PET	polyester
Tape N	Maxell	PET	polyester

Table 10.2: The Table summarizes the results of the FTIR spectroscopic analysis in ATR presented in Chapters 8 and 9. In the first column there are the tape samples. For each of them, the material composing the shiny side and the matt side is indicated. Tapes are identified only by the brand, because the model was unknown for all but three (Tape sample E: BASF SPR 50 LHL; and Tape sample M and N: Maxell UD 50-60).
Table footnote a: The presence of degradation products or of a mixture of materials does not allow the identification solely on the basis of FTIR.

to plan an adequate solution ("this problem was more than a slight setback: the whole project was in danger" [98, pp. 40-41]).
Having said this, the present study highlighted a large variety of materials even among the polyester-based tapes (see Table 10.2). Such a variety suggests that a one-fits-all approach to thermal treatment is not possible – nor is preferable to a try-and-error approach based on the ignorance of the tapes' chemical and mechanical properties.
Another important observation about the analyses conducted in this work is that the FTIR analysis in ATR shows a negligible presence of water on the tapes surface. This contradicts the sources that claim that thermal treatment is aimed at "drying" tapes, literally "extracting" the water that they have absorbed during years of storage in dump environments. Water is considered to be the responsible of the stickiness exhibited by the tapes: "hydrolysis [is] the process by which the chemical that bonds the recording oxide to the polyester base absorbs moisture from the air" [85, p. 2]. The experience of the Austrian Mediathek just exposed confirms this belief, as does everyone who proposes food dehydrators in place of thermo-incubators. Food dehydrators use heat source and air flow to reduce the water content of foods: "dehydrating is a method of food preservation in which



(a) Tape sample A (b) Tape sample B

Fig. 10.3: Tape sample A: acetone extraction test.

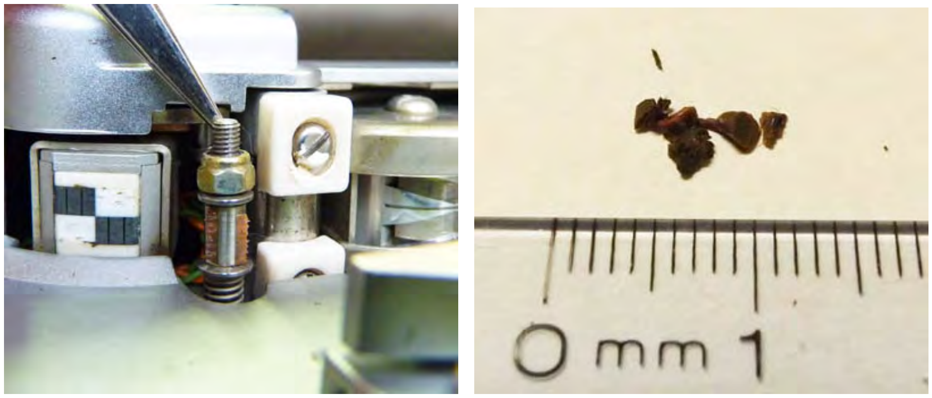
moisture is removed from the food"[3] (italics of the author). Removing water from magnetic tapes, in whatever form, seems to be pointless, since the analyses showed that the presence of water was less than 1% in all tape samples.

At the same time, the quality of some FTIR analyses was too poor to allow the characterization of the materials (in particular, the matt side of the tape samples B, E, I and L). The reason might be a mixture of components, some of which have probably originated from the process of hydrolysis, or which have been in the tape since manufacturing. This would call for further study on the chemical nature of the degradation products that can originate from the process of hydrolysis. The author intends to conduct this study on the residue of the acetone extraction test, namely on the tape samples that have completely melted or that have been destroyed in incubation.

In fact, the acetone extraction test have been particularly interesting. The outcome was unexpected, as the source that inspired the test in this work does not report any case where the tapes melted or got destroyed, which was the case of tape samples A, B and G (Figures 10.3(a) and 10.3(b)) [79]. Another work on the experimental results of the acetone extraction test does not report similar cases either [83]. The test could not be performed on the melted/destroyed samples. The reasons might be the materials' nature or the process of degradation involving the tape. Either way, to gain more information about the materials is of paramount importance, in fact a study to determine the nature of the powders is currently being carried out.

The study of the thermal behavior of the tapes by means of TGA measurements has been considered of great interest, since the initial motivation for this experience was the thermal treatment used for compensating the effects of the SBS-SSS. The results of the TGA showed that below 150 °C the weight loss is extremely limited (less than 1%). Typically, this loss is due to adsorbed water, with more or less strength. These results suggest that the measurements might be repeated in the future with a slower heating ramp, with the aim of highlighting the liberation

[3] Source: website of well-known producer of food dehydrators and roaster ovens: `http://www.nesco.com/`



(a) Sticky residue on the recorder (b) Sticky residue

Fig. 10.4: Sticky residue from a magnetic tape affected from SBS-SSS.

of adsorbed water or other volatile substances.

Two of the tape samples that have been analyzed in this work were affected by SBS-SSS (samples I and L). The results indicate that the entity of their degradation was not severe, since the tapes were not melted nor destroyed during the acetone extraction test. However, the weight loss of the samples is consistent with the literature about damaged tapes (6.30% and 5.80%, against an average 1.35% of the samples in better condition). This indicates that the magnetic coating is not perfectly adherent to the substrate. Moreover, the residue that the tapes affected by SBS-SSS leave on the audio heads of the recorder has been analyzed (Figure 10.4), and the presence of iron suggests that a portion of the information is physically detached from the coating (Figure 10.5). The entity of the modification on the audio signal induced by the detachment of the sticky residue will be certainly interesting to investigate in the future.

This exploratory study showed that conducting chemical analyses on magnetic tapes can prove very useful within the scope of preservation and restoration programmes. In the future, the author wishes to keep investigating the products of degradation by means of the acidity tests, in order to determine hydrosoluble substances, generally of acid nature, produced by hydrolysis. Another aspect to explore is the acidity of the tape surfaces by means of a chemical method developed at the Department of Industrial Engineering (chemical sector) of the University of Padova. The research schedule also includes the Atomic Force Microscopy (AFM) analysis, finalized at studying the morphology of the surfaces; the Gas Chromatography-Mass Spectrometry (GC-MS); and the broadband dielectric relaxation spectroscopy.
Finally, a mechanical test has been conducted on the tape samples M and N, respectively before and after treatment. These samples, plus a sample of blank tape before treatment, originated from the same reel, the model of which is known (see Section 9.2). In the end, only the samples M and N have been considered, but the

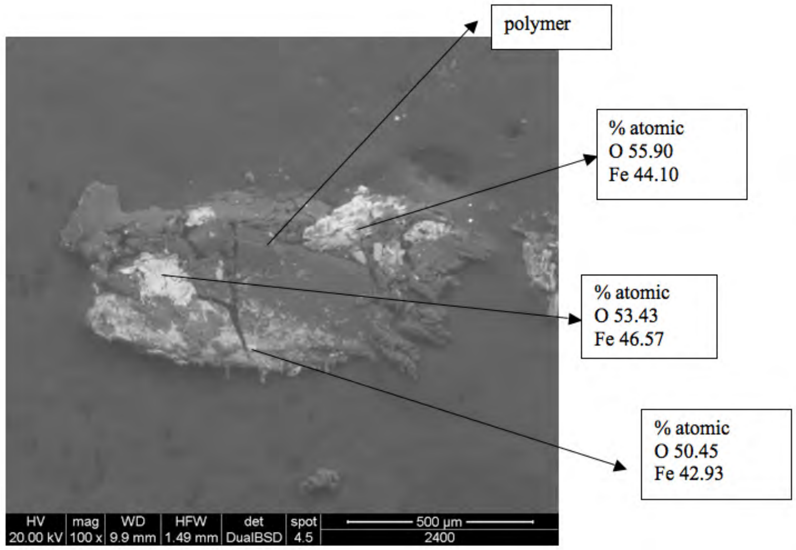
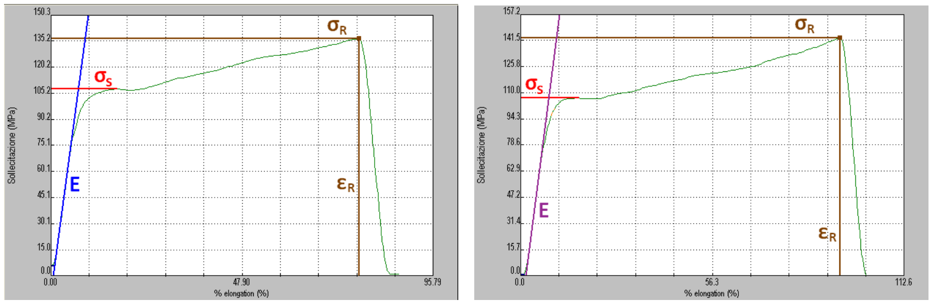


Fig. 10.5: Sticky residue from tape sample L.

data about the blank tape is available in Appendix D (see Table D.1).
For comparative purposes, the elastic module (E) and the yield strength (σ_s) have been determined. The tensile strength at break and the percent elongation at break have also been determined, even if this data is not very significant: the binder separates from the base at an elongation of 5%, after which the tape is considered compromised. Below 5%, the backing's elasticity allows it to return to essentially the same length and shape as when it was under no tension. Beyond 5%, the tape is permanently distorted [99, p. 2]. In this test, a typical polyester sample is reported to elongate 100%. The tape samples M and N reached an elongation of 139.2% and 138.8% respectively. The threshold of permanent deformation of the substrate (5%) corresponds to a stress of about 60 MPa (Figure 10.6), however it should be noted that a much lower stress is sufficient to detach the magnetic coating from the substrate, therefore the tape becomes useless significantly below an elongation of 5%.
The results of this test are consistent with the audio analyses of the tape samples: the differences between the same samples before (or after) the treatment have the same order of magnitude of the differences between the samples before and after the treatment, suggesting that they are due to measurement error.
During regular handling and usage, magnetic tapes are not subject to forces the entity of which is comparable to those applied in a tensile test (the values are reported in Tables 9.2 and D.1). This test has been attempted in order to understand if any difference in the mechanical properties of the same tape sample before and after thermal treatment is noticeable. The test did not show any significant difference, in accordance with the other analyses carried out on tape samples M and N. This result is also consistent with that obtained in a similar test reported in [79, p. 39]: "the data obtained from the friction test did not reveal significant



(a) Before treatment (Tape sample M) (b) After treatment (Tape sample N)

Fig. 10.6: Tensile testing on magnetic tapes before treatment (a) and after treatment (b). Figures show the elastic module (E), the yield strength (σ_S), the tensile strength at break (σ_R) and the percent elongation at break (%). The percent elongation (%) is on the x-axis, while the stress (in MPa) is on the y-axis. The values associated to each sample are reported in Table 9.2.

differences between the five tapes and did not detect property changes during incubation at 60 °C". However, this might still be an interesting test to repeat on a tape sample that has been diagnosed with SBS-SSS, contrary to that used at this preliminary stage.
Nevertheless, magnetic tapes are subject to mechanical stress when played on a reel-to-reel recorder, especially at stop/start and during rewind at high speeds. The entity of the stress depends on the model of the recorder and on its technical condition. To learn more about the relation between the state of preservation of a tape and the stress caused by the recorder, which occasionally causes old tapes to break, it may be interesting to perform a *shock tensile test*. This test is mentioned in a study conducted by the Scotch/3M tape manufacturer on polyester and acetate tape backings in 1969 [99, p. 4].

In the author's experience, as well as in the experience of most practitioners in the field, thermal treatment does have a positive effect on tapes affected by SBS-SSS. For the exploratory experiment described in Chapter 9, a tape without any sign of SBS-SSS has been used. This may be the reason why no modifications have been observed after the treatment: heat is supposed to strengthen the polymeric chains, but if they are already integer there will be no effect. An important result of this experiment is that it proved that no damages occurred either, which is a useful information because it ensures that thermal treatment does not bring destructive side effects (at least not to tapes with a characterization similar to that used in the experiment), and that it can be applied while researchers work to casts a brighter light on the matter. In this sense, the author agrees that the "lack of understanding of the sticky shed problem does not justify inaction on the part of audio archivists, since sticky shed grows gradually worse over the years" [81, p. 3]. The preliminary analyses presented in this work have not been sufficient to determine the modifications that involve magnetic tapes during and after thermal treatment. In order to achieve this goal, the experiment reported in Chapter 9 may be repeated in the future, using a tape affected by SBS-SSS: if thermal treatment is effective, the tape will not shed magnetic material during re-play anymore, and very likely a change in the mechanical and chemical properties will be observed. If the audio signal shows some changes too, an alignment between the waveform and the magnetic crystals (adequately magnified by means of the Electronic Microscopy) could be attempted.

Part IV

Assessment

11

Assessment

This Chapter presents the financed research projects involving prestigious sound archives to which the methodology described in Chapter 4 has been applied. The author has participated in the projects, working inside the archives in tight connection with the archival personall on a daily basis: at the Fondazione Arena di Verona for 25 months, and at the Scuola Normale Superiore di Pisa for 12 months.

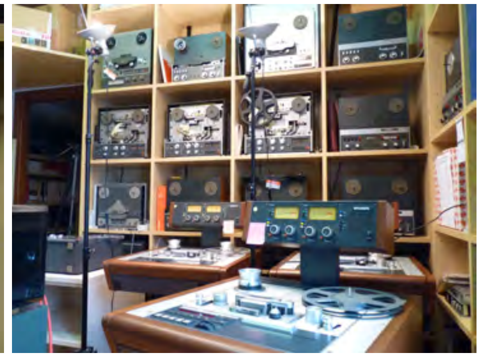
11.1 Fondazione Arena di Verona: 2009-2011

In 2009, the audiovisual archive of the Fondazione Arena di Verona and the Department of Computer Science of the University of Verona started a collaboration finalized at the digitization of the sound collection owned by Arena. The joint project lasted two years and accomplished the following goals:

1. definition of a methodology for preservation, after a survey on the state of preservation of the archive and of its peculiarities (number and type of documents, genre of the recordings, objectives of the digitization, ...);
2. definition of an operational protocol for the re-mediation of the audio documents and for the management of the laboratory (maintenance routines for technical equipment, rules for the documents handling and storage during treatment, ...);
3. realization of a laboratory, inside the archive, fully equipped to support the active preservation of audio documents (Figure 11.1-a);
4. knowledge transfer to the archive personnel (on a methodological level, and on an applied level: use of the technical equipment, use of the original software tools developed on purpose during the project, physical restoration of the audio carriers, ...);
5. creation of over 1,200 preservation copies of different types of audio documents (magnetic tapes, optical discs and digital non-audio carriers).

The archive comprises tens of thousands of audio documents stored on different carriers (from wax cylinders to digital carriers), nearly a hundred pieces of equipment for replay and for recording (from wire to magnetic tape recorders and phonographs) and bibliographic publications (including monographs and all issues

(a) Open-reel tapes



(b) Audio lab

(c) Photographic workstation

(d) Audio workstation

Fig. 11.1: (a) Open-reel-tapes of the historical section of the archive of the Fondazione Arena di Verona; (b) in foreground, an reel-to-reel recorder Studer A812; in the background, on the shelves, some of the reel-to-reel recorders donated by the heirs of Mario Vicentini; (c) photographical workstation; (d) one of the workstations for the re-mediation of audio documents at the Fondazione Arena di Verona.

of more than sixty music journals from the 1940's to 1999). The audio archive is divided in a historical section, containing the live recordings of the operas staged every year at the Arena during the summer season, and the Mario Vicentini section, named after its donor and the estimated value of which is 2, 300, 000 Euros. The archive is being enriched every year with the recordings of the new opera seasons, now memorized on digital data storage devices.

Most recordings consist in live performances of classical operas staged in an open-air setting, the Arena di Verona. On the average, the audio documents presented a good state of preservation, except for some among the oldest open-reel tapes (late 1960s and early 1970s), a lot of Compact Cassettes from 1981 to 1983, and Compact Discs from the early 2000s which proved unreadable. The precision incubator commonly used for the thermic treatment of tapes with specific syndromes [45, 79, 83] has been largely used, and with satisfactory results in nearly all cases. The large number of documents stimulated the development of original software tools to

(a) Open-reel tapes (b) Cleaning the pinch roller

Fig. 11.2: (a) Some open-reel tapes of the archive section named after Mario Vicentini at the Fondazione Arena di Verona; (b) detail of the cleaning procedure of the pinch roller of a reel-to-reel recorder. Tutorials and demonstrations have been produced and collected during the activity in the audio laboratory: some are freely accessible online[1].

control and to automatize various aspects of the preservation process, and most importantly to perform periodical controls over the archive of preservation copies in order to avoid inconsistencies with very negative consequences on the information retrieval system. Manual control is out of question because, by the end of the project, the preservation copies almost reached 2 TB, equal to over 18,000 single files. Four pieces of original software have been developed by the author, and all of them are still in use at the archive over a year after the end of the project without need of further assistance (Figure 11.1-b). To learn more about the project, see [70, 100].

11.1.1 Software description

During the project, original software has been developed to support, to automatize and to control some tasks of the preservation process. In this Subsection, four different applications are described. These applications have been the first attempt to fill the gap between manual work and sophisticated automation, which was later achieved with AudioGRAFO PreservationPanel (see Subsection 11.2).
All of them are Java standalone applications with a graphical user interface (GUI).

11.1.1.1 REVIVAL Archive Control

The REVIVAL Archive Control application is able to perform specific controls on every preservation copy in the long-term archive (e.g., missing folders, empty folders, wrong file names, ...). Some controls could be performed with existing tools, some would require a little shell programming: the software comprises them

[1] `http://www.dei.unipd.it/~bressanf/tesi/tesi2013/` → `Multimedia` → `Supplementary material`

(a) (b)

Fig. 11.3: Screenshots of the pieces of software developed by the author for the archive of the Arena di Verona: (a) REVIVAL Archive Control main panel; (b) REVIVAL Batch Renamer main panel.

all, and offers the user a simple friendly interface. A good degree of automatization is achieved by hard-coding the structure of the archive (paths to files and folders). The choice of the controls was based on the experience matured during my work at the Fondazione Arena di Verona. The archival routines involve a lot of low-level file processing, and without adequate (software) tools, the archive results in an inconsistent, unreliable and therefore useless dataset. The number of inconsistencies revealed (all unintentionally introduced by human operators) proved alone the usefulness of this application. It is currently used by the staff of the audio archive of the Fondazione Arena di Verona. Figure 11.3(a) shows a screenshot of the program: the labels are in Italian, but other languages can be easily implemented.

11.1.1.2 REVIVAL Batch Renamer

The REVIVAL Batch Renamer application is able to batch-rename the audio/image files according to the signature of the associated preservation copy. Contrary to most existing freeware for batch-renaming files, this application was programmed to reflect the specific structure of the long-term archive, thus calculating filenames and finding paths automatically. The usefulness of this application consists in reducing the action of batch-processing to very few operations (drag-drop-click). Considering that the archival routines involve a lot of low-level processing (rename, move files, . . .), the amount of time saved is significant, along with the ideally complete elimination of errors introduced by the human operator. It is currently used by the staff of the audio archive of the Fondazione Arena di Verona. Figure 11.3(b) shows a screenshot of the program: the labels are in Italian, but other languages can be easily implemented.

(a) (b)

Fig. 11.4: Screenshots of the pieces of software developed by the author for the archive of the Arena di Verona: (a) REVIVAL Checksum Calculator main panel; (b) REVIVAL Checksum Control in action.

11.1.1.3 REVIVAL Checksum Calculator

The REVIVAL Checksum Calculator application is able to calculate the MD5 checksum for the audio files in each preservation copy and to save the resulting string(s) to the correct folder in a conveniently formatted file. The usefulness of this application lays in the ability to batch-process all of the documents in the archive. It is currently used by the staff of the audio archive of the Fondazione Arena di Verona. Figure 11.4(a) shows a screenshot of the program: the labels are in Italian, but other languages can be easily implemented.

11.1.1.4 REVIVAL Checksum Control

The REVIVAL Checksum Control application is able to perform a periodic control over the integrity of the audio files stored in the long-term archive. The application accesses every audio file in the archive and calculates its MD5 checksum, then compares it with the MD5 checksum that was calculated when the file was stored (its value is retrieved from the archive database). It notifies the user in case of mismatches between the two strings. It is currently used by the staff of the audio archive of the Fondazione Arena di Verona. Figure 11.4(b) shows a screenshot of the program: the labels are in Italian, but other languages can be easily implemented.

11.2 Scuola Normale Superiore di Pisa: 2011-2013

Audio recordings play an important role in the field of linguistics: from life stories to dialect investigations, they provide researchers with invaluable first hand material. Unfortunately first hand does not mean unchanged with respect to the original acoustic source: capturing an acoustic event is never a neutral operation, as explained in Chapter 3. Especially for those areas of linguistics that employ

Fig. 11.5: One of the workstations for the digitization of audio documents at the Laboratory of Linguistics of the Scuola Normale Superiore di Pisa.

frequency analysis (formant and pitch detection), the requirements of accuracy, reliability and authenticity of the audio material, mentioned in Subsection 3.2.3, cannot be renounced. Aware of the risks of audio material with uncertain origin, the research team of the Laboratory of Linguistics at the Scuola Normale Superiore di Pisa started a project in collaboration with the University of Siena finalized at:

1. applying the methodology for preservation to the audio documents of the area of linguistics, after a study of their characteristics (most problems are related to the fact that the recordings have been gathered on the field, often in inadequate conditions, with non-professional equipment and inexpensive carriers, . . .);
2. realizing a restoration laboratory, inside the laboratory of linguistics, fully equipped to support the active preservation of audio documents;
3. transferring knowledge to the technical staff of laboratory of linguistics to enable autonomy after the end of the project (on a methodological level, and on an applied level: use of the equipment, use of the original software tools developed on purpose during the project, physical restoration of the audio carriers, . . .);
4. creating an archive of preservation copies of different types of audio documents (open-reel tapes, Compact Cassettes, Digital Audio Tapes and digital non-audio carriers).

Even if the importance of audio documents is acknowledged in the community of linguistics, this project has been the first-ever on the Italian territory to introduce the competences of preservation into a laboratory of linguistics. For over a year, the author has worked inside the laboratory in tight connection with the linguistics research team, in a pro-active multidisciplinary attitude, bridging the gap between the disciplines' approaches and vocabularies. As a result, the original

(a) (b)

Fig. 11.6: (a) A moment of the analysis of the audio format for an open-reel tape. Note that the tapes are always handled wearing cotton gloves; (b) in-house maintenance routine of a reel-to-reel recorder.

software system described in Chapter 6 was developed, with the subsequent benefits of reducing processing timing, of enabling the treatment of a greater number of documents, and of gaining complete control over the data growth and integrity. The software system has been in use 24/7 since September 2011, and it is currently being used by the preservation staff (2 people based in Pisa) and by the cataloguing staff (5 people based in other cities of Italy, exchanging data through a network connection). By the time this work is being written, a total of 759 preservation copies have been created, equal to 1.7 TB; 10,000 single files; and 945 hours of re-recorded audio.

A major question that had to be solved is related to the item 4 in the above list of objectives: the laboratory of linguistics holds its own collection of audio recordings, but the research project had the ambition of censusing and collecting as many external public and private archives as possible on the territories where the Tuscan language (*vernacolo* toscano) is spoken. This results in a highly heterogeneous set of documents, differing in number, recording format, decade of creation, state of preservation and quality of the description of the content. The archives that accepted to collaborate (over twenty to date, and more joining) sent their material over to the laboratory, where it would be processed and eventually returned to their original location. This is a good example of a scenario where the original document is not under the responsibility of the preservation staff after the treatment, which shows the importance of creating preservation copies that contain absolutely complete information and of the best quality possible, since it is not possible to perform extra controls, comparisons and analysis – just as in the scenarios where the physical original is lost, stolen or destroyed. To learn more about the project, see [101, 102].

Part V

Interactive Multimedia Installation

12

Interactive Multimedia Installations

"This is not about reality, it is about imaginary structures that are useful."
Ted Nelson[1]

This Chapter introduces the problem of preserving Interactive Multimedia Installations, a recent form of art with a tight relation with technology. It can be considered as a natural evolution of the author's work on audio documents, as Interactive Multimedia Installations and audio documents share some of the same problems, with additional complications due to the multiplicity of media, time-specificity, site-specificity, and the combination of these elements in the process of interaction with the visitor/user. A multi-layer model for the preservation of Interactive Multimedia Installations is presented (Section 12.7), and some representative case studies are presented (Section 12.8).

12.1 Introduction

Since the 1970s, computers have become the main tools to explore the acoustic world by deconstructing the sound matter at the level of elementary attributes of signals relying on different analysis techniques, while programming languages and synthesis techniques have allowed a nearly total control over the sonic material.
During the 1990s physical and spectral modeling was enhanced and various interfaces for musical creativity were developed and widely spread. The exploration of different levels of complexity, from physics to phenomenology and semantics, was made possible by improved tools that balanced cost and efficiency.
The musical works created with these technologies are represented in a *fixed* form (i.e., recorded music), and the problems related to their preservation are the main subject of this work (see previous Chapters).

[1] The quotation comes from an interview to Ted Nelson, accessed on Youtube on March 25th, 2013 (`http://www.youtube.com/watch?v=WEj9vqVvHPc`).

More recently, the role played by multimedia within the performing arts has become more and more important, most notably in the music field, where the opening to interaction between images and sounds fostered the experimentation of new expressive solutions by the artists. Along with the evolution of the creative processes, the development of increasingly more sophisticated audiovisual technologies affected the ways in which the public acknowledges the artistic event, its habits and aesthetics. With innovative solutions for mutual interaction, music, dancing and video turned into "expanded disciplines" [103], thus giving birth to "Interactive Music Installations" (IMIs). At present, the spotlight is on physically-based sounding objects that can be manipulated and embodied into tangible artifacts that support continuous interaction. Technology offers the tools to detect and control sets of variables which modify specific elements within a system (sensors), it relies on an enhanced computational power and it pays special attention to design strategies.

Generally IMIs are able to detect and analyze motion, speech, sounds produced by one or more users, in order to control sound synthesis, music and visual media (laser effects, video, virtual avatar) in real-time, and to modify the environment (setting and mobile robots). IMIs observe and act within a certain environment, modifying their own structure and responses in a dynamic way according to the users' behavior (same gestures have different effects in different settings). Basically IMIs are able to retrieve general features in a Gestalt-like approach to the detection of sound and motion.

Unlike virtual reality, IMIs do not aim at deceiving the human sensory system, but to extend reality, allowing the user to interact with an expanded world by means of technology, mainly for artistic and aesthetic purposes. "The *fusion of art and life* is an essential aspect of the installations" [104]. Particularly important in this sense is the SAME project [2] that aims at creating a new end-to-end networked platform for active, experience-centric, and context-aware active music listening/making.

12.2 Motivation and impact

The motivation for investing in the preservation of Interactive Multimedia Installations is not only related to the cultural field: the main reasons can be summarized as follows.

- *Urgency*: See point *Short Life Expectancy* of Section 12.6.
- *(Re-)achieving European excellence leadership in the field*: Interactive Multimedia Installations are part of the European artistic history, which sees artists and scientists collaborating to promote and develop art. The preservation of Interactive Multimedia Installations may (re-)connect artists and scientists from all over Europe, with the intention to recover more masterpieces through new

[2] `http://www.sameproject.eu/` (last visited on February 10th, 2013).

praxis and new tools designed to overcome the actual boundary of obsolescence (especially of digital-born objects), which represents the main threat to cultural heritage. A successful model for preservation would enable the creation of a common European repository, that institutions (e.g., archives) and artists could populate with descriptions, data, pictures, videos and testimonies. The model would also result in a set of guidelines for a consistent organization of the data within the repository. Artists would be encouraged to produce a documentation about their new works along the lines of the framework: thus, the very important goal of actively involving the artists in the process of preservation would be achieved, and the long-term storage planning would be optimized.

- *The awareness of this problem is increasing in the archival community.* A lively and strong network exists between the communities of archive science, musicology, engineering and design. The topic of preserving contemporary pieces of Installation Art is clearly highlighted in the Sound and Music Computing (SMC) Roadmap [13]: the SMC community is the one that fosters the development of new technologies for artistic applications, of new languages and aesthetics, therefore it is its direct concern to maintain this patrimony, avoiding the waste of valuable knowledge that should be made available for future artists and audiences. Moreover, the problem of preserving ephemera (including interactive systems) and intangible cultural heritage is a hot topic in the archival community [105].
- *Supporting the industry of performing arts*: the European artists involved with Installation Art are extremely prolific and they keep driving technological development with their ideas and requests for new tools to take a step ahead the current solutions. Their creativity represent a valuable cultural asset for Europe, but at the same time it is the main resource of the young Creative Economy, as defined by the Report 2008 of UNCTAD [9], according to which "creativity generates economic growth and development". This is evident talking about Installation Art: realizing complex or massive artworks that are disassembled after display is a terrible waste on the cultural side just as much as on the economical side.
  (i) Replicating installations would call for more exhibitions, therefore more public, and more cultural circulation, with direct and indirect economic income and a predictable positive impact on the arts; (ii) Preserving should mean providing researchers, students and all citizens with reliable material for studies in the Humanities and Science, collecting a repository of artworks that has never been available before as such. The vision described by the UNCTAD in [9] considers its ultimate objective a contribution the the shaping of a society where cultural assets are at the core of the quality of life, and Cultural Industries are the main driving sector. In this sense, the actions planned by the preservation process have a double valence: they are all relevant in cultural terms, but they also have an impact or provide a chance for profit activities based on high-profile contents.
- *Supporting scholarly studies*: It is not possible to fully appreciate the variety of expressive possibilities of Interactive Multimedia Installations starting from the audio/video recordings: they can be experienced only by means of the direct interaction. Museums are seeking solutions that allow the visitors to experi-

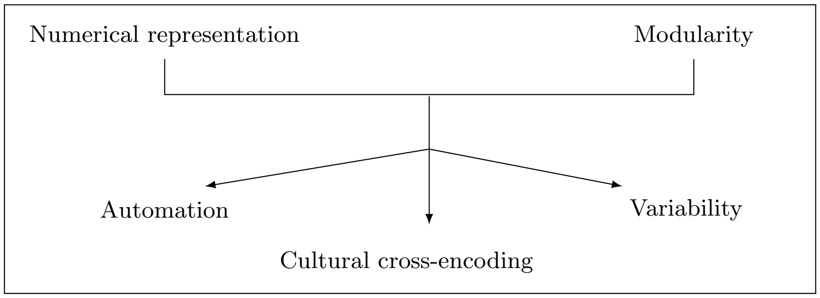


Fig. 12.1: Hierarchical representation of the differences between old and new media, according to [107]. In Manovich's opinion, they are not absolute laws but "general tendencies of a culture undergoing computerization".

ence this interaction, with the recreation of the hardware devices and with a "correct" (from both technological and philological points of view) porting of the software.
Already in 1996 Curtis Roads stated that "programming concepts can suggest functions that might not occur to one outside of the context of programming. This is of signal importance in music composition, since the integration of programming concepts into the musical imagination can extend the boundaries of the imagination itself.That is, the language is not simply a tool with which some preconceived tasks or function can be accomplished; it is an extensive basis of structure with which the imagination can interact, as well" [106].

12.3 Multimedia and Interaction

Multimedia today refers to something more than juxtaposition of multiple media. This implicit reference was introduced during the digital-machine driven revolution of the last six decades, where the term "medium" is not to be intended etymologically (elseways, anything providing a multi-sensory stimulation would be multimedia, which is not the present technological-related meaning). In [107], a definition of "new media" is given by a set of principles schematized in Figure 12.1: numerical representation, modularity, automation, variability and cross-cultural encoding. "New media" are configured according to two levels: a computer level (including data structures, file formats, functions and variables) and a cultural level (a classic novel, a favorite picture). These concepts are relevant to the present study in that they provide conceptual tools for modeling the objects that need to be preserved. For a complete discussion on "new media" (simply "media" hereafter) see [107].
In a similar way, interaction today holds a technological-related meaning, and in this case the definition matches the etymology. As human beings, our experience of the world is basically inter-active and, in this sense, our most familiar condition. The novelty resides in that, due to unprecedented computational power, today *machines* support interaction. More precisely, they support real-time multimodal interaction, with increasingly sophisticated design, inspired by the model of "ubiq-

uitous computing" [108–110].

With decades, traditional forms of art have gradually implemented visual and sonic material, shattering the doctrine of *medium specificity* [111], as described ably by Dick Higgins in [112] during the 1960s with the neologism *Intermedia*.
In its mature expressions, Installation Art is meant to be physically explored, surrounding the performer/user with physical stimuli out of which a significant experience is created. Its fundamental features are site-specificity, time-specificity and interaction. The next Section briefly traces the history of installation art from Duchamp's readymades to Interactive Multimedia Installations.

12.4 Historical overview

12.4.0.5 The evolution of electroacoustic music

The unprecedented technological evolution occurred during the XIX century out of a solid faith in positive science and the driving promise of human progress, fueled a bizarre picture of prophetic visions, scientific demonstrations, musical experimentations, technological innovations, new necessities and desires, and the reformulation of new theories that can be considered the ground for the electronic experience.
During the World Wars of the XX century, Telecommunication technologies and Electroacoustics have been extensively employed and applied. Their fast development was supported and encouraged by the massive financial resources allocated by the leading Governments. But as peace was restored in 1945, and the world was about to be reconstructed, the scientific and technological achievements needed to be reinvented for a pacific, social use [3]. At the same time, the members of rather lively intellectual groups over Europe and Northern America started 'rebuilding society' on the ruins of the armed conflict. It is during those years of hardships and strong desire for novelty, that music and technology forged their connection to last. Despite earlier experimentations, in fact, it is only during the 1950s that composers attempted original aesthetic languages for sound generators, processors and recorders. Although the constraints imposed by technology invariably dictated the methods of working, it was a crucial step to disengage from the musical tradition definitively. Composers had shown a growing resentment for the conventional musical forms and the limited tonal vocabulary since the late XIX century, but they had tried to escape them by extending, forcing until breaking the rules with the same instrumental organic and the same set of twelve notes on which the tonal system was based. Atonality, (dissonant) politonality and serialism are notable examples of such attempts, however stating 'non A' uses, indirectly refers to and depends upon the existence of the symbol 'A'.
That is why the use of electronic devices for sound synthesis and processing resembles a revolution rather than an innovation. Unlike atonality and other techniques, in fact, only technological revolution radically changed the way composers

[3] "The perfection of these pacific instruments should be the first objective of our scientists as they emerge from their war work." Editor's note to [113].

(a) (b)

Fig. 12.2: (a) Marcel Duchamp with his "Bicycle Wheel" from 1913; (b) The Philips Pavilion at the Expo 1958 in Brussels.

approached and conceived the creative process. At last, they had direct access and control over the sound matter [114]. In other words: (a) *timbre*, which implied a re-definition of "noise" and its role in music; and (b) *space* became part of the musical parameters for composition.

In the early days of experimentation, the most used type of carrier was the magnetic tape, and regardless of the sound synthesis and processing methods employed, the compositions realized back then got generically labeled *tape music* – with differences that are mainly pointed out from the viewpoint of the sound material (e.g., *musique concrète*, *electronic music*), usually resulting in a geographical subdivision of tendencies and schools, often gathered around the most influent research/production centers in Europe (Paris, Cologne, Milan).

The combination of electronic sounds (synthesized/processed in real-time) with acoustic sounds (of a human player performing) resulted in a category of works known as *Live Electronics*, where "the sounds produced by voices or traditional instruments are electronically captured and processed in real-time, without involving pre-recorded material" [63].

Along the decades, thanks to the rapid evolution of technology and the visionary attitude of artists seeking original creative solutions, electroacoustic music progressively started including new media, first putting them next to each other without much interaction, then achieving such an interplay among sound, images and movement that it gets very difficult to separate them without losing the sense of the whole (i.e., the meaning of the artwork). Following this trend, electroacoustic music today appears as an "expanded discipline" [103] and thus the line between Interactive Multimedia Installations is very fine (see next paragraphs). Some examples of artistic works in this sense are presented in Subsections 12.8.1, 12.8.2 and 12.8.6.

12.4.0.6 From Installation Art to Interactive Multimedia Installations

Edgar Varèse's "Poème électronique", presented in 1958 at the Brussels Worlds Fair (Figure 12.2(b)), is often regarded as the first multimedia installation in the modern sense. Commissioned to Le Corbusier's for the first major international exhibition to follow the Second World War, it was intended as a showcase of Philips' engineering progress, with an impressive multimedia display. It involved architecture, music, acoustics, electro-acoustics, and by implication, sculpture in a complex synthesis, providing a number of original metaphors for exploring sound space.
However Installation Art was not born multimedia. Marcel Duchamp's *Readymades* are the first form of art that disrupted the perception of the ordinary world in the 1910s, by unexpected ways of assembling regular manufactured objects. Often including moving parts (like "Bicycle Wheel", 1913, Figure 12.2(a)), his Readymades were also referred to as *Kinetic Art*, putting an emphasis on dynamic aspects.
All along the XX century, artists have proved to be highly attracted by new technologies, offering novel expressive solutions regardless of their original purpose. With decades, traditional forms of art have gradually implemented visual and sonic material, shattering the doctrine of *medium specificity* [111], as well described by Dick Higgins in [112] during the 1960s with the neologism *Intermedia*.
In its mature expressions, Installation Art was meant to be physically explored, surrounding the performer/user with physical stimuli out of which a significant experience is created. Its fundamental features are site-specificity, time-specificity and interaction. Unlike virtual reality (VR) and multimediality, Installations do not aim at deceiving the human sensory system, but to extend reality, allowing the user to interact with an expanded world by means of technology, mainly for artistic and esthetic purposes.
At the same time, the increasingly sophisticated audiovisual technologies have affected the ways in which the public acknowledges the artistic event, its habits and aesthetics. Interactive Music Installations are able to detect and analyze motion, speech, sounds produced by one or more users, in order to control sound synthesis, music and visual media (laser effects, video, virtual avatar) in real-time, and to modify the environment (setting and mobile robots). They observe and act within a certain environment, modifying their own structure and responses in a dynamic way according to the users' behavior (same gestures have different effects in different settings).

12.4.0.7 SMC Artworks

Early *tape music* and Duchamp's *Readymades* had basically nothing in common (excepted a strong explorative vocation, rooted in the crisis of culture that characterized the XIX century). However, the first paragraphs of this historical overview showed that, at some point of their evolution, Electroacoustic Music and (Interactive) Installation Art came to share a close relation with the new technologies.
Speaking for the present days, it is very easy to prove that a multimedia performance and a composition for Live Electronics are not alike, and it makes perfect

sense to treat them separately, according to the approach. At the same time, the common thread of SMC is technology applied to sound and music, and in this sense it is equally interested in multimedia performances, interactive installations and in all artistic expressions where sound and music are important elements in the process of creating a meaningful experience.
Summarizing the historical overview, it can be said that Installation art "rejects concentration on one object in favor of a consideration of the relationships between a number of elements or of the interaction between things and their contexts" [115], whereas SMC artworks refer to those particular installations where sound or music are the privileged element (medium) in the aesthetic and communicative experience.

12.5 The preservation of Interactive Multimedia Installations

> "The future is just a kind of past that hasn't happened yet. And obsolescence is innovation in reverse". [116, p. 11]
> The preservation of traditional cultural heritage (sculpture, architecture, paintings, etc., and what is not strictly considered art, i.e., early printed books, documents, maps, etc.) relies on methodologies refined over decades and centuries. Unfortunately, Interactive Multimedia Installations benefit from such approaches minimally, because of the distribution of the contents over multiple media (intangible component). However, much can be learned from the experience matured in the audio field, where the dichotomy medium-content has proved traditional approaches to be inadequate if the meaning of the artifact does not coincide with its physical expression.
>
> An official document issued by UNESCO [1] reported that in 2002 seventy to eighty per cent of documentary heritage in Eastern and Central Europe was estimated to be inaccessible or in urgent need of preservation (see Chapter 2). The most authoritative institutions in the field agree that at present the most reliable technology for long-term preservation is digital, as it allows easy copying without loss of information. As a drawback, specific dangers such as failure without any warning should be considered, as well as the necessity to re-think concepts such as authenticity, ownership and copyright of the documents. Periodical data verification is mandatory in digital repositories [2], mainly performed with checksum comparisons – although more sophisticated validation systems are desirable, i.e., overcoming the bit stream level and performing quality control on the contents and their relations.

Synthesizing tangible and intangible objects into digital preservation copies[4] causes the multiplicity of documents (multimedia) to be encoded as "unimedia" [56]. Despite the fact that digital technology is considered future proof, the exponential pace of technological evolution brings about a shift from the traditional focus on degradation of physical media to the awareness of the risks of obsolescence of the stored data.

Interaction introduces an additional element of complexity to the problem of preservation, already raised by some musical "open works" such as *Scambi* (1957) by Henry Pousser. A *systemic* approach was proposed to overcome the limits of the current approach, which requires that objects are (made) static for preservation. In this sense, an analogy can be made between interactive multimedia systems and *open systems*. According to [117], every living organism is essentially an open system that maintains itself in a continuous inflow and outflow (a building up and breaking down of components) so long as it is alive. The commonalities with interactive multimedia systems are remarkable.
A good model for preservation should base on time-dependent aspects of interactive systems, rather than distort the present ones to forcedly deal with it. Section 12.7 discusses a possible solution that considers these aspects.

Current trends of multimedia artistic works show an increasing attention for full-body interaction. According to the embodied approach to the study of music cognition [118], corporeal and nonverbal articulations may enable a paradigm shift in the preservation of cultural heritage, in particular of interactive processes. The crucial idea is that body gestures may hold meaningful significations with respect to the subjective experience of involvement with music, i.e., that body movement may provide efficient musical descriptors different from the traditional text-based descriptors, which are effective for some features but totally fail to attain others.

A particular class of works that should be considered for preservation consists of the replications, the reinterpretations and the virtual models that resulted from important recovery actions, some of which were financed by the European Union, such as DREAM (Digital Re-working/re-appropriation of ElectroAcoustic Music, 2010-2012)[5] and VEP (Virtual Electronic Poem: VR-simulation of the Poème Électronique by Le Corbusier, E. Varèse and J. Xenakis (1958), 2002-2004)[6].

[4] In [33], a preservation copy (or archive copy) is defined as "the artifact designated to be stored and maintained as the preservation master". It consists in an organized data set that contains *all* the information carried by the original document, accompanied by the metadata and the documentation about the preservation process.
[5] `http://dream.dei.unipd.it/` (last visited on February 10th, 2013).
[6] `http://www.edu.vrmmp.it/vep/` (last visited on February 10th, 2013).

Finally, a model for the preservation of Interactive Multimedia Installations would enable the creation of a common European repository, that institutions (e.g., archives) and artists could populate with descriptions, data, pictures, videos and testimonies. The model would also result in a set of guidelines for a consistent organization of the data within the repository. Artists would be encouraged to produce a documentation about their new works along the lines of the framework: thus, the very important goal of actively involving the artists in the process of preservation would be achieved, and the long-term storage planning would be optimized.

12.6 Problems related to preservation

- *Time-varying and interaction*: Unlike audio recordings, Interactive Multimedia Installations do not come in a fixed form: as they have been defined in the Introduction of this article, they are rather time-varying systems. The variations in time may be programmed to occur automatically, or they might require an external event (most commonly, a user's action). Variations in time and interaction introduce some of the most complex problems in the preservation of Interactive Multimedia Installations, however they are not completely new: they gave been previously raised by musical *open works* such as "Scambi" composed by Henry Pousser in 1957 ([119, 120]). And speaking of the present days, the preservation of intangible cultural heritage (e.g., traditional dances) is among the hottest topics in the archival community research agenda.
  Two levels of interaction can be observed: intrinsic and extrinsic[7]. The first refers to the relations that exist among the elements of the Installation, and the way they are build and programmed to interact; the latter refers to the interaction that occurs between the Installation, as a unity, and the user(s). Both require an adequate documentation.
  An analogy can be made between Interactive Multimedia Installations and open systems: according to [117], every living organism is essentially an open system that maintains itself in a continuous inflow and outflow (a building up and breaking down of components) so long as it is alive. The commonalities with Interactive Multimedia Installations are remarkable. The multi-level approach proposed in this article tries to capture the aspect of Interactive Multimedia Installations as living organisms, with their continuous inflow and outflow, and a lifespan that is limited in time.
- *The artistic factor*: Even assuming there was a good model for archiving a time-varying system with elements of interaction, there would be another

[7] These levels have been introduced by Marc Leman during the lecture "Interactive Multimedia Installations – A viewpoint from social embodied music cognition" at the Workshop "Le Installazioni Multimediali Interattive: conservazione e fruizione" organized by the authors at Villa Contarini in Piazzola sul Brenta (Padova, Italy) on September 11th, 2010. Web page: `http://www.villacontarini.com/newseventi2010_ita.htm`

difficult question to address: an Installation is an assembly of artifacts characterized by intrinsic and extrinsic time and space relations, but in its highest cultural interpretation it is a work of art. And it is precisely that level of interpretation that motivates all efforts for preservation, so it is very important to make sure that the aesthetic experience provided by the Installation is somehow present in the preservation copy. But where does art lie? Does it stay "dormant" until someone interacts with the Installation and make it "happen"? As long as the definition of Installation Art remains open in the international community, the model to represent it has to be as general as possible. Most definitions do not help this process: "The installation is an expansion of a three-dimensional space, with the notable difference with sculpture, that the axes with which matter is being organized are not exclusively internal to the work, but also external" (quoted in [103, p. 1]). Where are the bounds of the "external"? Does it include the room, the exhibition, the building, the world? Minard suggests that "the fusion of art and life is an essential aspect of the installations" [104, p. 10]: but how do you preserve "life"? The question is merely provoking, but the recurrent use of the term "life" in most definitions of Installation Art is revealing: there must be something "essential", as remarked by Minard, about Installations that is related to "life". This relation might be the key to understand why artists are not generally interested in the preservation of their works, which is a very common trend, despite the fact that it is extremely surprising in the viewpoint of archivists and scholars. This trend has been confirmed by many people who usually work with artists, for example the staff of exhibition galleries, that the authors have met at conferences and symposia during the last years: the most common guess is that artists conceive their works with an intrinsic element of *transientness* and that it is part of their conceptual plan that the work "lives once" and no more (this would make them not interested in any effort to "save" the work, because this has been synonym of "making it static" so far). In Section **??** it has been said that having the artists involved in the process of preservation is highly desirable: as trivial as this may seem, not enough emphasis is put on this point, because in the real life experience this is easily said and hardly often done.

- *Short Life Expectancy*: Another aspect that makes the preservation of Interactive Multimedia Installations an urgent matter is that they are characterized by a very short Life Expectancy (LE). While sculptures and other traditional cultural materials can last several centuries, audiovisual media have proved to have a LE that can be measured in decades or years due to their physical-chemical instability. Interactive Multimedia Installations are affected by the problem of a short LE in different ways. From the least to the most serious, these are:
  1. *Degradation of physical elements*: even if the creation of a preservation copy provides that the physical elements of the Installation are digitized for archiving, it is nevertheless desirable that they are maintained. Wether it is a wooden chair, a glass bowl, a neon light or

another object, the LE of these elements can be measured in decades and centuries.

2. *Degradation of HW/SW*: the tight interconnection with technology takes its toll in obsolesce: hardware, software environments, file formats, programming languages have a LE that can be measured in years, except in some cases (e.g., programming languages).
3. *Loss of knowledge about the setting*: if no adequate documentation has been produced before the Installation is dismantled or moved to the next location, *the LE may even coincide with the time of the exhibition.* This type of loss characterizes Interactive Multimedia Installations. It is more common than it might be suspected: there might be technical sketches or compositional notes, but a thorough technical scheme of the system is almost always missing (see next point). Besides, it is common practice to adapt minor aspects of the Installation on the spot, due to frequent unexpected restrictions on the exhibiting venue (and these adaptations are almost never documented).

- *Absence of score/notation*: Interactive Multimedia Installations are also characterized by the absence of a score or notation, as in the conventional musical analogue. The definition of a standard language to express the combination of events occurring on multiple media is an open research thread. All that is available are technical sketches and annotations by the author (see previous point). The scarcity of documentation about the assembly and the functioning of the whole dramatically increases the risk that the knowledge about the Installation is lost by the time it is dismantled or moved (see previous point).

The multiplicity of problems raised by Interactive Multimedia Installations calls for a "transdisciplinary" approach [121], making way for new professional figures, whose added value precisely resides in the ability of switching contexts. The multi-level approach presented in this article assumes that the preservation copy of a Multimedia Interactive Installation is realized by a multidisciplinary scientific team.

12.7 Proposed solutions: a multilevel approach

A good model of Interactive Multimedia Installations for preservation should be compatible with different objectives of preservation:

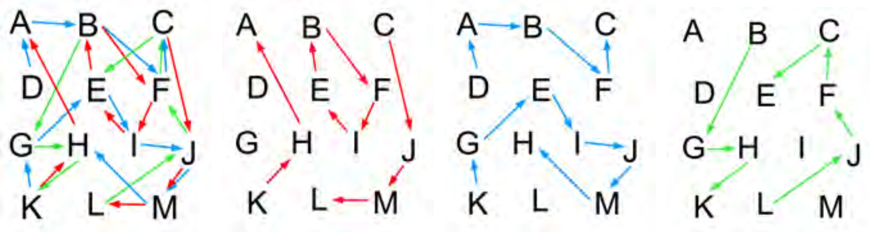
- support (future) scholarly studies;
  - historical
  - philological
  - musicological analyses
- enable (future) re-installation;
  - replication
  - re-interpretation
- archiving (conservative approach).

Fig. 12.3: Characteristics of the multilevel approach to preservation. Each level (bits, data, record, experience) can be static/dynamic, physical/logical, and has a limited life expectancy. Levels are depicted on the x-axis, properties on the y-axis, and values on the z-axis. The properties static/dynamic and physical/logical assume only two values or states: lower for static and physical, upper for dynamic and logical. Colors refer to the bins associated with the life expectancy of each level expressed in years.

At the same time, it should allow for different approaches to the fruition of the preserved object:
- documental
- aesthetic (re-create the experience, i.e. feel it again)
- sociological (what the installation meant to the people of the era, how it was perceived)
- reconstructive (replicate the work as faithfully as possible).

One of the few works related to Interactive Multimedia Installations is the ontology approach used in [122] and [123] to describe them and their internal relations to support the preservation process. In [124], the author proposed a functional categorization of documents as an extension of the CIDOC Conceptual Reference Model (CIDOC-CRM), an ISO standard for describing cultural heritage [125–127]. Their work is presented in the next paragraph.

Given that the creative process is impossible to freeze, a combination of approaches is desirable, defined as distinct levels of preservation, not necessarily sequential, with different purposes and ways to be performed. Each level pursues different goals, but they may present overlapping contents. Two forms of preservation are considered: static, where records are created once and not altered, and dynamic, where records are changed and updated.



(a) All layers (b) Layer 1 (c) Layer 2 (d) Layer 3

Fig. 12.4: The figures show how the elements contained in a *preservation copy* of an Interactive Multimedia Installations should be able to support different *narrative trajectories*, each reflecting the different approach (vision) that a potential user may have with respect to the work. The data structure employed for the representation of the elements should be flexible enough to enable multiple relations – and why not, also new relations dynamically proposed by the users.

Preservation approach	**Static/Dynamic**	**Physic/Logic**	**Life expectancy (Years)**
Preserve the Bits	Static	physical	$5-10$
Preserve the Data	Dynamic	physical	> 30
Preserve the Record	Static	Logic	$10-20$
Preserve the Experience	Dynamic	Logic	> 30

Table 12.1: Characteristics of the multilevel preservation approach in the IMI field.

Finally, levels may consist of a physical or logical content. Figure 12.3 shows each level and the associated properties.
In most forms of traditional artistic expressions, the artifact coincides with the work of art. In Interactive Music Installations, however, it is less clear where the art lies, as it usually "happens" during the process of interaction. Preserving the installation as it was presented to the public falls within the scope of current approaches to preservation, yet the creative process is something impossible to freeze. Therefore, in this sense, the preservation is an ongoing process: nothing has ever been preserved: it is being preserved. In our opinion, in order to grant a permanent access, which is the ultimate objective of preservation, a combination of approaches is desirable. The *model* that underlies the interaction process is essential. This leads to different levels of preservation, with different purposes and ways to be performed. Moreover, we must consider that two forms of preservation exist: static where records are created once and not altered and dynamic where records keep changing. The next paragraphs describe a multilevel preservation approach, which is summarized in Table 12.1.

Preserve the bits – Each part of the original installation that can be directly preserved: physical, life expectancy 5-10 years. All the data are kept in the original format (the problem of their interpretation is a mat-

ter aside), and the risk of introducing alterations must be avoided. It is a physical and static form of preservation, and it works in the original contexts. It still requires metadata preservation and refreshing. There can be physical and digital objects. Preserving the digital objects will follow the general conceptual model defined in the OAIS Reference Model [128]. This means that each digital object will be accompanied by its representation information, preservation description information (i.e. reference, context, provenance and fixity) and descriptive information.
Preserve the data – Technical notes, comments and useful information about the realization of the installation: dynamic, physical, life expectancy up to 30 years. Includes high level descriptions of algorithms and models. No special attention is paid to presentation and context. It is a physical and dynamic form of preservation, as it could be necessary to use new design languages, possibly developed on purpose.

Preserve the record – Any element that was modified or updated in respect of original installation: static, logical, life expectancy 10-20 years. Includes re-interpretation of the patches and information about the context. Costs are balanced against utility, and appearance is not necessarily preserved. It is a logical and static form of preservation. Some risks are tolerated, if not necessary (e.g., migration to new informatics environments). The results of each intervention should be checked using philological instruments. This level needs another layer of information about activities *actually* performed in the performance (the actual activities performed during a performance can be different from the necessary activities mentioned at the *bit* level).

Preserve the experience – Any document that bears witness to some aspect of the installation: dynamic, logical, life expectancy up to 30 years. Includes hardware, software, interviews, audio/video recordings, usability tests of the original system, as well as information about people (composers, directors, performers, technicians) involved in the original performance and their roles. Resembles a museum-like approach, that aims at keeping track of the history of the installation. It may require emulators or old computers (emulators reproduce a whole system, or a program; system emulators require us to use old interfaces; program emulators may use current interfaces) and/or migration in new systems (*reinterpretation*). Although emulation has been known as a method that could create the original look and feel of the work [129], [116] showed that this was not easily achievable, owing to many differences between the original hardware platforms and their emulated counterparts, such as CPU speeds, as well as looks and feels of the new hardware platforms. Reinterpretation seems to be a preferred approach, where the artworks could be entirely encoded using a symbolic notation [130]. It is a logical and dynamic form of preservation, necessary for a long term action (> 30 years). Its existence may be more important than the content, although it does not help re-use, it is expensive and not oriented to fruition.

The rapid obsolescence of the new technologies employed in Interactive Music Installations complicates the maintenance of hardware/software (bits and data). Besides, some installations base their interaction on objects that are meant to be used or consumed by the users (food, perishable material, etc.). This implies that parts of the installation may literally not exist anymore after the interactive process is over (no bits to preserve). The approaches described above do not require sequentiality, as they basically pursue different goals. Quite the contrary, they may occasionally show overlapping contents.

12.8 Case Studies

Since the definition of *SMC artwork* allows a large variety of creative expressions, whose common thread is the use of sound and music mediated by technological means (see Subsubsection 12.4.0.7), it may also include works that differ in a significant way, in terms of media involved and entity of the resources required for assembling and/or exhibiting them.
This section presents a set artworks to represent such variety. The works were selected with the purpose of offering a synthetic but complete overview of the most significant typologies of SMC artworks (*tape music*, open work, interactive installations, Live Electronics with spatialization, massive architectural acoustic space). Some of the examples are milestones of the history of music of the XX century. Some have already been addressed with preservation programmes, others are sitting in depositories and sadly fading away, mainly for lack of fundings.

12.8.1 "Continuo" by Bruno Maderna

"Continuo" (1958) is a composition for monophonic magnetic tape with a duration of 8'03"; the original tape is stored at the sound archive of the RAI in Milan, Italy. Maderna realized this work at the Studio di Fonologia Musicale of the RAI (Milan), employing the following equipment:

- 9 oscillators
- white noise generator
- band pass filters (2-10 Hz)
- amplitude and ring modulator
- reverberation chamber
- alteration of tape speed recording with or without pitch-shift

The idea is that a single sound is taken through twenty-two different stages of change, linked together on tape (a "continuous" process of transformation, hence the name of the piece). Each new stage adds a minute bit of elaboration to the basic sound, so that the piece at some level becomes about sound itself. Sources dispute whether the original sound is a pure, electronically generated sound or a note blown on the flute by Severino

Gazzelloni. It is not possible to reconstruct the compositional process, because there are no score, notes, tape chunks or working sketches left. The only analysis that has been attempted so far is a classification of the sound materials by means of a analysis-by-synthesis approach.

12.8.2 "Scambi" by Henri Pousseur

Writing about Scambi in 1959, Pousseur ended by envisaging the day when technology would allow listeners to make their own realizations of the work (either following his 'connecting rules' or not) and to "give the, now *active*, listener the experience of a temporal event open to his intervention and which could therefore be elevated in type, as vital, creative freedom" [131]. Pousseurs definition of 32 sequences and set of connecting rules are all we have, and as Pousseur has said many times, need not be followed. Structure, therefore, would be only a matter of connection (or, if not, succession), and although the profile of each sequence is determined in pitch, duration, and other parameters, there can be no definition of the structure of the whole, except that extracted from any realization.
There are two types of material: chirrupping and pointilliste, and sustained, longbreathed sounds, which are variously overlaid.

12.8.3 Selection of works by composer Carlo De Pirro.

Carlo De Pirro (1956-2008: music composer, professor at the Conservatory of Music "F. Venezze" in Rovigo, from 1982 to 2008) has devoted the last decade of his prolific life to creating innovative interactive works including "Piazza Pinocchio", a massive installation exhibited at the Expo 2002 in Neuchâtel (CH). Carlo De Pirro realized most of his works with the scientific support of the Centro di Sonologia Computazionale (CSC) of the University of Padova, where many of his works are deposited and waiting to be restored.
The works by Carlo De Pirro show how important the underlying model is in the process of preservation: many of his praised works lie unassembled, and the untimely passing of the artist erased any chance to inquire about his real intentions. With insufficient documentation left, we are unable to make sense of some surviving objects and patches. This emblematic example proves the importance of organizing preservation actions in collaboration with the artists and everyone who bears witness to the work – and to do that now, as long as they are around: after all, *cultural heritage is about people and for people.*

In 2009, the CSC started a self-financed project aimed at the preservation and at the restoration of the works realized by Carlo De Pirro during his collaboration with the CSC research team. The project is called CAPIRE (CArlo de PIrro: Restoring an Experience) and it has been supported by the Association Carlo De Pirro [8] since its foundation, in 2011.

[8] `http://csc.dei.unipd.it/depirro/` (last visited on February 10th, 2013).

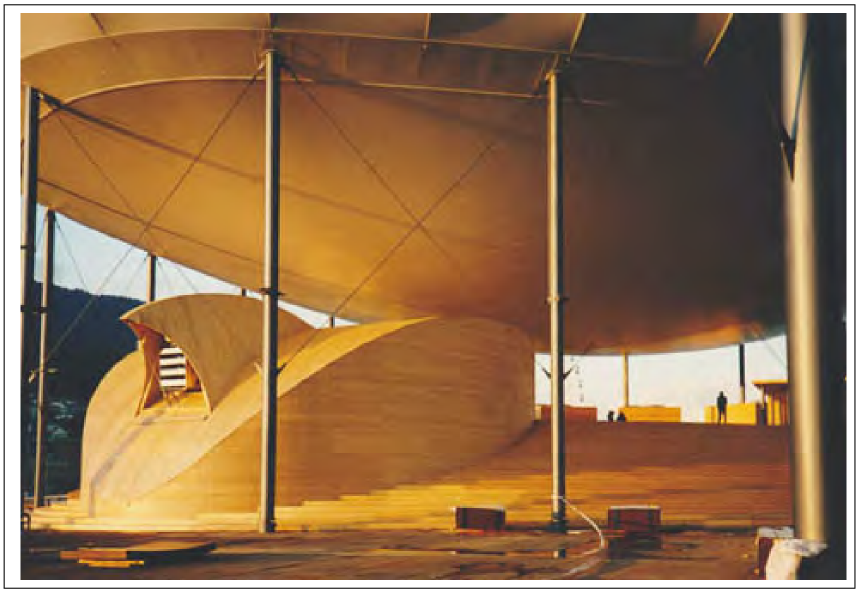


Fig. 12.5: Rear view of the structure representing the whale in the "Piazza Pinocchio" at the Expo 2002 in Neuchâtel (CH).

12.8.3.1 Piazza Pinocchio

The scientific partners of De Pirro's "Piazza Pinocchio" were Sergio Canazza and Antonio Rodà, part of the research team at the CSC, while the artistic director was Roberto Masiero (Professor in History of Architecture at the University of Venice). This IMI was also motivated by scientific aims, which were to test some movement analysis patches, for the measurement of high level features and to investigate some kinds of mapping between movements and music and its effect on a children audience. Moreover, an additional goal was to test the reliability of the Eyesweb environment [9]. during a long time performance (18 hours/day; 6 months).

Concept – In the contest of Expo 2002, Switzerland built some wood platforms in its four major lakes. Each platform (80 x 30 meters) was dedicated to an artistic topic or to a scientific discipline. Our exhibition was installed in the platform dedicated to Artificial Intelligent and Robotics (Figure 12.5). The system was made by a room for children, like a magic room, in which each gesture became sound, image, color. In this system the visitors are been involved in a communication of expressive and emotional content in non-verbal interaction by multi-sensory interfaces in a shared and interactive mixed reality environment. From the gestures of the visitors (captured by two video-cameras) are extracted the expressive content conveyed through full body movement. Mapping strategies will convey the

[9] `http://www.infomus.org/eyesweb_ita.php` (last visited on February 10th, 2013)

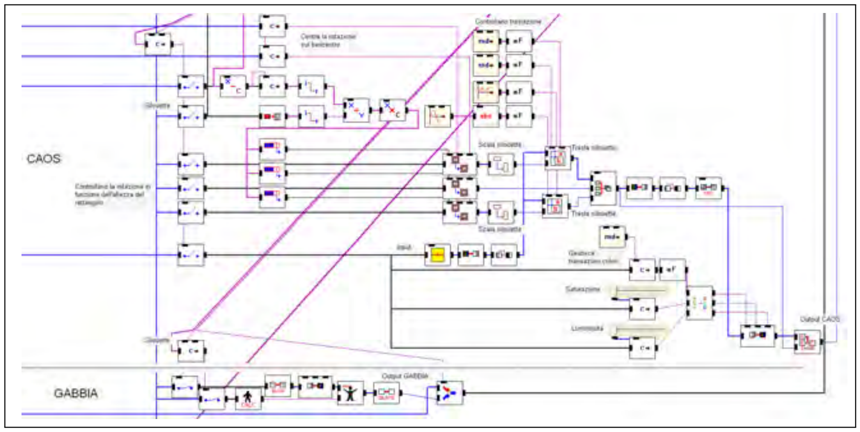


Fig. 12.6: Two examples of the real time video processing: caos multiplies, rotates, and shifts the user's silhouette; gabbia (cage) shows a skatch of the user's skeleton inserted in a square box.

expressive content onto a multimedia output (audio and video). The system focused on full-body movements as primary conveyors of expressive and emotional content. This approach implies a new and original consideration of the role that the physical body plays with respect to interaction. During the 6 months, the exhibition was visited by a large audience: the Swiss organization reckons about 4 millions of visitors. The exhibition was very appreciated in its artistic content.

Technical description – The setup was based on two video-cameras to capture full-body movements inside the room and two video-projectors to render the real-time video-processing in the room. Computation was carried out with a computer cluster (using Pentium III 800MHz, 128 MB Ram, HDD 16GB, Windows 2000) composed by: two PC to process the video captured information, called V1 and V2, and one PC to render audio content, called A. Sound was amplified by five loud-speakers (4 independent channel + 1 subwoofer). All the three PCs has installed and running Eyesweb 2.4.1 for both audio and video processing.

Description of the employed patches – Patch 1. This patch is installed on PC V1 and is dedicated to the processing of the video, captured by the first video-camera. The patch is divided in two parts: the first, analyzes the video streaming, in order to calculate some high level features; the second, implements several algorithm for the real time processing of the video-streaming (Figure 12.6 shows two examples of these algorithms). The patch is connected via MIDI to PCs V2 and A.
Patch 2. This patch is installed on PC V2 and is dedicated to the processing of the video, captured by the second video-camera. On the base of the high level features received from PC V1, the patch processes the video streaming in real-time and send the results to the video-projectors.

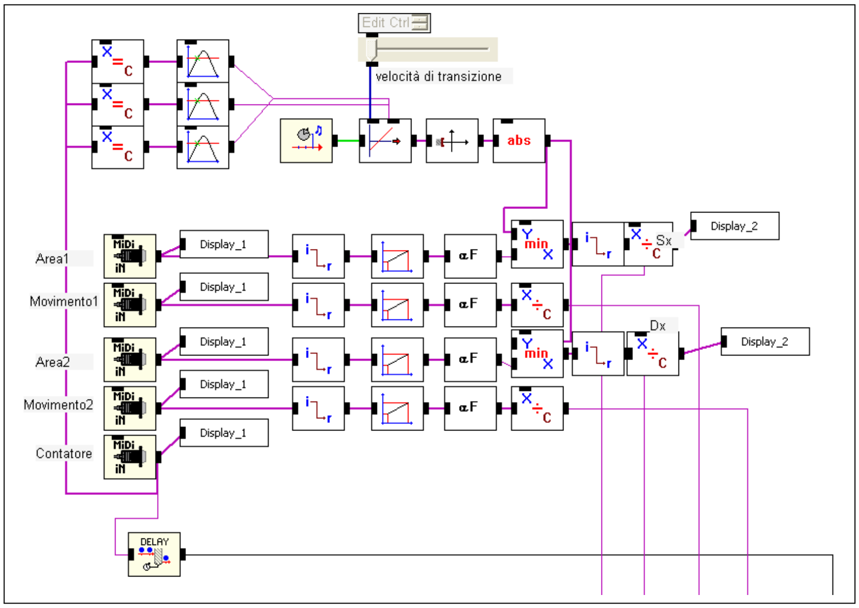
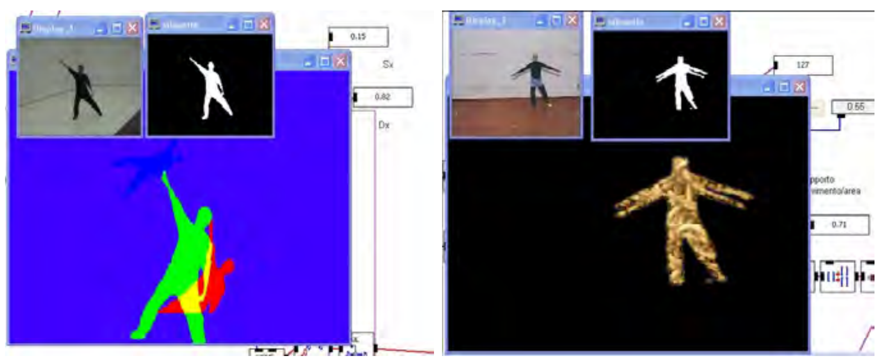


Fig. 12.7: Eyesweb patch dedicated to audio processing. The MIDI input representing the high level features calculated by the patches 1 and 2. These are used to control the audio file composed by Carlo De Pirro.

Patch 3. This patch (Figure 12.7) is installed on PC A and is dedicated to the render of audio content. On the base of the high level features received from PC V1, the patch processes in real time some audio tracks, composed by Carlo De Pirro.

Preservation – During the first 2 months of the preservation project carried out in CSC (University of Padova), the *bits preservation* task has been carried out: we created the conservative copies of all the documents related to the installation (software, textual, audio and video documents, etc.). In addition we described algorithms and models used by the installation (*preserving the data*). Finally, we migrated the patches in new Eyesweb environment in order to run the installation using new hardware with the Windows XP and Vista O.S. (preserving the record): Figure 12.8 show two frames of a patch running. We are carrying out the *experience preservation* step: we collected the original hardware and software, and some interviews to the authors. The more difficult task is probably the re-creation of the original space: the magic room (with the same material). We have the original plan: up to now, lack of an adapted museum space and financial funds.



(a) The *caos* patch (b) The *worms* patch

Fig. 12.8: The *caos* patch (a) and the *vermi* (worms) patch migrated in new environment, with a new release of Eyesweb and Windows XP.

12.8.4 Carillon della Materia

The Carillon della Materia was part of the installation "Piazza Pinocchio" presented at the Expo 2002, and it is currently exhibited at the Parco Collodi near Pisa, Italy.

Concept – Inspired by the tale of Pinocchio, the composer created a structure where common tools of a carpenters workshop turned into musical instruments, hit by mallets at different speed and strength. De Pirro composed a musical score for the Carillon, of which the moving parts were automatically activated by means of a MIDI interface.

Technical description – The Carillon consists in a wooden structure to which handsaws, circular saws and trowels are attached, with some pieces of Murano glass in tribute to Venice. The moving parts of the Carillon were controlled by an electronic device developed on purpose [132], according to a musical score composed by De Pirro and transmitted via MIDI (Figure 12.9).

Preservation – The wooden frame of the Carillon was damaged during the long travels to the venues it was exhibited at. When it was donated to the Parco Collodi in 2002, it was reinforced, repainted and then exposed inside a larger wooden shell resembling a capsized boat, hanging from the ceiling just like in Neuchâtel.
In early 2009, a team from the Department of Information Engineering of the University of Padova traveled to Pisa and to Vicenza to gather photographic material and interviews with people who were involved in the installation. Since electronic controls were made on purpose, and the technical documentation is missing, today the structure is unable to emit a sound because none of the members of the original development team is

Fig. 12.9: The Carillon della Materia at the Expo 2002 in Neuchâtel (CH) during setup. The Carillon was exhibited inside a wooden house on the artificial island dedicated to "Piazza Pinocchio". The Carillon was hung to the ceiling in order to avoid harm due to the circular saws in motion.

able to work on the Carillon in its current location. No audio/video recordings were made at the Expo 2002, so we actually do not know how it is supposed to sound according to the composer's idea. All the multimedia available about the Carillon is currently stored in the archive of the Centro di Sonologia Computazionale in Padova.
The Carillon is an example of installation of which we still have the physical components (the bits), but we lack the knowledge to make a sense out of it, preferably a sense that is faithful to the original intention of the author. Even so, the destiny of this installation is interesting: today it keeps being appreciated as a silent piece of sculpture at the Parco Collodi.

12.8.5 *Il Caos delle Sfere: Anche tu pianista con 500 Lire*

The interactive music installation *Il Caos delle Sfere: Become a Pianist with 500 Italian Lire* has been presented for the first time at the "Biennal of the Young Artists of Europe and Mediterraneo" Giovani Artisti di Europa e del Mediterraneo" in Rome, 1999; afterwards the exhibition toured in other artistic manifestations until year 2004. Scientific and technical partners were Nicola Orio and Paolo Cogo, at that time, members of Computational Sonology Centre of the University of Padova, while Carlo De Pirro was the involved artist. Although this IMI did not have scientific aims, it has been based on the results of a joint research work on music interaction called "Controlled Refractions" [133], on the interaction between

Fig. 12.10: The installation "Il Caos delle Sfere" during its realization at the composer's home in 1999. From left to right: Veniero Rizzardi, composer Carlo De Pirro, the scientific partners from CSC, Paolo Cogo and Nicola Orio. The Disklavier can be observed on the left, next to the monitor of the computer used to control the installation, and to the pinball machine.

a pianist and a computer through a music performance.

Concept – The basic idea was to use a common gaming machine, such as a electronic pinball, to control an automatic performance played on a Disklavier (Figure 12.10). The kind of interaction introduces a large amount of unpredictability on the obtained sound, because normal users have only a loose control on the "silver ball". Given that normally all the electronic pinballs give auditory feedback to the user, the basic idea of the composer was to avoid a one-to-one mapping between the objects hit by the ball and the generated sound. Moreover, the composer decided that a good player should be rewarded with a more interesting and complex performance than a naïve player. To this end, the amount of interaction varied according to the evolution of the game. The more levels were reached, the more complex and virtuosistic was the generated performance on the Disklavier. The game starts with some pre-written sequences; when the user changes to a new level, some automatically generated sequences start to play while the user partially controlled depending on the kind of targets he is hitting. At new level the style of automatic sequences changes, so it does the way the user can control them.

Technical Description – The installation was based on a popular electronic pinball "The Creature from the Black Lagoon". The choice of this particular pinball, which is one of the first to introduce the concept of dif-

Fig. 12.11: The installation “Il Caos delle Sfere” replicated at the exhibition “Visioni del Suono. Musica elettronica all’Università di Padova” organized by the University of Padova and by the Conservatorio di Musica “C. Pollini” of Padova in May 2012.

ferent levels of a match where the player has to archive a number of goals that correspond to levels in the game, partially influenced the technical and artistic choice as explained in the previous section. The first technical goal was to monitor the game (levels and targets) minimizing the need to interface with the preexisting electronic. To this end, it has been chosen to split the signal coming from the pinball switches to track the targets hit by the ball. The level of the game was monitored by splitting the signal going to the pinball lights. It can be noted that the in this way it is only possible to estimate the level of the game and that some of the features (i.e. the actual number of points) have been neglected. The acquisition was made through an electronic circuit that has been designed ad hoc, which sends to the PC the information about switches and lights through the parallel port. A PC running Windows acquires the data through the parallel port, processes the information through a software developed in C by the technical team. The software is able to play, generate, and modify melodic sequences according to the indication provided by the composer. The result is sent to the Disklavier through the MIDI port, using the environment Midishare developed by Grame[10] and now available open source. The Disklavier, which could be either a grand or a upright piano depending on the place of the installation, was the only sound source. The goal was to minimize the presence of digital media, for instance, the PC has almost no graphical user interface.

Preservation – The *bits preservation* task has been partially carried out by creating conservative copies of all the software, the music sequences to be played at different levels. The electric scheme of the acquisition board has

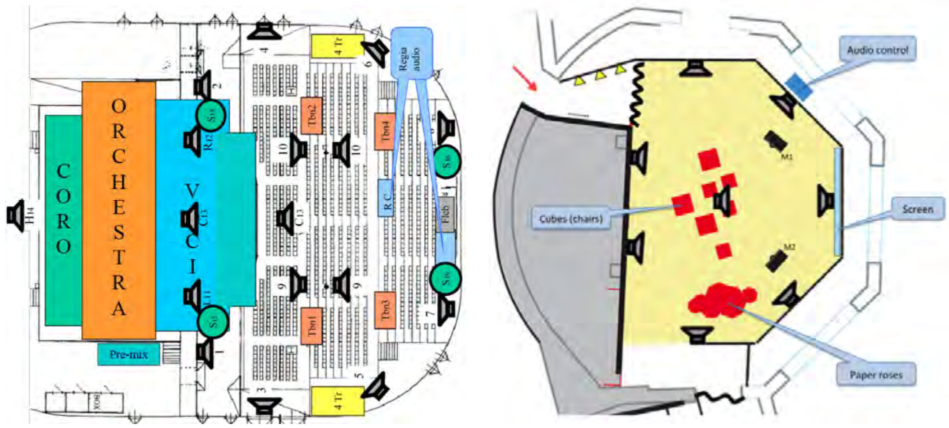
[10] `http://www.grame.fr/` (last visited on February 10th, 2013).

been digitized as well, while the notes of the composer about the installation are still in the process of being gathered. As regards the *data preservation*, a small team has been created for the definition of the used algorithms that, being developed in direct collaboration with the composer with a try-and-error approach, have been left mostly undocumented. Due to technical choices made about ten years ago, in particular the use of the parallel port and of a proprietary compiler which is no more supported, the *record preservation* is still an open issue. The *experience preservation* has to deal with the fact this IMI was not conceived for a particular space, and in fact it has been presented at different occasions from small indoor to large outdoor places. On the other hand, the experience preservation is directly related to the correct functioning of the electronic pinball, which has been completely restored. The installation is currently stored at the Centro di Sonologia Computazionale in Padova, and it has been replicated in May 2012 at the exhibition "Visioni del Suono. Musica elettronica all'Università di Padova" organized by the University of Padova and by the Conservatorio di Musica "C. Pollini" of Padova (Figure 12.11).

12.8.6 "Medea" by Adriano Guarnieri

"Medea" was presented for the first time in Venice, at the Teatro la Fenice, in October 2002. It is a piece of contemporary music that employs the concept of "expressive spatialization" as a core compositional rationale. Its score was written with a precise reference to sound spatialization, with the aim of achieving a more powerful and complete message by means of the expressive matching between the instrumental gestures and the sound moving in space.
The musicians were distributed among the audience and around the hall, and Live Electronics was assigned a considerable task. Space is a compositional parameter that has been largely explored by contemporary artists, not only in the field of electronic music. Distributing musicians in a physical space requires no technology and in this sense it cannot be considered a novelty (see the multiple choir technique, known as "cori battenti", developed in Venice during the Renaissance), but moving sound through arrays of speakers with meaningful mapping strategies could only made possible by relatively recent technological devices. Today spatialization is a musical parameter that cannot be ignored in any music genre, but in some cases (such as Medea) it is crucial to the fruition of the piece as it represents the key to a significant aesthetic experience. Replicating the Medea setup (Figure 12.12) poses problems related to its complexity, besides the fact that it is very difficult to think of a stereo reduction (e.g., for commercial release) that maintains the spatial relations unaltered. In addition, interactive and improvisational sections turn "Medea" into an "open work", bringing in the problems associated with varying artworks .

Recreation of the electroacoustic space – During the exhibition "Visioni del Suono. Musica elettronica all'Università di Padova" (see Subsection 12.8.5), the audio/video recordings of the Medea produced in 2002 have



(a) 2002 (b) 2012

Fig. 12.12: Overview of the spatialized amplification scheme for Andriano Guarnieri's "Medea": (a) shows the scheme of the Palafenice in 2002; (b) shows the eight-channel adaptation for the exhibition "Visioni del suono" in 2012. The videos were projected on the main screen hanging from the wall in front of the red cubes, and on two smaller monitors on the floor (M1 and M2). The yellow area was destined to the exhibition, while the corridor running along the external walls housed technical material, as well as the digital workstation for audio control, which was hidden from the visitors.

been adapted and presented to the public. Mo. Alvise Vidolin, responsible of the Live Electronics in the original staging together with Nicola Bernardini, took care of the adaptation. A selection of scenes from the live recording of the performance in Venice has been re-organized for an eight-channel spatialization, in combination with three screens (a bigger one hanging in front of the spectator, and two smaller ones on the floor, one left one one right) loop-playing scenes from the opera and from the original video track. The selection included some instrumental, some choral and some solo parts. In this case, the replication was clearly not aimed at reproducing the opera, nor at re-interpreting it giving birth to another [version of the] opera. Its sole intent was to showcase the original staging, by using the existing material documenting Medea (a multitrack recording of the last performance in 2002, and a video recording with stereo sound in DVD format, directed by Giovanni Di Capua). Nevertheless, the setting of the Medea in the exhibition resembled that of a multimedia installation: walking into the room dedicated to Medea, the visitors had the impression of entering another space, thanks to the play of lights and to the decoration of the room (red cubes of different sizes in front of the main screen for the visitors to sit down, and some dozens of paper red roses collected on the right side of the room).

Adriano Guarnieri, who is living a healthy life and still composing, was not involved in the preparation of the showcase, but he was present at the opening of the exhibition. He did not know exactly how the opera would

Fig. 12.13: Screenshot of the patch developed in Max/MSP for the re-installation of Andriano Guarnieri's "Medea" in 2012. The spatialization is controlled with the module SpAAce, developed by Mo. Alvise Vidolin.

look like, but he trusted Mo. Vidolin, a long-time collaborator and a most praised name in the field of contemporary music. Guarnieri was enthusiastic about the adaptation, and commented: "Questa è a vera Medea!"[11]
The link between the original Medea and its adaptation is obviously Mo. Alvise Vidolin, who has a deep knowledge of the score and who has personally taken care of the first staging of the opera, working in tight collaboration with the composer. He was interviewed by the author on March 4th, 2013 at the Centro di Sonologia Computazionale (CSC). The interview lasted about an hour, and it focused on the original production of the opera, the long gestation, the extra-musical complications, the [live] electroacoustic plan, and eventually the recent adaptation. The interview has been audio-recorded, processed, enriched with descriptions and extra material, and stored in the historical archive of the CSC. Figure 12.12 reports the scheme of the amplification in 2002 (left) and in 2012 (right).

12.9 Future directions

There are relevant aspects regarding the preservation of SMC artworks that may be explored in the next future, especially corporeal measurements and automation;.
Corporeal measurement – The current trends of SMC artistic works show an increasing attention for full-body interaction. According to the embodied approach to the study of music cognition [118, 134, 135], corporeal and nonverbal articulations may provide the key for a paradigm shift in the preservation of cultural heritage, namely of interactive processes. The crucial idea is that body gestures may hold meaningful significations with respect to the subjective experience of involvement with music, i.e., that body movement may provide efficient musical descriptors different from the

[11] "This is the real Medea!" Source: oral communication of the composer.

traditional text-based descriptors, which are effective for some features but totally fail to attain others.

The idea that musical involvement is based on the embodied imitation of moving sonic forms has a long tradition [136]. Truslit , also in [13], sees corporeal articulations as manifestation of the inner motion heard in music. The current embodied cognition approach is an alternative to disembodied cognition, where the mind is to be considered to be functioning on its own (in line with Descartes' *dualism* introduced in the XVII century).

Gestures may have different degrees of sophistication and may vary in their nature (e.g., spontaneous/rehearsed, natural/conventional, and more), but they are a shared means of communication among human beings (i.e., they are socially functional), therefore descriptors can be expressed and understood by other human beings. But how can we establish meaningful connections between corporeal measurements (e.g., skin conductance, heart rate) and subjective perception of intentionality? The problem is that corporeal articulations and descriptors of physical reality rely on fundamentally different ontologies, and a mapping might not be straightforward.

Corporeal measurements are relevant to the field of SMC artworks preservation for several reasons, not all of which require the interpretation of the physical descriptors at a subjective level and therefore could be implemented quite easily. It is the case of Live Electronics compositions, where the performer has a certain control over the system behavior by means of his movements (not necessarily full-body). In order to keep record of a performance, monitoring the way in which the player moved is an important step in the process of reconstructing the behavior of the system. In a similar way, Interactive Installations may benefit from such detections, with the main difference that the subject observed is not the performer but a single user or a group of users.

It is clear that in this cases, quantitative data are sufficient and the only problem may consist in an effective way of representing those data for storage. Even without interpretation in terms of articulations and intentionality, observing users visiting an Installation, or more specifically *interacting* with it, may provide useful information about the quality of the design of the Installation (which might directly interest the artist for further modifications), and the users' overall response to the multimodal stimuli induced by the system. More generally, if in other words we consider Installations as a set of (partially) controlled environments, we can use them as a privileged point of view on some aspects of the human behavior. Installations define a semantic space [137] explored by the users basing on the cues designed by the artist, combined with their own curiosity, creativity, motivation to experiment and learn, that is out of their own personal attitude.

Conversely, should we succeed in drawing meaningful connections between physical descriptors and articulations, corporeal measurements would enable a revolutionary way of accessing and understanding aesthetic experiences, which are likely to be the ultimate reason why we engage with works of art. Nevertheless aesthetics remains an elusive phenomenon, extremely refractory to quantitative measurements and unambiguous descrip-

tions, and probably this is the reason why in spite of its current popularity in "cultural studies", it has little impact in modern music research (i.e., empirical, computational, brain science).
From the fruition viewpoint, behavioral information could be easily applied to Implicit Human-Centered Tagging (IHCT) ([138, 139]) in galleries and museums housing Interactive Installations, besides providing a powerful tool for archival and retrieval of SMC artworks repositories. *Visitors' profiling* is currently being applied to museographic projects [140] to increase the immersivity or the understanding of cultural contents by means of interactive technologies, toward an active fruition of cultural heritage.

Automation – People are currently involved in every step of the preservation process: curation, selection, description, and management of digital collections require personnel and are very labor intensive. Even if storage costs are minimal, archives have recently expressed the concern that long-term digital archiving might not be affordable unless acquisition, description, data management, and access controls are highly automated [73].
Unfortunately automation in the preservation field is scarcely feasible for what concerns all those tasks that involve decision making combined with high-level cultural training, e.g., evaluating the provenance of (the content of) a document, sorting the elements within a system designed for artistic and aesthetic purposes, and so on. The field of audio restoration provides a good analogy: most algorithms for noise removal are highly effective today, yet restoration is assigned to highly trained personnel. In other words, no machine available today can do the job of a human being when it comes to managing cultural contents. Consequently, in the next future, there are few chances that the first part of the preservation process (i.e., 1) evaluation of the state of preservation of the document with subsequent actions of physical restoration, 2) philological analysis, 3) re-mediation and 4) high-level description) will be automated. Nevertheless, once the documents have been organized and stored in a digital format, 1) low-level description, 2) periodical data validation and 3) data refresh/migration from aging media may be automated.

12.10 Conclusions

The main problems related to the preservation of Interactive Multimedia Installations were introduced. Effective methodologies for preservation are an urgent matter because the works' life expectancy is alarmingly short compared to other cultural materials. To date, acceptable methods to represent and preserve complex digital entities that contain combinations of text, data, images, audio, and video, and that require specific software applications, do not meet the requirements for an effective preservation of Interactive Multimedia Installations. Moreover, current cataloguing standards provide that documents are classified by homogeneous typologies and, consequently, that Interactive Multimedia Installations are dismembered for storage, which may result in the impossibility to reassemble the work as a whole unless protocols of interoperability among repositories are defined. The author presented the core of a possible solution, consisting in a multilayered approach, able to support different goals for preservation (documenting, academic studies, ...) and re-installation (new exhibitions, interpretations, tributes, ...).

Part VI

Conclusions

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Conclusions

This work presented the authors original research in the field of Cultural Heritage preservation. In particular, sound archives and interactive multimedia installations have been considered. The purpose of the work was to show that the contribution of different areas of knowledge is necessary for the definition of a scientific methodology for preservation. The proposed methodology has been described in Chapter 4. A computer science based approach to quality control has been the guiding thread of the work. The main areas covered span from computer science to materials science and chemistry. Within the field of preservation, specific expertise can be developed in the following directions:

• **hardware/software equipment**: archives have been growing used to computer based applications for a long time, mainly for administrative purposes and for managing their catalogues. The activities involved in preservation have a high technological component, and they call for specific tools, not only in terms of original [open-source] software, but also of hardware in a broad sense: from new devices for the physical restoration of audio carriers, to customized recorders (e.g., able to support non-standard speeds). In fact, this direction could be further divided into two fields of expertise (physical equipment and software tools), but they are rather presented together because the working environment for preservation is conceived as a *system* in the author's view, and she believes that every piece of the final HW/SW equipment should be "aware" of the others and be realized accordingly. The competences necessary to expand the knowledge in this direction are computer science, archival science and audio preservation. Activities involve: the evaluation of the needs of an archive in terms of operative infrastructure, the definition of technical requirements in a highly collaborative approach, the documentation of the devices customizations with electrical schemes; etc. This topic has been addressed in Chapter 5 and in Chapter 6.

• **degradation of audio carriers**: the history of audio recording has produced a great variety of carriers and formats, each of which is characterized by a specific behavior when subject to varying environmental conditions and mainly to the consequences that come with aging. Appendix B and Appendix C give an idea of entity of this variety, and it expresses the need to document the signs of degradation thoroughly, even more for new generations that are not familiar with obsolete carriers and must be trained to handle them properly during the preservation process. The competences necessary to specialize in this direction are in history of recording technology, in materials science and in chemistry. There is much room for further studies on novel recovery methods for degraded carriers, for diagnostic tools, and also for the expansion of the list of signs and symptoms proposed in Appendix B, aiming at obtaining a comprehensive reference manual. This topic has been addressed from Chapter 7 to Chapter 10.

• **storage environments**: competences in archival science, materials science and chemistry are required. Activities involve: the planning of storage environment meeting adequate requirements for the safeguard of different types of audio media at varying conditions (resources, objectives, access frequency, etc.); the definition of disaster recovery strategies; the definition of safety measures that the archival staff must be aware of; etc. Further study may include experiments on behavior of audio documents at varying conditions (temperature, relative humidity, exposure to artificial/natural light), ... This topic has been addressed in Chapter 3.

• **evaluation of sound collections**: assessing the condition of a sound collection is a preliminary step of paramount important, because the preservation schedule mostly depends on it. The reasons why effective [non-destructive] evaluation tools are not yet available are that: (i) sound collections are extremely diversified; (ii) the objectives of preservation programmes are different and they influence the approach to the documents; (iii) the research on the effects of aging and of environmental conditions on audio documents is recent (see 'degradation of audio carriers' on this list). The need for methodological and operative tools is a hot topic in preservation (for example see [34,79,85]). The competences necessary to advance in this direction are at least archival science, materials science, preservation and history of sound recording techniques. This topic has been addressed in Appendix C.

• **cultural awareness**: as has been said in Chapter 3, indirect passive preservation consists of different preventative strategies with an indirect influence on the audio documents, including political/legislative actions for the safeguard of cultural heritage. According to this broad meaning of passive preservation, the activities involved in this direction are potentially unlimited, and essentially regard the promotion of the cultural awareness about cultural heritage. First, it is important that archival institutions internalize the rationale behind a scientific methodology applied to the safeguard of their materials, and secondly it is important that the public is aware of the aspects of preservation and that it accesses the documents with a critical approach (especially with relation to authoritativeness and reliability). The competences required in this direction span from archival science to communication strategies, but can be extended to many others including the systematic production of scientific dissemination (publications and lectures). The author's publications in multidisciplinary journals and conferences, some of which are reported in Appendix G, and the seminars/courses she has held parallel to the Ph.D. (at other Universities, like the University of Pisa, and at Music Conservatories) were moving in this direction.

This brief list shows that the area of audio documents preservation is not limited to the A/D conversion of the audio signal, as is often thought, and that there is room for new professional figures with specific expertise in this field. These figures are highly requested on the labor market, especially as more archives face the problem of documents failure due to aging, in the analogue as well as in the digital domain.

The operational protocol proposed in this work embodies the funding principles of the methodology for the preservation of audio documents exposed in Chapter 4:

- "accurate, verifiable, and objective" procedures cite[p. 35]storm80a
- measurements based on an ideally objective knowledge
- modern playback equipment, fully compliant with the format specific parameters of the recordings
- a careful documentation of all measures employed and of each manipulation applied (ensure reversibility) [58].

The methodology has been applied and perfected in research projects involving sound archives of musical (operatic) and of linguistics interest. The research project in which the author has collaborated have been described in Chapter 11.
The software tools presented in this work are characterized by a development that has been conducted with a trans-disciplinary approach, achieved by means of a tight and prolonged collaboration of the researchers in computer science and engineering with the experts of different scientific disciplines (musicologists, linguists, archivists, ...). This collaboration created the conditions for many opportunities of mutual confrontation and for a better modeling of the requirements, for a deeper understanding of the others' terminology and methodology, ... This approach was mainly reflected by:

1. the design of the database (reconciliation of different approaches to preservation, information modeling);
2. the formalization of the workflow (accordance between the theory of preservation and laboratory practice): sustainability and processing timing, assistance to re-mediation sessions and cataloguing on parallel workstations.

Besides improving the quality of the laboratory work, the results obtained prove that the introduction of original software tools in the process of active preservation of audio documents opens the way for an effective answer to the methodological questions of reliability with relation to the recordings as documentary sources, also clarifying the concept of “faithfulness” to the original and situating it in the precise limitations of the audio equipment technology.

The architecture of the software system reflects the founding principles of the methodology applied to the active preservation audio documents. Assuming that those principles are agreed upon and respected, the system can be adapted to the needs of other archives at low cost – a desirable objective that would help correct preservation practices to spread, encouraged by the use of adequate and freely shared tools.

Part VII

APPENDIX

A

PreservationPanel and CataloguingPanel menu functions

This Chapter includes part of the software documentation produced for PreservationPanel and CataloguingPanel during the research projects described in Chapter 11. The style is intentionally half-way between a user manual and a technical documentation, as required by the research consortia of the projects.

The interfaces of PreservationPanel and CataloguingPanel share two bar menus: PSKit and Information . This chapter describes the functions in each menu.

A.1 PSKit menu

A.1.1 About

Displays the credits of the program in a floating window, as in Figure A.1).

A.1.2 Database connection

The database connection is one of the first things that both PreservationPanel and CataloguingPanel test at launch. It does not make sense for them to operate without a database connection, since their paramount features are data ingestion and retrieval: that is why in case of a failed connection the programs print an error message and exit with code 1.
The data required for the database connection are:
- database URL
- name for the database user
- password for the database user
- suitable driver

The database URL, the user name and the password are in the configuration file `pskit.conf`. The driver name is hard coded in the class `Len.java` (`com.mysql.jdbc.Driver`) and its location needs to be specified in the launch command or in an environment variable.

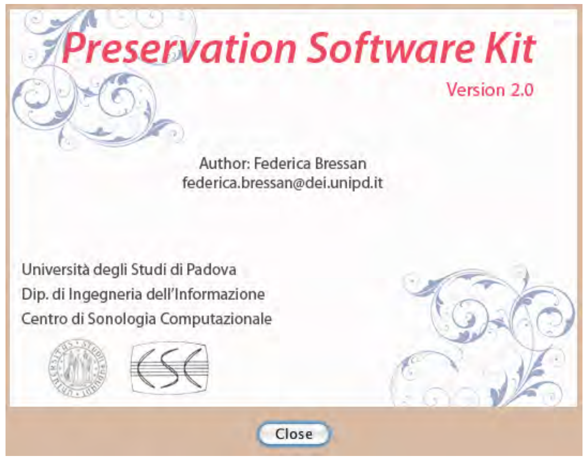


Fig. A.1: Credits of the program, displayed when the `PSKit` → `about` menu is selected.

Fig. A.2: The window shows the current database connection data, that can be changed at runtime: this operation can cause a new connection to be established successfully or the program to terminate with a code other than zero.

A.1.2.1 Changing the database connection at runtime

The database connection can be changed at runtime, using the function in the menu `PSKit` → `Database` (shortcut cmd+D). A pop-up window appears and shows the current connection data (Figure A.2). If new connection data are entered and the OK button is pressed, the program:

1. warns the user that the current connection will be closed and that unsaved data will be lost
2. if the user wishes to continue, closes the current database connection according to the protocol (the method `db.close` is invoked from the class `Cueri`)
3. tries to establish the new connection
4. (a) if the connection is successful, the program updates the variables in the class `Len.java` and the variable with the text of the configuration file (`DatabaseConnection.conf_file`), and it reloads the interface with the new data; (b) if the connection fails, it restores the previous variables values, it prints an error message and exits with code 1.

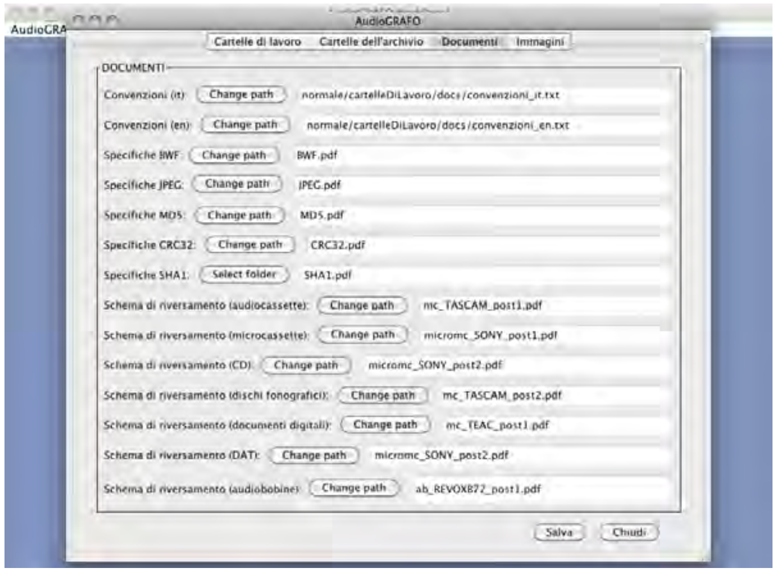


Fig. A.3: One of the panels of the menu for the management of the paths to the files and folders necessary during the execution of PreservationPanel and CataloguingPanel .

A.1.3 Settings of the paths to the files and folders

For a correct functioning, PreservationPanel and CataloguingPanel require the access to some files and folders on the user's local machine during execution. They never require the access to paths that are outside the main PSKit folder containing the Java classes: they do not reach the user's home, the root folder or other potentially private or delicate locations, nor try to modify any parameter/setting of the operating system. In order to increase the flexibility and the portability of the programs, these paths have been parametrized. The strings corresponding to the paths are memorized in the database table `path`, and they are associated to the workstations by means of the key specified in the `key.txt` file. See Section A.1.2 for the retrieval of this data at program launch and for the handling of exceptions.

A.1.3.1 Editing the paths at runtime

During the working session, PreservationPanel and CataloguingPanel allow to edit one or more paths by means of the menu item `PSKit` → `Paths and folders` (*shortcut*: crtl+I for Windows and cmd+I for OS X). Figure A.3 shows one of the panels to make the changes. When the `Save` button is pressed, the data are saved in the database table `path`.

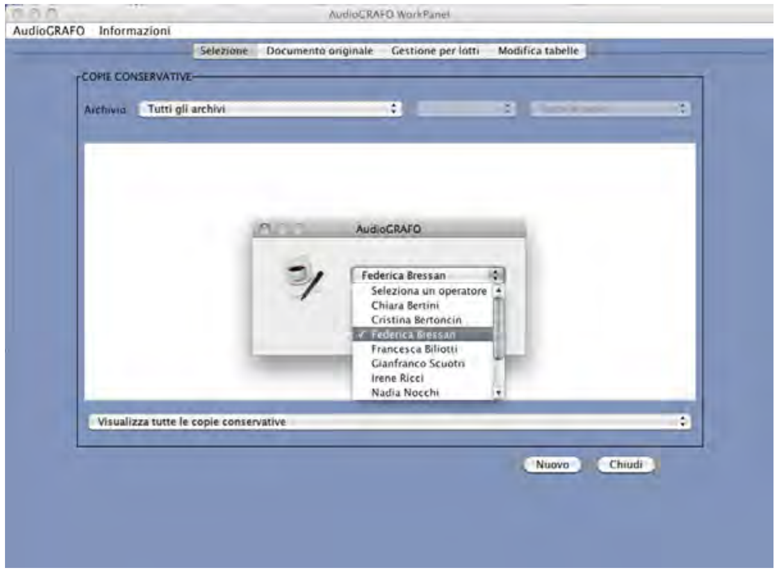


Fig. A.4: Menu for the selection of the current working session.

A.1.4 Selection of the operator responsible for the working session

All of the operations performed during a working session of PreservationPanel or CataloguingPanel are associated to an operator, who is considered the responsible for the operations. The operator's identifying code is memorized in the database (e.g., in the table `cc` when a new preservation copy is created, or in the table `unita` when a new ARMA is created). The name of the operator responsible for the creation of a preservation copy is reported in the descriptive sheet accompanying the copy. The selection of the operator is performed by means of the menu item `PSKit` $\rightarrow$ `Operator` (*shortcut*: ctrl+O for Windows and cmd+O for OS X).

The selection of the user associated to the current working session does not only allow to attribute the responsibility of the creation of a document, but allows to filter the documents presented to the user in the welcome panels of PreservationPanel and CataloguingPanel . For safety reasons, each operator onyl visualizes his/her own documents, which brings some additional advantages in the management of the working process. However, the users can decide to visualize the documents of a colleague, modifying the selection in the menu `PSKit` $\rightarrow$ `Operator`. This option gives a user the chance to edit a colleague's document, which has advantages and disadvantages, but on the other hand it also gives the possibility to perform comparisons between one's work and the others', which has advantages and is desirable considering the complexity of the material involved.

A.1.5 Audio

PreservationPanel is able to provide the user with an audio feedback when some actions are performed, such as in the Batch processing tab. The audio feedback is associated to the language option and it changes accordingly (messages are spoken in different languages). Some audio messages are useful during the working session, because they notify the user that a task is complete (in particular for long tasks such as metadata extraction or data transfer, during which the user usually switches to other applications and is not aware of what PreservationPanel is doing); other audio messages are not useful in this sense, but for example they greet the user at the beginning of the working session with a "welcome" sound.

The audio feature can be turned on and off with the function in the menu `PSKit` → `Audio`. Its status is displayed with a checkbox next to the menu item: checked means on, unchecked means off. It can be changed at runtime. When it is changed, (1) the boolean variable that tells PreservationPanel wether to play a sound or not (in the class `JFederica`) is updated, and (2) the variable with the text of the configuration file (`DatabaseConnection.conf_file`) is updated.

The status of the audio feature is also saved in the `pskit.conf` file, that is dynamically updated by PreservationPanel during the working session according to the menu checkbox selection.

A.1.6 Language

PreservationPanel and CataloguingPanel support multilingual working sessions. Currently the supported languages are Italian and English, but the strategy by which multilingualism is implemented makes it easy to add new languages in the future. The default language is Italian. The language can be (1) selected at launch with the option '-l' appended to the command; or (2) changed at runtime with the function in the menu `PSKit` → `Language`.

When the language is changed at runtime, the user is warned that the current session will be closed because changing the language (currently) requires that the program is restarted. The user is also warned that consequently all unsaved data will be lost. If the user wishes to proceed, the program closes the current session and starts a new one, displaying the box with the language selection (Figure A.5).

A.2 Information menu

A.2.1 Archive codes

Displays the complete list of the archives, of the archives sections and subsections present in the database, associated with their identifying 5-digits

Fig. A.5: Window for the language selection displayed at the beginning of a new session if the option '-l' is appended to the launch command, or if the function in the `PSKit` → `Language` menu is selected.

code. The data is displayed in a floating window and it is retrieved each time the menu item 'Archive codes' is selected, therefore the list is always up to date.

A.2.2 Conventions

Displays the list of conventions adopted by PreservationPanel and by CataloguingPanel in a floating window. The number of conventions is intentionally restrained. They currently regard the distinction between the selection items 'none' or 'unknown' for PreservationPanel , and the date format and the field for the bibliography of an ARMA for CataloguingPanel .

B

Symptoms and signs of degradation of audio carriers

This document provides a complete list of the symptoms and of the signs of degradation that can apply to each type of audio carrier. The types considered are: open-reel tape, Compact Cassette, Compact Disc, Digital Audio Tape, digital non-audio carrier, phonographic disc, Microcassette, MiniDisc. The list of symptoms and signs of degradation was obtained crossing multiple publications:

(A) Sueiro M. (2008), "AVDb - Audio and Moving Image Survey Tool", Columbia University Libraries, New York, NY.
(B) IASA (1999), "IASA Cataloguing Rules. Appendix C: Terms for describing the physical condition of sound recordings", IASA Editorial Group, M. Miliano edit.[1]
(C) Casey M. (2008), "FACET (Field Audio Collection Evaluation Tool) – Format Characteristics and Preservation Problems Version 1.0", Indiana University, IN.
(D) NFSA (2007) "Technical Glossary of Common Audiovisual Terms", National Film and Sound Archive (NFSA), Canberra, Australia[2].

Only few symptoms and signs of degradation mentioned in the publications have not been retained. When the definitions were overlapping, mainly due to choices of terminology, they have been grouped. The author finds that the comparison among the definitions is useful and interesting, despite the fact that sometimes (A) refers to (B), and that (C) informs that some adaptations were made from (B) and from (D). The result is a comprehensive list, critically reconfigured in the light of the author's experience, suitable for a preservation that is sustainable for the types of archives considered in this study. The list will hopefully keep being perfected and enriched in the future.
Table B.1 summarizes the complete list of symptoms and of signs of degradation, with the indication of the type of carrier they apply.

[1] http://www.iasa-web.org/content/appendix-c-terms-describing-physical-condition-sound-recordings – last visited on February 4, 2013.
[2] http://nfsa.gov.au/preservation/glossary/ – last visited on December 10, 2012.

Table B.1: List of symptoms and of signs of degradation for each types of audio carrier. Key to abbreviations: AB = open-reel tape, CC = Compact Cassette, CD = Compact Disc, DAT = Digital Audio Tape, DF = digital non-audio carrier, PD = phonographic Disc, MCC = microcassette, MD = MiniDisc.

N.	Symptom/Damage	AB	CC	CD	DAT	DF	PD	MCC	MD
1.	Tape pack/Wind quality	✓	✓		✓			✓	
2.	Pack: Blocking	✓	✓		✓			✓	
3.	Pack: Leafing	✓	✓		✓			✓	
4.	Pack: Loose wind	✓	✓		✓			✓	
5.	Pack: Windowing	✓	✓		✓			✓	
6.	Pack: Spoking	✓	✓		✓			✓	
7.	Dirt, dust, oil	✓	✓	✓	✓	✓	✓	✓	✓
8.	Other particulates	✓	✓	✓	✓	✓	✓	✓	✓
9.	Liquid stains	✓	✓	✓	✓	✓	✓	✓	✓
10.	Splices	✓							
11.	Vinegar odor	✓							
12.	Mold	✓	✓	✓	✓	✓	✓	✓	✓
13.	Pests	✓	✓	✓	✓	✓	✓	✓	✓
14.	Other bio[logical contamination]	✓	✓	✓	✓	✓	✓	✓	✓
15.	Powder, crystals	✓	✓		✓			✓	
16.	Tears, breaks	✓	✓		✓			✓	
17.	Brittle, curling	✓							
18.	Folds, cinching	✓	✓		✓			✓	
19.	Cupping	✓	✓		✓			✓	
20.	Edge damage	✓	✓		✓			✓	
21.	Backcoat shedding	✓	✓		✓			✓	
22.	Magnetic coating shedding	✓	✓		✓			✓	
23.	SBS-SSS	✓	✓		✓			✓	
24.	SBS-UP	✓	✓		✓			✓	
25.	Bleeding	✓	✓		✓			✓	
26.	Curvature	✓	✓		✓			✓	
27.	Embossing	✓	✓		✓			✓	
28.	Layer adhesion	✓	✓		✓			✓	
29.	Kink/Wrinkle	✓	✓		✓			✓	
30.	Magnetic Losses	✓	✓		✓			✓	
31.	Manufacturing surface defect	✓	✓		✓			✓	
32.	Gummy deposit	✓	✓		✓			✓	
33.	Loose pad		✓		✓			✓	
34.	Damaged shell/housing		✓		✓			✓	✓
35.	Corrosion					✓	✓		
36.	Imprinting						✓		
37.	Chemical residue						✓		
38.	Discoloration			✓			✓		
39.	Waxy exudate						✓		

Continued on next page

Table B.1 – *Continued from previous page*

N.	**Symptom/Damage**	**AB**	**CC**	**CD**	**DAT**	**DF**	**PD**	**MCC**	**MD**
40.	Wear						✓		
41.	Scratches, gouges			✓		✓	✓		✓
42.	Cracks, chips			✓		✓	✓		✓
43.	Warp			✓		✓	✓		✓
44.	Crazing						✓		
45.	Peeling			✓			✓		
46.	Label damage			✓			✓		
47.	Centre damage or fault			✓			✓		
48.	Blister			✓			✓		
49.	Print-through	✓	✓		✓			✓	

The following Sections, one for each type of carrier, provide a definition of the symptoms and of the signs of degradation listed in Table B.1. The definitions were taken from the publications listed above, with some occasional note from the author. When no definition was given in the publications, the author suggested her own. (The capital letter associated to the definitions correspond to the publications in the above list. Letter F indicates the author's own notes and definitions.)
A remark about the Soft Binder Syndrome – Sticky Shed Syndrome (SBS-SSS) and the Soft Binder Syndrome – Unidentified Problems (SBS-UP). The author has chosen to adopt the reading of [84], according to which SSS is a particular case of SBS, a broader category including all tapes exhibiting "stickiness, shedding, and/or squealing" [84]. Tapes that respond to thermal treatment (the most common remedy for these symptoms) are classified as SBS-SSS. Tapes that show the same symptoms but do not respond to thermal treatment are classified as SBS-UP. See Chapter 7 of this work for the author's research on the matter.

B.1 Open-reel tapes

This Section presents the list of the definitions for the symptoms and for the signs of degradation that apply to open-reel tapes. The first six items form a group that refers to different aspects of the tape pack / wind quality. All other items are single.

1. **Tape pack/Wind quality**

   (D) The structure formed by, and comprised solely of, tape wound on a hub or spindle.

   (F) Overall evaluation of the tape pack / wind quality: see the descriptions in AppendixC for some examples.

2. **Blocking** [**Stepped Pack** according to the terminology in (C); **Pack slip** according to the terminology in (D); and **Leafing** according to the terminology in (A)]

(A) A condition where the tape pack is either wound or has fallen against one of the flanges of the tape reel instead of being suspended in the middle. This often leads to damaged edges from the tape scraping across the flange as it winds. If there are also popped strands, they may be severely bent.

(B) Whole blocks of adjacent layers of tape have shifted sideways relative to the rest of the tape pack. Usually the result of horizontal storage, transport or rough handling. Blocking can result in damage to the edges of the tape and localised stress where lateral movement has occurred.

(C) Many groups of misaligned layers that may look like ridges across the tape pack. This is sometimes called feathering or scatter wind. Individual layers that are misaligned are called popped strands.

(D) A lateral slip of selected tape windings causing high or low spots (when viewed with tape reel laying flat on one side) in an otherwise smooth tape pack.

Pack slip can cause subsequent edge damage when the tape is played, as it will unwind unevenly and may make contact with the tape reel flange.

3. **Leafing** [**Popped strands** according to the terminology in (C)]

(B) Single layers of tape are protruding from the tape pack. Usually this is the result of spooling too quickly for the tension/alignment of the transport, and for the characteristics of the tape, causing momentary entrapment of air between layers. Leafing may occur individually or in groups, and exposes tape edges to potential damage.

(C) The tape pack may have individual layers of tape misaligned with each other so that some layers stick up from the others. These misaligned layers are often called popped strands. Many groups of misaligned layers indicate a condition that is called either a stepped pack or feathering. Sometimes this is the result of winding the tape on fast forward or rewind and can be corrected by playing from beginning to end on play without stopping.

(D) Protruding turns or ribs of audio tape sticking out from the pack. This is caused by high speed spooling and can result in damage to the tape.

4. **Loose wind**

(B) Individual layers of tape are loosely wound on the tape pack. This is due to lack of fastening of the end of the tape. It may cause slippage of the tape pack on playing, and lead to cinching.

5. **Windowing**

(A) Windowing refers to "deformation of the layers of tape within the tape pack to the extent where light can be seen through it". Also called "windows" or "windage holes".

(B) Deformation of the layers of tape within the tape pack to the extent where light can be seen through it.

(C) A gap in the tape pack caused by obvious pack deformation. You can actually see through the pack, like looking through a window, because of the separation of tape layers.

(D) Deformation of the tape pack to the extent that light can be seen through spaces or 'windows between the tape layers.

6. **Spoking**

(A) "Radial lines or spokes appearing in a tape pack, caused by adjacent layers of tape suffering similar deformation(s)." (IASA) This indicates severe physical deformation.

(B) Radial lines or spokes appearing in a tape pack, caused by adjacent layers of tape suffering similar deformation(s).

(C) Usually the tape pack has uniform, circular layers. Sometimes the circle is not uniform and the layers curve non-uniformly, looking a bit like waves. It also may appear as if there are kinks in the circle. There will often be radial lines, or a pattern radiating out from the hub, known as spokes. Excessive tension leads to spoking which results from the outer layers in the pack compressing the inner layers so that the turns develop a small kink instead of a smooth curve. These kinks align radially and look like a spoke when you look through the flange from the edge of the tape.

(D) A shrinkage-induced effect that causes a reel tape to form regular angles rather than a circular wrap.

7. **Dirt, dust, oil**

(C) The presence of dirt or other foreign matter on or in the tape pack. A significant amount of foreign matter may cause drop-outs or lead to spacing loss from poor tape-to-head contact.

8. **Other particulates**

(A) Tape reels exhibiting other materials that cannot quite be described as dirt, dust, oil, or foreign objects. The distinction can be vague.

9. **Liquid stains**

(F)

10. **Splices**

(A) Splices are often visible as white-colored lines along the tape pack, although they can be quite difficult to detect.

(B) Small piece of special adhesive tape used to join two pieces of recorded material to form a single piece. Case (1) Dry splice: Adhesive on splice is dry, or the splice is brittle. It results in drop-out of sound at the splice and on the adjacent tape layers where the adhesive has left a deposit. A dry splice may come away during playback. Case (2) Sticky splice: Adhesive from the splice sticks adjacent layers of tape together and can cause information drop-outs where the adhesive has left a deposit.

(D) Tape splices are recognized by the ends being butted together (sometimes referred to as butt splice), the whole splice is held together across its width by adhesive tape. They are usually noticeable[, in case] of breakage or as part of the editing process. Tape splices do not overlap, they are merely 'butted together.

11. **Vinegar odor**

(A) Tape reel exhibiting a "vinegar" or "lemony" odor, which is indicative of advanced chemical breakdown of acetate.

(B) Technically, de-acetylation of cellulose acetate substrates which may produce acetic acid as a by-product, and gives rise to the characteristic vinegar odor. May be accompanied by brown or white crystals on the tape pack.

(C) Vinegar Syndrome affects acetate-based tape only – polyester, PVC, and paper tape do not suffer from this problem. The presence of acetic acid as part of the degradation process gives a definite vinegar smell to tapes with this problem, although the ability to differentiate by smell is highly individual and somewhat subjective. In some cases there is no doubt: if you notice a strong vinegar smell immediately after opening a tape box, it is likely that [the syndrome] is present. When the box has been open for a few seconds the acetic acid dissipates and the smell is no longer as perceivable. Note that VS is infectious, and tapes with this condition must be kept away from the rest of the collection.

(D) Vinegar syndrome is a term used to describe the chemical reaction that goes on during the deterioration of cellulose triacetate film support.

When cellulose triacetate begins to decompose, 'deacetylation occurs and the acetate ion reacts with moisture to form acetic acid, producing a vinegar odour when the can is opened.

The presence of the odour does not mean the film has degraded, but rather that the reaction is taking place. However, the reaction is continuous, and once started, it cannot be stopped or reversed. In fact, the reaction is autocatalytic, which means it feeds on itself and speeds up over time.

12. **Mold**

(A) "Mold usually takes the form of white or grey patches on the surface, with a characteristic [fuzzy] structure visible under low-power magnification." (IASA).

(B) Usually takes the form of white or grey patches on the surface, with a characteristic structure visible under low-power magnification. Exacerbated by high humidity or contact with organic material.

(C) Look for patterned, fuzzy, thread-like, or hairy-looking growths on the surface of the tape pack. Typically, these growths are white in color on open reel tape although they may also be black, brown, or mustard-colored. Try to distinguish mold from other types of visible contamination such as dirt, which may look similar but usually does not appear as fuzzy or patterned.

(D) Mould on tape usually takes the form of white patches on the edge of the tape pack and is caused by dampness or contact with organic material.

13. **Pests**

(A) evidence of pest contamination: vermin, insects, etc.

14. **Other bio[logical contamination]**

(A) other types of biological contamination (e.g. bacteria).

15. **Powder, crystals**

(A) tape reels exhibiting crystalline residue on the tape itself. Albeit rare, this is a sign of advanced chemical degradation.

16. **Tears, breaks**

(F)

17. **Brittle, curling**

(A) Tape reels that breaks easily, or with advanced "corkscrew" deformation.

(C) The transverse warping of magnetic tape, sometimes called cupping, most commonly seen on acetate-based tapes. This can cause poor contact between the tape and playback head resulting in signal loss. It may manifest as edge curling or the entire tape may exhibit cupping.

18. **Folds, cinching**

(A) Cinching refers to "the rippling of tape layers when bunched up from pack slippage or uneven tension. Cinching can permanently deform the substrate, resulting in rapid, cyclical fluctuations of sound level, as the creased tape passes across the playback heads".

(C) [Cinching:] The wrinkling, or folding over, of tape on itself in a loose tape pack. This may occur when a loose tape pack is stopped suddenly, causing outer tape layers to slip past inner layers, which in turn causes a buckling of tape in the region of the slip.

(D) The wrinkling, or folding over, of audio tape on itself in a loose tape pack.

Normally occurs when a loose tape pack is stopped suddenly, causing outer tape layers to slip past inner layers, which in turn causes a buckling of tape in the region of slip. Results in large dropouts or high error rates.

19. **Cupping**

(A) Cupping refers to the curving of the tape perpendicularly to the tape path so that, in extreme cases, the tape adopts the shape of a half pipe.

20. **Edge damage**

(A) Edge damage refers to wear or deformations along the edges of the tape, often seen as small ripples along the edge of the tape ("scouring").

(D) When the edge of an audio tape is not straight or flat.

(F) puo' essere la conseguenza di un cattivo avvolgimento. –: li mettiamo in relazione?

21. **Backcoat shedding**

(A) Shedding can occur in the magnetic or back coating side of the tape; it refers to tape particles falling off the base, and it is a very serious condition

(B) Backcoat particles coming away from the substrate and accumulating on surfaces in contact with the back of the tape. Apart from the loss of functionality of the backcoat itself, loose debris can deposit on the playing surface of the adjacent layer of the tape, impairing playback quality (as opposed to magnetic coating shedding or magnetic coating lift).

(C) A failure of the binder/oxide (magnetic pigment) coating to adhere to the substrate film, resulting in the delamination – the peeling away – of one from the other.

22. **Magnetic coating shedding**

(B) Opposite of backcoat shedding. Also called magnetic coating lift.

23. **SBS-SSS** [**Sticky tape** according to the terminology in (D)]

(C) A tape that sticks to the guides and heads of the tape machine, squeals, and often exhibits massive oxide and backing shed. [It] appears to occur only on backcoated tapes. [Includes Oxide (Magnetic Pigment) Loss:] Oxide flakes or powder (brown colored if the tape oxide coating is brown) on any of the points along the tape path where the oxide part of the tape makes contact with the guides, heads or rubber parts of the tape machine's transport system.

(D) Audio and video tape characterized by a soft, gummy, or tacky tape surface. This tape has experienced a significant level of hydrolysis so that the magnetic coating is softer than normal. The tape is characterized by resinous or oily deposits on the surface of the magnetic tape.

24. **SBS-UP**

(C) [Tapes that] squeal and stick but show little or no oxide shedding, do not have a back coating, and do not respond to baking.

25. **Bleeding**

(B) Inks or dyes on the surface or writing on the backcoat, seeping through the tape layer.

26. **Curvature**

(B) Tape has a tendency to stay rolled up. Modern PET based tapes have more of a tendency to 'remember' the shape in which they are packed and to flow or deform plastically in response to pressures and stresses within the pack.

27. **Embossing**

(B) Physical damage to a tape caused by foreign matter that has become embedded within the tape pack, or by deformities in the hub.

(D) Physical damage to the oxide of a tape caused by foreign matter, usually dust, that has become embedded within the audio tape pack.

28. **Interlayer adhesion** [**Blocking**[3], and/or **Pinning**, according to the terminology in (C) and in (D)]

(B) The surface of one layer of tape is sticking to the back of the succeeding layer.

(C) The layer-to-layer adhesion or sticking together of adjacent layers of tape, usually due to long-term storage under conditions of high relative humidity or temperature, deterioration of the binder, or excessive tape pack stresses. The term pinning is also used to describe small, limited areas where there is adhesion. [This sign of deterioration] may result in delamination, depending on how the layers are separated. Sometimes layers will appear to adhere because of static electricity which can be discharged, solving the problem.

(D) The sticking together or adhesion of successive windings in a tape pack or film reel. Blocking can result from:
a) deterioration of the binder
b) storage of tape reels at high temperatures, and/or
c) excessive tape pack stresses.
d) storage of gelatin emulsion film at high relative humidity and tight wind tension
e) adhesion from film decomposition products

(F) Si puo' manifestare, ma non necessariamente, in concomitanza con SBS-SSS o SBS-UP o giunte logorate.

29. **Kink/Wrinkle**

(B) Kink: a crease on a layer of tape. Wrinkle: multiple creases in the tape.

(D) Kink: a crease on a layer of tape. Wrinkle: multiple creases in tape, usually caused by poor threading.

[3] The term used by (C) and by (D) in this case coincides with another syndrome listed in this study, that refers to the tape pack / wind quality. Be careful not to confuse them.

30. **Magnetic losses**

(B) The tape has been partially or fully demagnetised or suffered from a loss of signal due to deterioration of the magnetic coating. (E.g. a section of the tape has been accidentally exposed to a bulk eraser, or magnetic particles may have physically deteriorated, resulting in a weaker signal).

31. **Manufacturing surface defect**

(B) Includes partial lack of coating, foreign inclusions, variations in width, edge finish or thickness, etc.

(D) Only applies to raw stock. Includes partial lack of oxide, variations in width or thickness etc.

32. **Print-through**

(D) The condition where low frequency signals on one tape winding imprint themselves on the immediately adjacent tape windings.

It is most noticeable on audio tapes where a ghost of the recording can be heard slightly before the playback of the actual recording.

33. **Gummy deposit**

(B) Glue-like substance on the tape. It accumulates on the heads and guides of the playback machine when the tape is played.

(D) Glue-like substance that accumulates on heads and guides of players when tape is played.

Infine, i sintomi seguenti a mio avviso sono di carattere secondario, ovvero non si manifestano per se ma si accompagnano ad altri sintomi (SBS-SSS o SBS-UP), quindi userei i termini inglesi per le descrizioni:
Squealing: High pitched noise caused by bowing action of tape on heads. May result from hydrolysis and/or loss of lubricants. May be accompanied bystiction.
Stiction: Tape sticks to heads and guides on the playback machine, and will not spool or play.

B.2 Compact Cassettes, Microcassettes and Digital Audio Tapes

This Section presents the list of the definitions for the symptoms and for the signs of degradation shared by Compact Cassettes, Microcassettes and Digital Audio Tapes. The first six items form a group that refers to different aspects of the tape pack / wind quality. All other items are single.

1. **Tape pack/Wind quality**

   Definition by (D): The structure formed by, and comprised solely of, tape wound on a hub or spindle.

   (F) valutazione generale dellavvolgimento e della superificie formata delle spire, v. metro di valutazione per esempi

2. **Blocking** [**Stepped Pack** according to the terminology in (C), and **Pack slip** according to the terminology in (D)]

   (B) Whole blocks of adjacent layers of tape have shifted sideways relative to the rest of the tape pack. Usually the result of horizontal storage, transport or rough handling. Blocking can result in damage to the edges of the tape and localised stress where lateral movement has occurred.

   (C) Many groups of misaligned layers that may look like ridges across the tape pack. This is sometimes called feathering or scatter wind. Individual layers that are misaligned are called popped strands.

   (D) A lateral slip of selected tape windings causing high or low spots (when viewed with tape reel laying flat on one side) in an otherwise smooth tape pack.

   Pack slip can cause subsequent edge damage when the tape is played.

3. **Leafing**

   (B) Single layers of tape are protruding from the tape pack. Usually this is the result of spooling too quickly for the tension/alignment of the transport, and for the characteristics of the tape, causing momentary entrapment of air between layers. Leafing may occur individually or in groups, and exposes tape edges to potential damage.

   (D) Protruding turns or ribs of audio tape sticking out from the pack.

4. **Loose wind**

(B) Individual layers of tape are loosely wound on the tape pack. This is due to lack of fastening of the end of the tape. It may cause slippage of the tape pack on playing, and lead to cinching.

5. **Windowing**

(A) Windowing refers to "deformation of the layers of tape within the tape pack to the extent where light can be seen through it".

(B) Deformation of the layers of tape within the tape pack to the extent where light can be seen through it.

6. **Spoking**

(A) "Radial lines or spokes appearing in a tape pack, caused by adjacent layers of tape suffering similar deformation(s)." (IASA) This indicates severe physical deformation.

(B) Radial lines or spokes appearing in a tape pack, caused by adjacent layers of tape suffering similar deformation(s).

(C) Usually the tape pack has uniform, circular layers. Sometimes the circle is not uniform and the layers curve non-uniformly, looking a bit like waves. It also may appear as if there are kinks in the circle. There will often be radial lines, or a pattern radiating out from the hub, known as spokes. Excessive tension leads to spoking which results from the outer layers in the pack compressing the inner layers so that the turns develop a small kink instead of a smooth curve. These kinks align radially and look like a spoke when you look through the flange from the edge of the tape.

(D) A shrinkage-induced effect that causes a reel tape to form regular angles rather than a circular wrap.

7. **Dirt, dust, oil**

(A) Cassettes exhibiting dirt, dust or oil, particularly inside the shell.

(C) The presence of dirt or other foreign matter on or in the tape pack. A significant amount of foreign matter may cause drop-outs or lead to spacing loss from poor tape-to-head contact.

8. **Other particulates**

(A) Cassettes exhibiting other materials that cannot quite be described as dirt, dust, oil, or foreign objects. The distinction can be vague.

9. **Liquid stains**

(F)

10. **Mold**

(A) "Mold usually takes the form of white or grey patches on the surface, with a characteristic [fuzzy] structure visible under low-power magnification." (IASA).

(B) Usually takes the form of white or grey patches on the surface, with a characteristic structure visible under low-power magnification. Exacerbated by high humidity or contact with organic material.

(C) Look for patterned, fuzzy, thread-like, or hairy-looking growths on the surface of the tape pack. Typically, these growths are white in color although they may also be black, brown, or mustard-colored. Try to distinguish mold from other types of visible contamination such as dirt, which may look similar but is usually does not appear as fuzzy or patterned.

(D) Mould on tape usually takes the form of white patches on the edge of the tape pack and is caused by dampness or contact with organic material.

11. **Pests**

(A) evidence of pest contamination: vermin, insects, etc.

12. **Other bio**[**logical contamination**]

(A) other types of biological contamination (e.g. bacteria).

13. **Powder, crystals**

(A) Cassettes exhibiting crystalline residue on the tape itself. Albeit rare, this is a sign of advanced chemical degradation.

14. **Tears, breaks**

(F)

15. **Folds, cinching**

(A) Cinching refers to “the rippling of tape layers when bunched up from pack slippage or uneven tension. Cinching can permanently deform the substrate, resulting in rapid, cyclical fluctuations of sound level, as the creased tape passes across the playback heads”.

(D) The wrinkling, or folding over, of audio tape on itself in a loose tape pack.

Normally occurs when a loose tape pack is stopped suddenly, causing outer tape layers to slip past inner layers, which in turn causes a buckling of tape in the region of slip. Results in large dropouts or high error rates.

16. **Cupping**

(A) Cupping refers to the curving of the tape perpendicularly to the tape path so that, in extreme cases, the tape adopts the shape of a half pipe. This is will usually only happen when a cassette has not been rewound all the way.

17. **Edge damage**

(A) Fairly uncommon in cassettes, edge damage refers to wear or deformations along the edges of the tape, often seen as minuscule ripples along the edge of the tape (“scouring”).

(D) When the edge of an audio tape is not straight or flat.

18. **Backcoat shedding**

(A) Shedding can occur in the magnetic or back coating side of the tape; it refers to tape particles falling off the base, and it is a very serious condition.

(B) Backcoat particles coming away from the substrate and accumulating on surfaces in contact with the back of the tape. Apart from the loss of functionality of the backcoat itself, loose debris can deposit on the playing surface of the adjacent layer of the tape, impairing playback quality (as opposed to magnetic coating shedding or magnetic coating lift).

19. **Magnetic coating shedding**

(B) Opposite of backcoat shedding. Also called magnetic coating lift.

20. **SBS-SSS** [**Sticky tape** according to the terminology in (D)]

(C) [Tapes that] exhibit sticking, squealing, and abnormal shedding. [Includes Oxide Loss:] Oxide flakes or powder (brown colored if the tape oxide coating is brown) on any of the points along the tape path where the oxide part of the tape makes contact with the guides, heads or rubber parts of the tape machine's transport system.

(D) Audio and video tape characterized by a soft, gummy, or tacky tape surface. This tape has experienced a significant level of hydrolysis so that the magnetic coating is softer than normal. The tape is characterized by resinous or oily deposits on the surface of the magnetic tape.

21. **SBS-UP**

(D) [Tapes that] squeal and stick but show little or no oxide shedding, do not have a back coating, and do not respond to baking.

22. **Bleeding**

(B) Inks or dyes on the surface or writing on the backcoat, seeping through the tape layer.

23. **Curvature**

(B) Tape has a tendency to stay rolled up. Modern PET based tapes have more of a tendency to 'remember' the shape in which they are packed and to flow or deform plastically in response to pressures and stresses within the pack.

24. **Embossing**

(B) Physical damage to a tape caused by foreign matter that has become embedded within the tape pack, or by deformities in the hub.

(D) Physical damage to the oxide of a tape caused by foreign matter, usually dust, that has become embedded within the audio tape pack.

25. **Interlayer adhesion** [**Blocking**[4], and/or **Pinning**, according to the terminology in (C) and in (D)]

(B) The surface of one layer of tape is sticking to the back of the succeeding layer.

[4] The term used by (C) and by (D) in this case coincides with another syndrome listed in this study, that refers to the tape pack / wind quality. Be careful not to confuse them.

(C) The layer-to-layer adhesion or sticking together of adjacent layers of tape, usually due to long-term storage under conditions of high relative humidity or temperature, deterioration of the binder, or excessive tape pack stresses. The term pinning is also used to describe small, limited areas where there is adhesion. [This sign of deterioration] may result in delamination, depending on how the layers are separated. Sometimes layers will appear to adhere because of static electricity which can be discharged, solving the problem.

(D) The sticking together or adhesion of successive windings in a tape pack or film reel. Blocking can result from:

a) deterioration of the binder
b) storage of tape reels at high temperatures, and/or
c) excessive tape pack stresses.
d) storage of gelatin emulsion film at high relative humidity and tight wind tension
e) adhesion from film decomposition products

(F) Si pu manifestare, ma non necessariamente, in concomitanza con SBS-SSS o SBS-UP o giunte logorate.

26. **Kink/Wrinkle**

(B) Kink: a crease on a layer of tape. Wrinkle: multiple creases in the tape.

(D) Kink: a crease on a layer of tape. Wrinkle: multiple creases in tape, usually caused by poor threading.

27. **Magnetic losses**

(B) The tape has been partially or fully demagnetised or suffered from a loss of signal due to deterioration of the magnetic coating. (E.g. a section of the tape has been accidentally exposed to a bulk eraser, or magnetic particles may have physically deteriorated, resulting in a weaker signal).

28. **Manufacturing surface defect**

(B) Includes partial lack of coating, foreign inclusions, variations in width, edge finish or thickness, etc.

(D) Only applies to raw stock. Includes partial lack of oxide, variations in width or thickness etc.

29. **Gummy deposit**

(B) Glue-like substance on the tape. It accumulates on the heads and guides of the playback machine when the tape is played.

(D) Glue-like substance that accumulates on heads and guides of players when tape is played.

30. **Loose [pressure] pad**

(A) This is a common ailment of compact cassettes, whereby the felt pad used to keep the tape pressed against the magnetic heads is loose or missing.

31. **Print-through** [It only applies to Compact Cassettes and Microcassettes.]

(D) The condition where low frequency signals on one tape winding imprint themselves on the immediately adjacent tape windings.

It is most noticeable on audio tapes where a ghost of the recording can be heard slightly before the playback of the actual recording.

32. **Damaged shell/housing**

(F)

Infine, i sintomi seguenti a mio avviso sono di carattere secondario, ovvero non si manifestano per se ma si accompagnano ad altri sintomi (SBS-SSS o SBS-UP), quindi userei i termini inglesi per le descrizioni:
Squealing: High pitched noise caused by bowing action of tape on heads. May result from hydrolysis and/or loss of lubricants. May be accompanied bystiction.
Stiction: Tape sticks to heads and guides on the playback machine, and will not spool or play.

B.3 Optical discs

This Section presents the list of the definitions for the symptoms and for the signs of degradation that apply to Compact Discs, and to optical discs by extension.

1. **Dirt, dust, oil**

(B) Dust, dirt or oiliness on the surface of the disc, usually resulting from poor storage conditions and handling.

2. **Other particulates**

   (A) discs exhibiting other materials that cannot quite be described as dirt, dust, oil, or foreign objects. The distinction can be vague.

3. **Liquid stains**

   (F)

4. **Mold**

   (A) "Mold usually takes the form of white or grey patches on the surface, with a characteristic [fuzzy] structure visible under low-power magnification." (IASA).

   (B) Usually takes the form of white or grey patches on the surface, with a characteristic structure visible under low-power magnification. Exacerbated by high humidity or contact with organic material.

5. **Pests**

   (A) evidence of pest contamination: vermin, insects, etc.

6. **Other bio[logical contamination]**

   (A) other types of biological contamination (e.g. bacteria).

7. **Discoloration [includes Hazing, Bronzing and Oxidation]**

   (A) Discs exhibiting a change in color on its surface.

   (B) Color change in disc. May be caused by aging or by temperature problems at the time the disc was pressed.

   (F) A type of corrosion that affects the reflective layer of the disc, usually starting at the edge and slowly working its way towards the center. With time the disc shows an increasing number of read errors, before becoming unreadable.

8. **Scratches**

   (F)

9. **Cracks, chips**

(A) A condition where the physical integrity of the sound disc has been compromised. This includes the following conditions defined by IASA:

a) Broken: The disc has broken into distinct parts
b) Chip: A small piece is missing, usually from the edge of the disc
c) Cracked or Cracking: A break without physical separation
d) Missing pieces: Disc has pieces missing from the recorded area.

(B) According to Sueiro: Breaks, Cracks, Chips and Missing pieces have been grouped. [Broken:] The disc has broken into distinct parts. [Crack:] A break without physical separation. [Chip:] A small piece is missing, usually from the edge of the disc. [Missing pieces:] Denotes [. . .] discs with missing pieces, which, as a result, cannot be consolidated.

10. **Warp** [**Curvature** according to the terminology in (D)]

(A) "Alteration in disc surface shape (usually along several planes)" (IASA).

(B) Alteration in disc surface shape (usually along several planes), causing the stylus to jump when the disc is played. Due to heat and/or uneven physical pressure on the disc.

(D) A disc that has a shallow U shape when viewed edge on, usually caused by exposure to heat and inadequate storage or shelving.

11. **Peeling**

(A) Another very severe condition characterized by a "failure of the bond between the substrate and [surface] layer[s]. Results in . . . sections of the surface . . . peeling away from the substrate of the disc" (IASA). Again, this often renders the content irretrievable, at least by traditional means.

(B) Failure of the bonding between the substrate and the surface layer. Results in large sections of the surface, or sometimes the entire face, peeling away from the substrate of the disc.

12. **Label damage**

(A) Discs without a label, or with a damaged label. (This condition does not affect the condition rating of the item, but warns of items whose future or present content identification may be difficult).

(B) The label is worn away, eaten by insects, or similarly affected.

(D) Labels that are worn away or eaten by insects.

13. **Centre damage or fault**

(B) The centre hole is chipped or otherwise unfit for centering the disc.

14. **Blister**

(B) Often caused by entrapped steam or air inclusion at the time the pressing was made.

B.4 Phonographic discs

This Section presents the list of the definitions for the symptoms and for the signs of degradation that apply to phonographic discs (vinyl, shellac, lacquer, and acetate discs).

1. **Dirt, dust, oil**

(B) Dust, dirt or oiliness on the surface of the disc, usually resulting from poor storage conditions and handling.

2. **Other particulates**

(A) discs exhibiting other materials that cannot quite be described as dirt, dust, oil, or foreign objects. The distinction can be vague.

3. **Liquid stains**

(F)

4. **Mold**

(A) "Mold usually takes the form of white or grey patches on the surface, with a characteristic [fuzzy] structure visible under low-power magnification." (IASA).

(B) Usually takes the form of white or grey patches on the surface, with a characteristic structure visible under low-power magnification. Exacerbated by high humidity or contact with organic material.

5. **Pests**

(A) evidence of pest contamination: vermin, insects, etc.

6. **Other bio[logical contamination]**

(A) other types of biological contamination (e.g. bacteria).

7. **Corrosion**

(A) Discs exhibiting rust or any other sign of corrosion.

(B) The metal substrate of a lacquer disc or of a metal part (e.g. stamper, mother) displays rust or some other form of corrosion.

8. **Imprinting**

(A) Imprinting refers to a visual pattern appearing on the disc surface, often (but not always) due to contact with another surface (e.g., a sleeve).

9. **Chemical residue**

(A) "Residue from a cleaning fluid or other chemical on the surface of the disc" (IASA); this is generally a condition noticeable over the entire surface of the disc, as opposed to 'liquid stains', which tend to be more localized.

(D) Any residue from chemical cleaning fluids left on the surface of an audio disc.

10. **Discoloration [or Darkening]**

(A) Discs exhibiting a change in color on its surface.

(B) Color change in disc. May be caused by aging or by temperature problems at the time the disc was pressed.

(D) Colour change in disc usually caused by by temperature problems in the pressing stage.

11. **Waxy exudate** [**Plasticizer exudation** according to the terminology in (C)]

(A) A waxy or powdery substance exuding from the disc surface, often palmitic acid. This is a common and severe problem in lacquer "acetate" discs, indicative of a major chemical breakdown in the disc's plasticizers.

(B) A waxy substance exuding from the surface of the disc. May be caused by a reaction between plasticizers in lacquer discs, and the packaging. Some shellac discs had excess or unstable wax in the binder which leaves a 'bloom' on the disc's surface. Often exacerbated by storage conditions.

(C) Plasticizer exudation manifests as a white, oily sheen that is easily spotted on the surface of the disc.

12. **Wear**

(A) "Worn grove walls... [often appear] as an overall dullness or grey grooves." (IASA).

(B) Worn groove walls, caused by stress of overuse, or replay with worn or inappropriate stylus. Often not easily seen with the naked eye, but appears as an overall dullness or grey grooves. It is more likely to occur during loud passages, and results in increased surface noise and decreased high frequency response.

13. **Scratches, gouges**

(A) This includes the following conditions defined by IASA:

a) Gouge: "Large, deep scratches"
b) Needle dig: "A very localized gouge due to a dropped soundbox with needle"
c) Needle run: "Curved scratch due to inappropriate handling"
d) Scratches: "Grooves scored with narrow lines"
e) Stitching: "A pattern resembling a series of small dashes or stitches running along the grooves of a disc"

(B) According to Sueiro: Gouge, Needle dig, Needle run, Scratches, Stitching have been grouped. [Gouge:] Large, deep scratches. This was sometimes done deliberately for contractual and copyright reasons to prevent further replay. [Needle dig:] A very localized gouge due to a dropped soundbox with needle. [Needle run:] Curved scratch due to inappropriate handling of the soundbox causing multiple ticks over the whole playing surface. [Scratch:] Grooves scored with narrow lines. The result of poor handling. [Stitching:] A pattern resembling a series of small dashes or stitches running along the grooves of a disc caused by wear from a stylus with insufficient compliance or excess tracking weight on more heavily modulated, low-frequency sections.

14. **Cracks, chips**

(A) A condition where the physical integrity of the sound disc has been compromised. This includes the following conditions defined by IASA:

a) Broken: The disc has broken into distinct parts
b) Chip: A small piece is missing, usually from the edge of a shellac disc
c) Cracked or Cracking: A break without physical separation
d) Missing pieces: Disc has pieces missing from the recorded area.

(B) According to Sueiro: Breaks, Chips, Cracks, Missing pieces have been grouped. [Broken:] The disc has broken into distinct parts (generally applies to shellac or glass-based lacquer discs, or to cylinders). [Crack:] A break without physical separation (generally applies to shellac discs and cylinders only). [Chip:] A small piece is missing, usually from the edge of the disc. [Missing pieces:] Denotes shellac or lacquer discs with missing pieces, which, as a result, cannot be consolidated.

15. **Warp** [**Curvature** according to the terminology in (D)]

(A) "Alteration in disc surface shape (usually along several planes)" (IASA).

(B) Alteration in disc surface shape (usually along several planes), causing the stylus to jump when the disc is played. Due to heat and/or uneven physical pressure on the disc.

(D) A disc that has a shallow U shape when viewed edge on, usually caused by exposure to heat and inadequate storage or shelving.

16. **Crazing**

(A) A very severe condition where "thin fracture lines occurring on the surface of a lacquer disc" appear. Often renders content irretrievable.

(B) Thin fracture lines occurring on the surface of a lacquer disc caused by shrinkage of the lacquer with respect to the substrate.

17. **Peeling** [**Delamination** according to the terminology in (D)]

(A) Very severe condition characterized by a "failure of the bond between the substrate and [surface] layer[s]. Results in . . . sections of the surface . . . peeling away from the substrate of the lacquer disc" (IASA). Again, this often renders the content irretrievable, at least by traditional means.

(B) Failure of the bonding between the substrate and the lacquer layer. Results in large sections of the surface, or sometimes the entire face, peeling away from the substrate of the lacquer disc.

(D) Delamination begins as obvious cracks that form in the discs coating, leading to separation of the coating from the base, leaving only the base material visible. This delamination may be limited to the edge or center of the disc where it does not yet affect the grooves that carry recorded content, or it may occur in the middle of the disc where content resides.

18. **Label damage**

(A) Enter a count of all sound discs without a label, or with a damaged label. (This condition does not affect the condition rating of the item, but warns of items whose future or present content identification may be difficult).

(B) The label is worn away, eaten by insects, or similarly affected.

(D) Labels that are worn away or eaten by insects.

19. **Centre damage or fault**

(B) The centre hole is chipped or otherwise unfit for centering the disc.

20. **Blister**

(B) Often caused by entrapped steam or air inclusion at the time the pressing was made. Causes clicks or other transient noise during playback.

(D) Small, burst bubbles on the surface of a disc. A manufacturing fault, occurring in disc pressings.

B.5 Digital non-audio carriers

This Section presents the list of the definitions for the symptoms and for the signs of degradation that apply to digital non-audio carriers (i.e., digital data storage devices non audio-specific: flash drives, memory cards, external Hard Disk Drives (HDDs), Compact Discs Recordable (CDs-R), Digital Versatile Discs (DVDs), . . . : this type does not include digital audio-specific carriers such as Compact Discs, Digital Audio Tapes and MiniDiscs).

1. **Dirt, dust, oil**

(B) Dust, dirt or oiliness on the surface of the carrier, usually resulting from poor storage conditions and handling.

2. **Other particulates**

(A) Carriers exhibiting other materials that cannot quite be described as dirt, dust, oil, or foreign objects. The distinction can be vague.

3. **Liquid stains**

(F)

4. **Mold**

(A) "Mold usually takes the form of white or grey patches on the surface, with a characteristic [fuzzy] structure visible under low-power magnification." (IASA).

(B) Usually takes the form of white or grey patches on the surface, with a characteristic structure visible under low-power magnification. Exacerbated by high humidity or contact with organic material.

5. **Pests**

(A) Evidence of pest contamination: vermin, insects, etc.

6. **Other bio**[**logical contamination**]

(A) Other types of biological contamination (e.g. bacteria).

7. **Corrosion**

(A) Carriers exhibiting rust or any other sign of corrosion.

(B) The metal substrate of the carrier or of a metal part displays rust or some other form of corrosion.

8. **Scratches, gouges**

(F) The carrier shows scratches on the surface.

9. **Crack, chips**

(F) The carrier has broken into distinct parts.

10. **Warp** [**Curvature** according to the terminology in (D)]

(A) “Alteration in disc surface shape (usually along several planes)” (IASA).

(B) Alteration in disc surface shape (usually along several planes), causing the stylus to jump when the disc is played. Due to heat and/or uneven physical pressure on the disc.

(D) A carrier that has a shallow U shape when viewed edge on, usually caused by exposure to heat and inadequate storage or shelving.

B.6 MiniDiscs

This Section presents the list of the definitions for the symptoms and for the signs of degradation that apply to MiniDiscs.

1. **Dirt, dust, oil**

(B) Dust, dirt or oiliness on the surface of the disc, usually resulting from poor storage conditions and handling.

2. **Other particulates**

(A) discs exhibiting other materials that cannot quite be described as dirt, dust, oil, or foreign objects. The distinction can be vague.

3. **Liquid stains**

(F)

4. **Mold**

(A) “Mold usually takes the form of white or grey patches on the surface, with a characteristic [fuzzy] structure visible under low-power magnification.” (IASA).

(B) Usually takes the form of white or grey patches on the surface, with a characteristic structure visible under low-power magnification. Exacerbated by high humidity or contact with organic material.

5. **Pests**

(A) evidence of pest contamination: vermin, insects, etc.

6. **Other bio[logical contamination]**

(A) other types of biological contamination (e.g. bacteria).

7. **Scratches, gouges**

(A) This includes the following conditions defined by IASA:

a) Gouge: “Large, deep scratches”
b) Needle dig: “A very localized gouge due to a dropped soundbox with needle”
c) Needle run: “Curved scratch due to inappropriate handling”
d) Scratches: “Grooves scored with narrow lines”
e) Stitching: “A pattern resembling a series of small dashes or stitches running along the grooves of a disc”

(B) According to Sueiro: Gouge, Needle dig, Needle run, Scratches, Stitching have been grouped. [Gouge:] Large, deep scratches. This was sometimes done deliberately for contractual and copyright reasons to prevent further replay. [Needle dig:] A very localized gouge due to a dropped soundbox with needle. [Needle run:] Curved scratch due to inappropriate handling of the soundbox causing multiple ticks over the whole playing surface. [Scratch:] Grooves scored with narrow lines. The result of poor handling. [Stitching:] A pattern resembling a series of small dashes or stitches running along the grooves of a disc caused by wear from a stylus with insufficient compliance or excess tracking weight on more heavily modulated, low-frequency sections.

8. **Cracks, chips**

(A) A condition where the physical integrity of the sound disc has been compromised. This includes the following conditions defined by IASA:

a) Broken: The disc has broken into distinct parts
b) Chip: A small piece is missing, usually from the edge of a shellac disc
c) Cracked or Cracking: A break without physical separation
d) Missing pieces: Disc has pieces missing from the recorded area.

(B) According to Sueiro: Breaks, Chips, Cracks, Missing pieces have been grouped. [Broken:] The disc has broken into distinct parts (generally applies to shellac or glass-based lacquer discs, or to cylinders). [Crack:] A break without physical separation (generally applies to shellac discs and cylinders only). [Chip:] A small piece is missing, usually from the edge of the disc. [Missing pieces:] Denotes shellac or lacquer discs with missing pieces, which, as a result, cannot be consolidated.

9. **Warp** [**Curvature** according to the terminology in (D)]

(A) "Alteration in disc surface shape (usually along several planes)" (IASA).
(B) Alteration in disc surface shape (usually along several planes), causing the stylus to jump when the disc is played. Due to heat and/or uneven physical pressure on the disc.
(D) A disc that has a shallow U shape when viewed edge on, usually caused by exposure to heat and inadequate storage or shelving.

10. **Damaged shell/housing**

(F)

C

Rating scales for the symptoms and signs of degradation

The evaluation grids presented in this Appendix define five levels of criticality for each symptom and for each sign of degradation listed in Appendix B. A textual description and, where possible, a photographic reference are associated to each level. The purpose is to provide parameters that are useful during the visual inspection in order to achieve a precise evaluation of its physical condition.

To date, standard evaluation techniques are missing, and so are automatic tools. As a consequence, it is impossible to formulate an *objective* assessment. The state of the art mostly includes collection-level applications, finalized at defining a priority for treatment (thus falling within the scope of *preservation planning*).
An example of this type of application is FACET (Field Audio Collection Evaluation Tool)[1], developed at Indiana University, that "ranks audio field collections[2] based on preservation condition, the level of deterioration they exhibit, and the degree of risk they carry" [142]. Another example is AVDb (Audio and Moving Image Survey Tool)[3], developed at Columbia University, the purpose of which is to "assign ratings for various factors (condition, environment, ...), generating a preservation priority based on the ratings" [49]. While FACET is a Java standalone application, AVDb comes in the form of a Microsoft Access tool.
The author's approach is not collection-oriented and, unlike the examples exposed, its purpose is not to define a priority for treatment. When an audio carrier's condition is evaluated according to the parameters here described, it has already been selected for preservation and it has already entered the

[1] http://www.dlib.indiana.edu/projects/sounddirections/facet/index.shtml – last visited on December 12, 2012.

[2] A body of archival material formed by or around a person, family group, corporate body, or subject either from a common source as a natural product of activity or function, or gathered purposefully and artificially without regard to original provenance [141].

[3] http://library.columbia.edu/services/preservation/audiosurvey.html – last visited on December 12, 2012.

process (the visual inspection is the second step of the Preparation of the carrier, according to the protocol described in Section 5.1.1). Secondly, some symptoms cannot be detected unless the carrier is played, such as SBS-SSS for Compact Cassettes or as gummy deposit due to degraded joints for open-reel tapes. Besides, the author's opinion is that visual inspection of audio carriers should be carried out by highly trained personnel, in possess of a good knowledge of present and past recording formats, combined with personal experience on the field.
Sueiro [49] says that AVDb "is designed to be used by surveyors who are not experts in audio-visual media, but who have a certain familiarity with broad categories: for example, you should be able to visually identify a sound tape reel". The author strongly believes that in order to perform a professional, efficient and reliable diagnosis of an open-reel tape (considering that the survival of the document depends on it), more than knowing how it looks like is required. The experience on the field may not only help the surveyor detect some signs of degradation with more accuracy, but it may lead to different ratings because some not-so-bad-looking damage sometimes correspond to serious problems at playback, and this type of knowledge only comes from experience.

As a closing remark, the author wishes to explain the rationale behind the unweighted five level rating scale. The main reason is that evaluations are based on visual inspections, which tend to be subjective and may vary according to the surveyor expertise. Without an objective measurement of the signs of degradation, weighs are arbitrary and lead to arbitrary results. At this stage of the research, a human evaluation is likely to be more accurate: at least someone is responsible of it, and it is "subjective but not arbitrary". Subjective means that the evaluation is the result of a set of choices made by an expert, who is directly responsible, and who can be asked to justify his/her choices. Similarly, an automatic procedure does not eliminate subjectivity, but in addition – unlike human evaluation – loses its control: the surveyors's task is to enter a numeric value that, combined with other numeric values, will return a numeric result, but unfortunately this does not make it objective. The surveyor chooses a numeric value out of his/her *subjective* evaluation and, because calculations do not consider nor control subjectivity, nobody is directly responsible and can eventually justify the result. This is why the author chose to define a five level rating scale for all symptoms and signs of degradation, without introducing weighs. The aim is to achieve an evaluation grid that attempts a formalization of the levels of criticality that an audio carrier can show, helping the surveyor as much as possible with rich descriptions and visual references.
The least structured alternative available is, as always, the field for free textual descriptions, but this solution clearly shows some limitations: everything is completely subjective, and it is difficult to draw any kind of information from the text in an automatic way. With the author's solution, a reference grid is provided so that the carriers with a level of criticality other than zero can be easily spotted, and at the same time the surveyor is

free to add his/her personal annotations (also regarding the measures taken to contrast the damage).

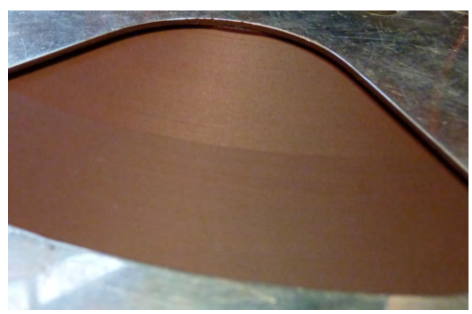
The following list summarizes the strong points of the author's solution, in particular precision (item 1), completeness (item 2) and flexibility (item 3):

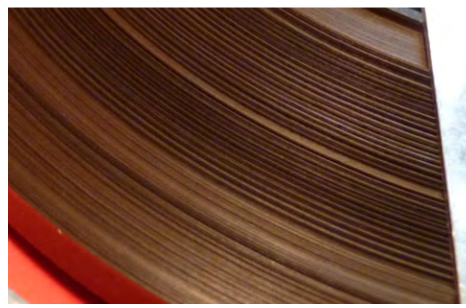
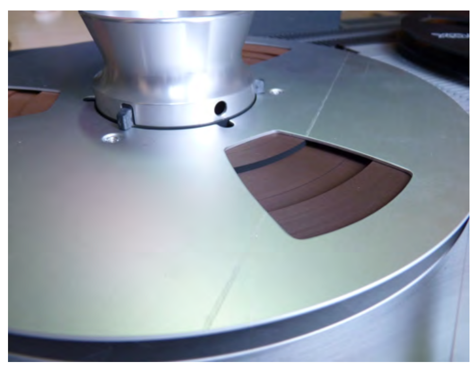
1. the evaluation grid provides a structured reference to rate the symptoms and the signs of degradation with numeric values;
2. numeric values are associated to textual descriptions and, where available, to visual documentation;
3. the surveyor is free to add his/her own annotations (providing more details on the symptoms, on the measures taken to contrast them, ...);
4. the resulting evaluation is subjective *and* accurate.

Having said this, in the author's opinion a satisfactory automatization of the evaluation of a carrier's physical condition will hardly appear anytime soon, being one of those aspects of preservation that will remain an intrinsic combination of "art and science" [51].

The following textual and visual descriptions will hopefully keep being perfected and enriched in the future.

C.1 Open-reel tapes

1. Tape pack/Wind quality		
0	The wind quality is perfect.	

1	Smooth pack with minor imperfections.	
2	Uneven pack without blocking nor damaged edges.	
3	Uneven pack with blocking or damaged edges. [The pack might have fallen for inadequate storage conditions (horizontal position of the tape) rather than rewind.]	

4	Tape completely loose or off the reel.	

2. Blocking		
0	The tape shows no signs of blocking.	
1	The tape shows misaligned packs, but this does not cause the tape to touch the flange during re-play.	
2	The tape shows misaligned packs, which causes the tape to touch the flange during re-play, with no serious consequence for the tape. It can be played, with special care, without restoration/optimization.	
3	The tape shows misaligned packs, which causes the tape to touch the flange during re-play, with corresponding consequence for the tape. Restoration/optimization is recommendable before re-play.	
4	The tape shows misaligned packs, causing the tape to touch the flange during re-play to the point that it cannot be played. Manual restoration/optimization is recommended, when possible.	

3. Leafing		
0	Leafing is completely absent.	
1	One or few single layers of tape are protruding from the tape pack.	

2	A significant number of single layers of tape are protruding from the tape pack, without causing problems during replay. The tape can be played without restoration.	
3	A significant number of single layers of tape are protruding from the tape pack, causing minor problems during replay. Restoration/optimization is recommended before replay.	
4	A significant number of single layers of tape are protruding from the tape pack, causing serious problems during replay. Restoration/optimization is required before replay.	

4. Loose wind		
0	The tape wind is not loose.	
1	The tape is slightly loose in some portions.	
2	The tape is slightly loose throughout its length.	
3	The tape is very loose throughout its length.	
4	The tape is loose throughout its length, causing collateral problems that need to be solved before replay (e.g., cinching).	

5. Windowing		
0	Windowing is completely absent.	
1	Evidence of windowing occurs once or twice along the tape length.	
2	Evidence of windowing occurs several times along the tape length, causing minor problems during replay.	
3	Evidence of windowing occurs several times along the tape length, causing significant problems during replay.	

4	Windowing is so accentuated that the tape need manual restoration/optimization in order to be played.	

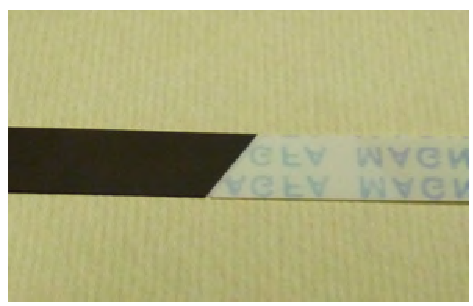
6. Spoking		
0	Spoking is completely absent.	
1	Slight evidence of spoking is visible, involving a small number of tape layers.	
2	Evidence of spoking is clearly visible, involving a significant number of tape layers, without causing significant problems during replay.	
3	Evidence of spoking is clearly visible, involving a significant number of tape layers, causing significant problems during replay.	
4	Spoking is so accentuated that it makes the tape unplayable.	

7. Dirt, dust or oil		
0	Dirt, dust or oil are completely absent.	
1	Slight and/or localized evidence of dirt, dust or oil is visible on the tape.	
2	Slight evidence of dirt, dust or oil is visible throughout the tape.	
3	Evidence of dirt, dust or oil is clearly visible throughout the tape.	
4	Dirt, dust or oil make the tape unplayable.	

8. Other particulates		
0	Other particulates are completely absent.	
1	Slight and/or localized evidence of other particulates is visible on the tape.	
2	Slight evidence of other particulates is visible throughout the tape.	

3	Evidence of other particulates is clearly visible throughout the tape.	
4	Evidence of other particulates makes the tape unplayable.	

9. Liquid stains		
0	Liquid stains are completely absent.	
1	Slight and/or localized evidence of liquid stains is visible on the tape.	
2	Slight evidence of liquid stains is visible throughout the tape.	
3	Evidence of liquid stains is clearly visible throughout the tape.	
4	Liquid stains make the tape unplayable.	

10. Splices		
0	Splices are absent or in perfect condition.	
1	The splices along the tape length are in very good condition.	
2	The splices along the tape length are in a passable condition. Optimization is recommended before replay.	
3	The splices along the tape length are in a bad condition. Optimization is required before replay.	

4	The splices along the tape length are severely damaged, causing collateral problems (e.g., sticky residue on adjacent layers). Optimization is difficult to achieve without compromising small portions of the tape before and after the splice.	

11. Vinegar odor		
0	No sign of vinegar odor.	Visual documentation not available: the symptom does not have visible effects.
1	A faint smell of vinegar is perceivable after the box/case is opened.	Visual documentation not available: the symptom does not have visible effects.
2	A definite but not pungent smell of vinegar is perceivable after the box/case is opened.	Visual documentation not available: the symptom does not have visible effects.
3	A pungent smell of vinegar is perceived after the box/case is opened.	Visual documentation not available: the symptom does not have visible effects.
4	A pungent smell of vinegar is clearly perceivable in the proximity of the box/case.	Visual documentation not available: the symptom does not have visible effects.

12. Mold		
0	No sign of mold.	
1	Evidence of mold is slightly visible on small portions of the tape.	
2	Evidence of mold is clearly visible on small portions of the tape.	
3	Evidence of mold is slightly visible all over the tape.	
4	Evidence of mold is clearly visible all over the tape.	

13. Pests		
0	Pests are completely absent.	
1	Evidence of pests is slightly visible on limited portions of the tape.	
2	Evidence of pests is clearly visible on limited portions of the tape.	
3	Evidence of pests is slightly visible all over the tape.	

4	Evidence of pests is clearly visible all over the tape.	

14. Other bio[logical contamination]		
0	Other bio are completely absent.	
1	Evidence of other bio is slightly visible on limited portions of the tape.	
2	Evidence of other bio is clearly visible on limited portions of the tape.	
3	Evidence of other bio is slightly visible throughout the tape.	
4	Evidence of other bio is clearly visible throughout the tape.	

15. Powder, crystals		
0	Powder, crystals are completely absent.	
1	Powder, crystals are hardly visible on the tape.	
2	Powder, crystals are visible on limited portions of the tape surface.	
3	Powder, crystals are visible on large portions of the tape surface.	
4	Powder, crystals cover most of the tape surface.	

16. Tears, breaks		
0	Tears, breaks are completely absent.	
1	Tears, breaks are present on the tape, but their extent does not affect replay.	
2	Tears, breaks are present on the tape, and their extent require that some restoration be done before replay.	
3	Tears, breaks are present on the tape, and their extent require that major restoration is done before replay.	
4	Tears, breaks make the tape unplayable.	

17. Brittle, curling		
0	Brittle, curling is completely absent.	
1	Negligible evidence of brittle, curling on the tape.	
2	Serious evidence of brittle, curling on the tape, without significant problems during replay.	
3	Serious evidence of brittle, curling on the tape, with significant problems during replay.	
4	Brittle, curling make the tape unplayable.	

18. Folds, cinching		
0	Folds, cinching are completely absent.	
1	Negligible evidence of folds, cinching on the tape.	
2	Serious evidence of folds, cinching on the tape, without significant problems during replay.	
3	Serious evidence of folds, cinching on the tape, with significant problems during replay.	
4	Folds, cinching make the tape unplayable.	

19. Cupping		
0	Cupping is completely absent.	
1	Negligible evidence of cupping on the tape.	
2	Serious evidence of cupping on the tape, without significant problems during replay.	
3	Serious evidence of cupping on the tape, with significant problems during replay.	
4	Cupping make the tape unplayable.	

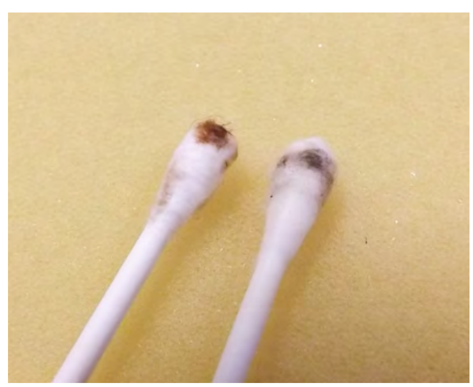
20. Edge damage		
0	Edge damage is completely absent.	

1	Edge damage is visible in very short portions of the tape, not causing problems during replay.	
2	Edge damage is visible in significant portions of the tape, causing minor problems during re-play.	
3	Edge damage is visible throughout the tape width, causing significant problems during re-play.	
4	Edge damage is accentuated throughout the tape, seriously compromising or even preventing re-play.	

21. Backcoat shedding		
0	No evidence of backcoat shedding.	
1	Slight evidence of backcoat shedding, causing no problems whatsoever during replay.	
2	Light evidence of backcoat shedding, causing minor problems during replay.	
3	Evidence of backcoat shedding, causing significant problems during replay.	
4	Backcoat shedding is so severe that the tape is unplayable.	

22. Magnetic coating shedding		
0	Magnetic coating shedding is completely absent.	
1	Magnetic coating shedding is localized, or occurs in a negligible way, in the tape length.	
2	Magnetic coating shedding is localized or spotted, and it occurs several times in the tape length.	

3	The magnetic coating shedding affects significant portions of the tape.	
4	The portions of the tape affected by magnetic coating shedding are wider than the integer ones.	

23. SBS-SSS		
0	No evidence of SBS-SSS.	 The picture shows how the cotton bud should look like after cleaning the heads of the tape recorder (unstained).
1	Negligible evidence of SBS-SSS: no restoration is required, but it is allowed at the operator's judgement.	 The picture shows the cotton bud after cleaning the heads of the tape recorder: a small quantity of residue.
2	Average presence of SBS-SSS: restoration is recommended.	
3	Significant presence of SBS-SSS: restoration is required.	 The picture shows two cotton buds after cleaning the heads of the tape recorder: the amount of deposit is significant.

4	SBS-SSS makes the tape unreadable.	 The picture shows the heads of the tape recorder after reading a tape with a severe SBS-SSS.

24. SBS-UP		
0	No evidence of SBS-UP.	
1	Negligible evidence of SBS-UP: no restoration is required, but it is allowed at the operator's judgement.	
2	Average presence of SBS-UP: restoration is recommended.	
3	Significant presence of SBS-UP: restoration is required.	
4	SBS-UP makes the tape unreadable.	

25. Bleeding		
0	No sign of bleeding.	
1	Very slight presence of bleeding.	
2	The presence of bleeding does not cause significant problems during replay.	
3	The presence of bleeding causes significant problems during replay, even in the case it affects a limited portion of the tape.	
4	Bleeding makes the tape unplayable.	

26. Curvature		
0	No sign of curvature.	
1	Very slight presence of curvature.	
2	The presence of curvature is not negligible, but it does not cause significant problems during replay.	

3	The presence of curvature causes significant problems during replay, even in the case it affects a limited portion of the tape.	
4	Curvature makes the tape unplayable.	

27. Embossing		
0	No sign of embossing.	
1	Negligible evidence of embossing.	
2	Slight presence of embossing, restoration is not necessary in case replay is not compromised.	
3	Significant presence of embossing, restoration is required in order to play the tape.	
4	Embossing makes the tape unplayable.	

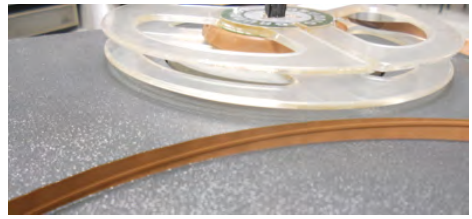
28. Interlayer adhesion		
0	No sign of interlayer adhesion.	
1	Negligible evidence of interlayer adhesion.	
2	Very slight presence of interlayer adhesion, restoration is not required in case replay is not compromised.	
3	Significant presence of interlayer adhesion, restoration is required in order to play the tape.	 The picture shows a possible consequence of unwinding a tape affected with interlayer adhesion: small portions of the tape back are stuck on the surface of the adjacent spire.
4	Interlayer adhesion makes the tape unplayable.	

29. Kink/Wrinkle

0	Kinking/Wrinkling is completely absent.	
1	Negligible evidence of kinking/wrinkling on the tape.	
2	Serious evidence of kinking/wrinkling on the tape, without significant problems during replay.	
3	Serious evidence of kinking/wrinkling on the tape, with significant problems during replay.	
4	Kinking/Wrinkling make the tape unplayable.	

30. Magnetic losses		
0	Magnetic losses are completely absent.	Visual documentation not available: the symptom does not have visible effects.
1	Localized magnetic loss, affecting a negligible portion of the tape length (inaudible effect).	Visual documentation not available: the symptom does not have visible effects.
2	Localized magnetic loss, with an audible effect (signal drop).	Visual documentation not available: the symptom does not have visible effects.
3	Extended magnetic loss and/or frequent in the tape length (audible effect).	Visual documentation not available: the symptom does not have visible effects.
4	The magnetic loss affects the entire tape length and the recording is completely erased.	Visual documentation not available: the symptom does not have visible effects.

31. Manufacturing surface defects		
0	No sign of manufacturing surface defects.	
1	Negligible manufacturing surface defects.	

2	Small manufacturing surface defects, with minor problems during replay.	
3	Significant manufacturing surface defects, with major consequences on replay.	
4	The tape is unplayable due to manufacturing surface defects.	

32. Print-through		
0	No sign of print-through effect.	
1	The imprinted signal is barely audible, the intelligibility of the useful signal is not affected.	
2	The imprinted signal is clearly audible, partially disturbing the intelligibility of the useful signal.	
3	The useful signal and the imprinted signal are almost equally loud, affecting the intelligibility of both.	
4	The imprinted signal is louder than the useful signal.	

Note: it should be annotated whether the print-through effect anticipates or follows the useful signal.

33. Gummy deposit		
0	Gummy deposit is completely absent.	
1	Negligible presence of gummy deposit, restoration is limited to simple cleaning.	
2	Slight presence of gummy deposit, restoration is needed in order to play the tape.	
3	Significant evidence of gummy deposit, with major consequences on replay. Restoration might affect adjacent portions of the tape.	

4	The tape is unplayable due to gummy deposit.	

C.2 Compact Cassettes, Microcassettes and Digital Audio Tapes

1. Tape pack/Wind quality		
0	Perfect pack.	
1	Smooth pack with minor imperfections.	
2	Uneven pack without blocking nor damaged edges.	
3	Uneven pack with blocking or damaged edges.	
4	Tape completely loose or outside the housing.	

2. Blocking		
0	The tape shows no signs of blocking.	
1	The tape shows misaligned packs, but this does not cause the tape to touch the flange during re-play.	
2	The tape shows misaligned packs, which causes the tape to touch the flange during re-play, with no serious consequence for the tape. It can be played, with special care, without restoration/optimization.	
3	The tape shows misaligned packs, which causes the tape to touch the flange during re-play, with corresponding consequence for the tape. Restoration/optimization is recommendable before re-play.	
4	The tape shows misaligned packs, causing the tape to touch the flange during re-play to the point that it cannot be played. Manual restoration/optimization is recommended, when possible.	

3. Leafing		
0	Leafing is completely absent.	
1	One or few single layers of tape are protruding from the tape pack.	
2	A significant number of single layers of tape are protruding from the tape pack, without causing problems during replay. The tape can be played without restoration.	
3	A significant number of single layers of tape are protruding from the tape pack, causing minor problems during replay. Restoration/optimization is recommended before replay.	
4	A significant number of single layers of tape are protruding from the tape pack, causing serious problems during replay. Restoration/optimization is required before replay.	

4. Loose wind		
0	The tape wind is not loose.	
1	The tape wind is slightly loose in some portions of the tape length.	
2	The tape wind is slightly loose throughout the tape length.	
3	The tape wind is considerably loose throughout the tape length.	
4	The tape wind is loose throughout the tape length, causing collateral problems that need to be solved before replay (e.g., cinching).	

5. Windowing		
0	Windowing is completely absent.	
1	Evidence of windowing occurs once or twice along the tape length.	
2	Evidence of windowing occurs several times along the tape length, causing minor problems during replay.	

3	Evidence of windowing occurs several times along the tape length, causing significant problems during replay.	
4	Windowing is so accentuated that the tape need manual restoration/optimization in order to be played.	

6. Spoking		
0	Spoking is completely absent.	
1	Slight evidence of spoking is visible, involving a small number of tape layers.	
2	Evidence of spoking is clearly visible, involving a significant number of tape layers, without causing significant problems during replay.	
3	Evidence of spoking is clearly visible, involving a significant number of tape layers, causing significant problems during replay.	
4	Spoking is so accentuated that it makes the tape unplayable.	

7. Dirt, dust or oil		
0	Dirt, dust or oil are completely absent.	
1	Slight and/or localized evidence of dirt, dust or oil is visible on the tape.	
2	Slight evidence of dirt, dust or oil is visible throughout the tape.	
3	Evidence of dirt, dust or oil is clearly visible throughout the tape.	
4	Dirt, dust or oil evidence makes the tape unplayable.	

8. Other particulates		
0	Other particulates are completely absent.	

1	Slight and/or localized evidence of other particulates is visible on the tape.	
2	Slight evidence of other particulates is visible throughout the tape.	
3	Evidence of other particulates is clearly visible throughout the tape.	
4	Evidence of other particulates makes the tape unplayable.	

9. Liquid stains		
0	Liquid stains are completely absent.	
1	Slight and/or localized evidence of liquid stains is visible on the tape.	
2	Slight evidence of liquid stains is visible throughout the tape.	
3	Evidence of liquid stains is clearly visible throughout the tape.	
4	Liquid stains make the tape unplayable.	

10. Mold		
0	No sign of mold.	
1	Faint evidence of mold is visible on small portions of the tape.	
2	Clear evidence of mold is visible on small portions of the tape.	
3	Faint evidence of mold is visible all over the tape.	
4	Clear evidence of mold is visible all over the tape.	

11. Pests		
0	Pests are completely absent.	
1	Evidence of pests is slightly visible on limited portions of the tape.	
2	Evidence of pests is clearly visible on limited portions of the tape.	
3	Evidence of pests is slightly visible all over the tape.	
4	Evidence of pests is clearly visible all over the tape.	

12. Other bio[logical contamination]		
0	Other bio are completely absent.	
1	Evidence of other bio is slightly visible on limited portions of the tape.	
2	Evidence of other bio is clearly visible on limited portions of the tape.	
3	Evidence of other bio is slightly visible throughout the tape.	
4	Evidence of other bio is clearly visible throughout the tape.	

13. Powder, crystals		
0	Powder, crystals are completely absent.	
1	Powder, crystals are hardly visible on the tape.	
2	Powder, crystals are visible on limited portions of the tape surface.	
3	Powder, crystals are visible on large portions of the tape surface.	
4	Powder, crystals cover most of the tape surface.	

14. Tears, breaks		
0	Tears, breaks are completely absent.	
1	Tears, breaks are present on the tape, but their extent does not affect replay.	
2	Tears, breaks are present on the tape, and their extent require that some restoration is done before replay.	
3	Tears, breaks are present on the tape, and their extent require that major restoration is done before replay.	
4	Tears, breaks make the tape unplayable.	

15. Folds, cinching

0	Folds, cinching are completely absent.	
1	Negligible evidence of folds, cinching on the tape.	
2	Serious evidence of folds, cinching on the tape, without significant problems during replay.	
3	Serious evidence of folds, cinching on the tape, with significant problems during replay.	
4	Folds, cinching make the tape unplayable.	

16. Cupping		
0	Cupping is completely absent.	
1	Negligible evidence of cupping on the tape.	
2	Serious evidence of cupping on the tape, without significant problems during replay.	
3	Serious evidence of cupping on the tape, with significant problems during replay.	
4	Cupping make the tape unplayable.	

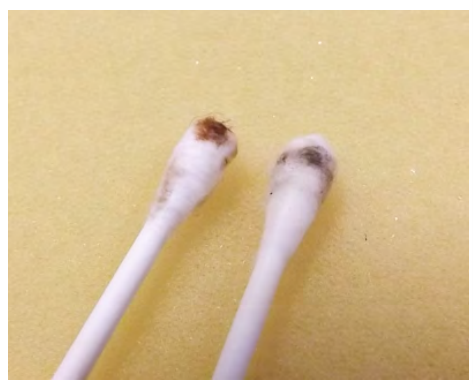
17. Edge damage		
0	Edge damage is completely absent.	
1	Edge damage is visible in very short portions of the tape, not causing problems during replay.	
2	Edge damage is visible in significant portions of the tape, causing minor problems during re-play.	
3	Edge damage is visible throughout the tape width, causing significant problems during re-play.	
4	Edge damage is accentuated throughout the tape, seriously compromising or even preventing re-play.	

18. Backcoat shedding

0	No evidence of backcoat shedding.	
1	Slight evidence of backcoat shedding, causing no problems whatsoever during replay.	
2	Light evidence of backcoat shedding, causing minor problems during replay.	
3	Evidence of backcoat shedding, causing significant problems during replay.	
4	Backcoat shedding is so severe that the tape is unplayable.	

19. Magnetic coating shedding		
0	Magnetic coating shedding is completely absent.	
1	Magnetic coating shedding is localized, or occurs in a negligible way, in the tape length.	
2	Magnetic coating shedding is localized or spotted, and it occurs several times in the tape length.	
3	The magnetic coating shedding affects significant portions of the tape.	
4	The portions of the tape affected by magnetic coating shedding are wider than the integer ones.	

20. SBS-SSS

0	No evidence of SBS-SSS.	 The picture shows how the cotton bud should look like after cleaning the heads of the tape recorder (immaculate).
1	Negligible evidence of SBS-SSS: no restoration is required, but it is allowed at the operator's judgement.	 The picture shows the cotton bud after cleaning the heads of the tape recorder: a very light sign of residue.
2	Average presence of SBS-SSS: restoration is recommended.	
3	Significant presence of SBS-SSS: restoration is required.	 The picture shows two cotton buds after cleaning the heads of the tape recorder: the amount of deposit is significant.

4	SBS-SSS makes the tape unreadable.	 The picture shows the heads of the tape recorder after reading a tape with a severe SBS-SSS.

21. SBS-UP		
0	No evidence of SBS-UP.	
1	Negligible evidence of SBS-UP: no restoration is required, but it is allowed at the operator's judgement.	
2	Average presence of SBS-UP: restoration is recommended.	
3	Significant presence of SBS-UP: restoration is required.	
4	SBS-UP makes the tape unreadable.	

22. Bleeding		
0	No sign of bleeding.	
1	Very slight presence of bleeding.	
2	The presence of bleeding does not cause significant problems during replay.	
3	The presence of bleeding causes significant problems during replay, even in the case it affects a limited portion of the tape.	
4	Bleeding makes the tape unplayable.	

23. Curvature		
0	No sign of curvature.	
1	Very slight presence of curvature.	
2	The presence of curvature is not negligible, but it does not cause significant problems during replay.	

3	The presence of curvature causes significant problems during replay, even in the case it affects a limited portion of the tape.	
4	Curvature makes the tape unplayable.	

24. Embossing		
0	No sign of embossing.	
1	Negligible evidence of embossing.	
2	Slight presence of embossing, restoration is not necessary in case replay is not compromised.	
3	Significant presence of embossing, restoration is required in order to play the tape.	
4	Embossing makes the tape unplayable.	

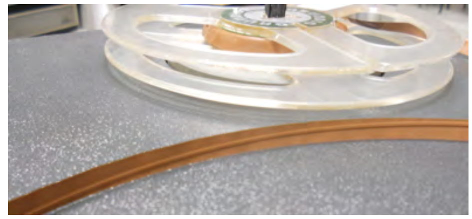
25. Interlayer adhesion		
0	No sign of interlayer adhesion.	
1	Negligible evidence of interlayer adhesion.	
2	Very slight presence of interlayer adhesion, restoration is not required in case replay is not compromised.	
3	Significant presence of interlayer adhesion, restoration is required in order to play the tape.	 The picture shows a possible consequence of unwinding a tape affected with interlayer adhesion: small portions of the tape back are stuck on the surface of the adjacent spire.
4	Interlayer adhesion makes the tape unplayable.	

26. Kink/Wrinkle

0	Kinking/Wrinkling is completely absent.	
1	Negligible evidence of kinking/wrinkling on the tape.	
2	Serious evidence of kinking/wrinkling on the tape, without significant problems during replay.	
3	Serious evidence of kinking/wrinkling on the tape, with significant problems during replay.	
4	Kinking/Wrinkling make the tape unplayable.	

27. Magnetic losses		
0	Magnetic losses are completely absent.	Visual documentation not available: the symptom does not have visible effects.
1	Localized magnetic loss, affecting a negligible portion of the tape length (inaudible effect).	Visual documentation not available: the symptom does not have visible effects.
2	Localized magnetic loss, with an audible effect (signal drop).	Visual documentation not available: the symptom does not have visible effects.
3	Extended magnetic loss and/or frequent in the tape length (audible effect).	Visual documentation not available: the symptom does not have visible effects.
4	The magnetic loss affects the entire tape length and the recording is completely erased.	Visual documentation not available: the symptom does not have visible effects.

28. Manufacturing surface defects		
0	No sign of manufacturing surface defects.	
1	Negligible manufacturing surface defects.	

2	Small manufacturing surface defects, with minor problems during replay.	
3	Significant manufacturing surface defects, with major consequences on replay.	
4	The tape is unplayable due to manufacturing surface defects.	

29. Gummy deposit		
0	Gummy deposit is completely absent.	
1	Negligible presence of gummy deposit, restoration is limited to simple cleaning.	
2	Slight presence of gummy deposit, restoration is needed in order to play the tape.	
3	Significant evidence of gummy deposit, with major consequences on replay. Restoration might affect adjacent portions of the tape.	
4	The tape is unplayable due to gummy deposit.	

30. Loose [pressure] pad		
0	[Pressure] pad in perfect condition.	
1	[Pressure] pad with negligible defects.	
2	[Pressure] pad with slight defects, requiring minor restoration.	
3	[Pressure] pad with significant defects, requiring major restoration or replacing.	
4	The [pressure] pad is missing and the surrounding area might be damaged, restoration might not be possible.	

31. Print-through		
0	No sign of print-through effect.	
1	The imprinted signal is barely audible, the intelligibility of the useful signal is not affected.	
2	The imprinted signal is clearly audible, partially disturbing the intelligibility of the useful signal.	
3	The useful signal and the imprinted signal are almost equally loud, affecting the intelligibility of both.	
4	The imprinted signal is louder than the useful signal.	

Note: it should be annotated whether the print-through effect anticipates or follows the useful signal.

32. Damaged shell/housing		
0	Housing in perfect condition.	
1	The housing has a negligible signs or minor cracks.	
2	The housing shows cracks and other damage that make it fragile. It might be restored or, at choice, replaced.	
3	The housing shows serious cracks or might come already broken in several pieces. Requires serious restoration or rather replacement.	
4	The housing is missing.	

C.3 Optical discs

1. Dirt, dust or oil		
0	Dirt, dust or oil are completely absent.	
1	Slight and/or localized evidence of dirt, dust or oil is visible on the disc.	
2	Slight evidence of dirt, dust or oil is visible all over the disc.	
3	Evidence of dirt, dust or oil is clearly visible al over the disc.	

4	Dirt, dust or oil evidence makes the disc unplayable.	

2. Other particulates		
0	No sign of other particulates.	
1	Slight and/or localized evidence of other particulates is visible on the disc.	
2	Slight evidence of other particulates is visible all over the disc.	
3	Evidence of other particulates is clearly visible all over the disc.	
4	Evidence of other particulates makes the disc unplayable.	

3. Liquid stains		
0	Liquid stains are completely absent.	
1	Slight and/or localized evidence of liquid stains is visible on the disc.	
2	Slight evidence of liquid stains is visible all over the disc.	
3	Evidence of liquid stains is clearly visible all over the disc.	
4	Liquid stains make the disc unplayable.	

4. Mold		
0	Mold is completely absent.	
1	Faint evidence of mold is visible on small portions of the disc.	
2	Clear evidence of mold is visible on small portions of the disc.	
3	Faint evidence of mold is visible all over the disc surface.	
4	Clear evidence of mold is visible all over the tape surface.	

5. Pests		
0	Pests are completely absent.	
1	Evidence of pests is slightly visible on limited portions of the disc.	

2	Evidence of pests is clearly visible on limited portions of the disc.	
3	Evidence of pests is slightly visible all over the disc surface.	
4	Evidence of pests is clearly visible all over the disc surface.	

6. Other bio[logical contamination]		
0	Other bio are completely absent.	
1	Evidence of other bio is slightly visible on limited portions of the disc.	
2	Evidence of other bio is clearly visible on limited portions of the disc.	
3	Evidence of other bio is slightly visible all over the disc.	
4	Evidence of other bio is clearly visible all over the disc.	

7. Discoloration		
0	Discoloration is completely absent.	
1	Slight signs of discoloration. Should not affect playability.	
2	Slight signs of discoloration. Might affect playability, restoration might be possible.	
3	Significant signs of discoloration. Affects playability, restoration might not be possible.	
4	Irreversible signs of discoloration, the disc is not playable.	

8. Scratches		
0	Scratching is completely absent.	
1	Negligible scratching on the disc surface.	
2	Very light scratching on the disc surface, playability might be affected in specific points.	
3	Scratching is clearly visible on the disc surface, playability is seriously affected.	

4	Scratching makes the disc unplayable.	

9. Cracks, chips		
0	Cracks, chips are completely absent.	
1	Negligible presence of cracks and chips. Playability is not affected.	
2	Small cracks and chips are present. Restoration is required in order to play the disc.	
3	Significant presence of cracks and chips. Restoration can be attempted in order to extract portions of the signal.	
4	Cracks, chips make the disc unplayable.	

10. Warp		
0	Warping is completely absent.	
1	Negligible presence of warping, does not affect playability.	
2	Slight presence of warping, might affect playability.	
3	Significant presence of warping, restoration can be attempted in order to extract portions of the signal.	
4	Warping makes the disc unplayable.	

11. Peeling		
0	Peeling is completely absent.	
1	Negligible presence of peeling, does not affect playability.	
2	Slight presence of peeling, might affect playability.	
3	Significant presence of peeling, restoration can be attempted in order to extract portions of the signal.	
4	Peeling makes the disc unplayable.	

12. Label damage

0	Label absent or in perfect condition.	
1	Negligible damage to the label, does not affect playability nor readability.	
2	Slight damage to the label, may disturb replay or compromise readability.	
3	Significant damage to the label, text is not readable and the disc playability might be significantly disturbed.	
4	The label is irreversibly damaged and so is the underlying portion of the disc.	

13. Centre damage or fault		
0	No sign of centre damage or fault.	
1	Negligible evidence of centre damage or fault. Playability is not affected.	
2	Slight evidence of centre damage or fault. Playability might be partially affected.	
3	Significant evidence of centre damage or fault. Playability is significantly affected.	
4	Centre damage or fault makes the disc unplayable.	

14. Blister		
0	Blisters are completely absent.	
1	Negligible evidence of blisters. Playability is not affected.	
2	Slight evidence of blisters. Playability might be partially affected.	
3	Significant presence of blisters. Playability is significantly affected.	
4	Blisters make the disc unplayable.	

C.4 Phonographic discs

1. Dirt, dust or oil

0	Dirt, dust or oil are completely absent.	
1	Slight and/or localized evidence of dirt, dust or oil is visible on the disc.	
2	Slight evidence of dirt, dust or oil is visible all over the disc.	
3	Evidence of dirt, dust or oil is clearly visible al over the disc.	
4	Dirt, dust or oil evidence makes the disc unplayable.	

2. Other particulates		
0	No sign of other particulates.	
1	Slight and/or localized evidence of other particulates is visible on the disc.	
2	Slight evidence of other particulates is visible all over the disc.	
3	Evidence of other particulates is clearly visible all over the disc.	
4	Evidence of other particulates makes the disc unplayable.	

3. Liquid stains		
0	Liquid stains are completely absent.	
1	Slight and/or localized evidence of liquid stains is visible on the disc.	
2	Slight evidence of liquid stains is visible all over the disc.	
3	Evidence of liquid stains is clearly visible all over the disc.	
4	Liquid stains make the disc unplayable.	

4. Mold		
0	Mold is completely absent.	
1	Faint evidence of mold is visible on small portions of the disc.	
2	Clear evidence of mold is visible on small portions of the disc.	
3	Faint evidence of mold is visible all over the disc surface.	

4	Clear evidence of mold is visible all over the disc surface.	

5. Pests		
0	Pests are completely absent.	
1	Evidence of pests is slightly visible on limited portions of the disc.	
2	Evidence of pests is clearly visible on limited portions of the disc.	
3	Evidence of pests is slightly visible all over the disc surface.	
4	Evidence of pests is clearly visible all over the disc surface.	

6. Other bio[logical contamination]		
0	Other bio are completely absent.	
1	Evidence of other bio is slightly visible on limited portions of the disc.	
2	Evidence of other bio is clearly visible on limited portions of the disc.	
3	Evidence of other bio is slightly visible all over the disc.	
4	Evidence of other bio is clearly visible all over the disc.	

7. Corrosion		
0	No sign of corrosion.	
1	A negligible evidence of corrosion is visible on the disc surface.	
2	A considerable evidence of corrosion is visible on the disc surface, but it does not affect playability.	
3	A considerable evidence of corrosion is visible on the disc surface, and it affects playability.	
4	The disc is not playable due to corrosion.	

8. Imprinting		
0	Imprinting is completely absent.	
1	A negligible evidence of imprinting.	

2	A considerable evidence of imprinting, not affecting playability.	
3	A considerable evidence of imprinting, affecting playability.	
4	The disc is not playable due to imprinting.	

9. Chemical residue		
0	No sign of chemical residue.	
1	A negligible evidence of chemical residue.	
2	A considerable evidence of chemical residue, not affecting playability.	
3	A considerable evidence of chemical residue, affecting playability.	
4	The disc is not playable due to chemical residue.	

10. Discoloration		
0	No sign of discoloration.	
1	A negligible evidence of discoloration.	
2	A considerable evidence of discoloration, not affecting playability.	
3	A considerable evidence of discoloration, affecting playability.	
4	The disc is not playable due to discoloration.	

11. Waxy exudate		
0	No sign of waxy exudate.	
1	A negligible evidence of waxy exudate.	
2	A considerable evidence of waxy exudate, not affecting playability.	
3	A considerable evidence of waxy exudate, affecting playability.	
4	The disc is not playable due to waxy exudate.	

12. Wear

0	Signs of wear are completely absent.	
1	A negligible evidence of wear.	
2	A considerable evidence of wear, not affecting playability.	
3	A considerable evidence of wear, affecting playability.	
4	The disc is not playable due to wear.	

13. Scratches, gouges		
0	Scratching, gouging is completely absent.	
1	Negligible scratching, gouging is visible on the disc surface.	
2	Very light scratching, gouging is visible on the disc surface, playability might be affected in specific points.	
3	Scratches, gouges are clearly visible on the disc surface, playability is seriously affected.	
4	Scratches, gouges make the disc unplayable.	

14. Cracks, chips		
0	Cracks, chips are completely absent.	
1	Negligible presence of cracks and chips. Playability is not affected.	
2	Small cracks and chips are present. Restoration is required in order to play the disc.	
3	Significant presence of cracks and chips. Restoration can be attempted in order to extract portions of the signal.	
4	Cracks, chips make the disc unplayable.	

15. Warp		
0	Warping is completely absent.	
1	Negligible presence of warping, does not affect playability.	
2	Slight presence of warping, might affect playability.	

3	Significant presence of warping, restoration can be attempted in order to extract portions of the signal.	
4	Warping makes the disc unplayable.	

16. Crazing		
0	Crazing is completely absent.	
1	Negligible presence of crazing, does not affect playability.	
2	Slight presence of crazing, might affect playability.	
3	Significant presence of crazing, restoration can be attempted in order to extract portions of the signal.	
4	The disc is not playable due to crazing.	

17. Peeling		
0	Peeling is completely absent.	
1	Negligible presence of peeling, does not affect playability.	
2	Slight presence of peeling, might affect playability.	
3	Significant presence of peeling, restoration can be attempted in order to extract portions of the signal.	
4	Peeling makes the disc unplayable.	

18. Label damage		
0	Label absent or in perfect condition.	
1	Negligible damage to the label, does not affect playability nor readability.	
2	Slight damage to the label, may disturb replay or compromise readability.	
3	Significant damage to the label, text is not readable and the disc playability might be significantly disturbed.	

4	The label is irreversibly damaged and so is the underlying portion of the disc.	

19. Centre damage or fault		
0	No sign of centre damage or fault.	
1	Negligible evidence of centre damage or fault. Playability is not affected.	
2	Slight evidence of centre damage or fault. Playability might be partially affected.	
3	Significant evidence of centre damage or fault. Playability is significantly affected.	
4	Centre damage or fault makes the disc unplayable.	

20. Blister		
0	Blisters are completely absent.	
1	Negligible evidence of blisters. Playability is not affected.	
2	Slight evidence of blisters. Playability might be partially affected.	
3	Significant presence of blisters. Playability is significantly affected.	
4	Blisters make the disc unplayable.	

C.5 Digital non-audio carriers

1. Dirt, dust or oil		
0	Dirt, dust or oil are completely absent.	
1	Slight and/or localized evidence of dirt, dust or oil is visible on the carrier.	
2	Slight evidence of dirt, dust or oil is visible on the carrier.	
3	Evidence of dirt, dust or oil is clearly visible on the carrier.	

4	Dirt, dust or oil evidence makes the carrier unreadable.	

2. Other particulates		
0	No sign of other particulates.	
1	Slight and/or localized evidence of other particulates is visible on the carrier.	
2	Slight evidence of other particulates is visible on the carrier.	
3	Evidence of other particulates is clearly visible on the carrier.	
4	Evidence of other particulates makes the carrier unreadable.	

3. Liquid stains		
0	Liquid stains are completely absent.	
1	Slight and/or localized evidence of liquid stains is visible on the carrier.	
2	Slight evidence of liquid stains is visible on the carrier.	
3	Evidence of liquid stains is clearly visible on the carrier.	
4	Liquid stains make the carrier unreadable.	

4. Mold		
0	Mold is completely absent.	
1	Faint evidence of mold is visible on small portions of the carrier, not affecting playability. Restoration is limited to simple cleaning.	
2	A significant evidence of mold is visible on small portions of the carrier. May or may not affect playability.	
3	A significant evidence of mold is visible on the carrier, affecting playability.	
4	The carrier is unreadable due to mold.	

5. Pests		
0	Pests are completely absent.	
1	Evidence of pests is slightly visible on limited portions of the carrier, not affecting playability.	
2	Evidence of pests is clearly visible on limited portions of the carrier. May or may not affect playability.	
3	Evidence of pests is visible on the carrier, affecting readability.	
4	The carrier is not readable due to pests.	

6. Other bio[logical contamination]		
0	Other bio are completely absent.	
1	Evidence of other bio is slightly visible on the carrier, not affecting readability.	
2	Evidence of other bio is clearly visible on the carrier. May or may not affect readability.	
3	Evidence of other bio is slightly visible on the carrier, affecting readability.	
4	The carrier is not readable due to other bio.	

7. Corrosion		
0	No sign of corrosion.	
1	A negligible evidence of corrosion is visible on the carrier.	
2	A significant evidence of corrosion is visible on the carrier, not affecting readability.	
3	A significant evidence of corrosion is visible on the carrier, affecting readability.	
4	The carrier is not readable due to corrosion.	

8. Scratches, gouges

0	Scratching, gouging is completely absent.	
1	Negligible scratching, gouging is visible on the carrier.	
2	Very light scratching, gouging is visible on the carrier. Readability might be affected in specific points.	
3	Scratching, gouging is clearly visible on the carrier. Readability is seriously affected.	
4	Scratching, gouging make the carrier unreadable.	

9. Cracks, chips		
0	Cracks, chips are completely absent.	
1	Negligible presence of cracks and chips. Readability is not affected.	
2	Small cracks and chips are present on the carrier or on the housing. Restoration may be required in order to read the carrier.	
3	Evident cracks/breaks on the carrier or on the carrier housing.	 Note: in case of carriers enclosed in a plastic/metal housing (HHDs), breaks do not necessarily affect the data.
4	Cracks, chips make the carrier unreadable.	

10. Warp		
0	Warping is completely absent.	
1	Negligible presence of warping, does not affect readability.	
2	Slight presence of warping, might affect readability.	

3	Significant presence of warping, restoration can be attempted in order to extract the data.	
4	Warping makes the carrier unreadable.	

C.6 MiniDiscs

1. Dirt, dust or oil		
0	Dirt, dust or oil are completely absent.	
1	Slight and/or localized evidence of dirt, dust or oil is visible on the tape or on the housing.	
2	Slight evidence of dirt, dust or oil is visible throughout the tape or on the housing.	
3	Evidence of dirt, dust or oil is clearly visible throughout the tape or on the housing.	
4	Dirt, dust or oil evidence makes the tape unplayable.	

2. Other particulates		
0	Other particulates are completely absent.	
1	Slight and/or localized evidence of other particulates is visible on the tape or on the housing.	
2	Slight evidence of other particulates is visible throughout the tape or on the housing.	
3	Evidence of other particulates is clearly visible throughout the tape or on the housing.	
4	Evidence of other particulates makes the tape unplayable.	

3. Liquid stains		
0	Liquid stains are completely absent.	

1	Slight and/or localized evidence of liquid stains is visible on the tape or on the housing.	
2	Slight evidence of liquid stains is visible throughout the tape or on the housing.	
3	Evidence of liquid stains is clearly visible throughout the tape or on the housing.	
4	Liquid stains make the tape unplayable.	

4. Mold		
0	No sign of mold.	
1	Faint evidence of mold is visible on small portions of the tape or of the housing.	
2	Clear evidence of mold is visible on small portions of the tape or of the housing.	
3	Faint evidence of mold is visible all over the tape or all over the housing.	
4	Clear evidence of mold is visible all over the tape or all over the housing.	

5. Pests		
0	Pests are completely absent.	
1	Evidence of pests is slightly visible on limited portions of the tape or of the housing.	
2	Evidence of pests is clearly visible on limited portions of the tape or of the housing.	
3	Evidence of pests is slightly visible all over the tape or all over the housing.	
4	Evidence of pests is clearly visible all over the tape or all over the housing.	

6. Other bio[logical contamination]		
0	Other bio is completely absent.	

1	Evidence of other bio is slightly visible on limited portions of the tape or of the housing, not affecting playability.	
2	Evidence of other bio is clearly visible on limited portions of the tape. May or may not affect playability.	
3	Evidence of other bio is visible throughout the tape or all over the housing, affecting playability	
4	Evidence of other bio is clearly visible throughout the tape or all over the housing.	

7. Scratches, gouges		
0	Scratching, gouging is completely absent.	
1	Negligible scratching, gouging is visible.	
2	Very light scratching, gouging is visible, playability might be affected in specific points.	
3	Scratches, gouges are clearly visible, playability is seriously affected.	
4	Scratches, gouges make the tape unplayable.	

8. Cracks, chips		
0	Cracks, chips are completely absent.	
1	Negligible presence of cracks and chips. Playability is not affected.	
2	Small cracks and chips are present. Restoration is required in order to play the disc.	
3	Significant presence of cracks and chips. Restoration can be attempted in order to extract portions of the signal.	
4	Cracks, chips make the disc unplayable.	

9. Warp

0	Warping is completely absent.	
1	Negligible presence of warping, does not affect playability.	
2	Slight presence of warping, might affect playability.	
3	Significant presence of warping, restoration can be attempted in order to extract portions of the signal.	
4	Warping makes the tape unplayable.	

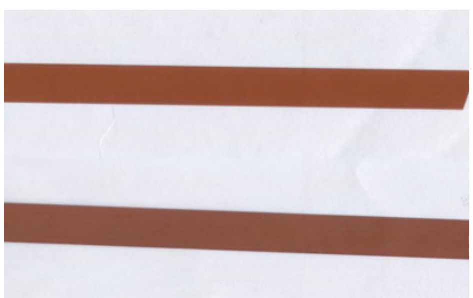
10. Damaged shell/housing		
0	Shell/housing in perfect condition.	
1	Minor damage to the shell/housing, not affecting playability. Restoration is not required.	
2	Minor damage to the shell/housing. Restoration is recommended especially if the shell/housing condition affects the tape playability.	
3	Major damage to the shell/housing. Restoration is required in order to play the tape.	
4	The shell/housing is so damaged that the tape is unplayable.	

D

Supplementary material: chemical analyses

This Chapter contains all the figures and the tables that have not been included in text in Chapter 8. Additional documentation is available separately[1].

D.1 Magnetic tape samples



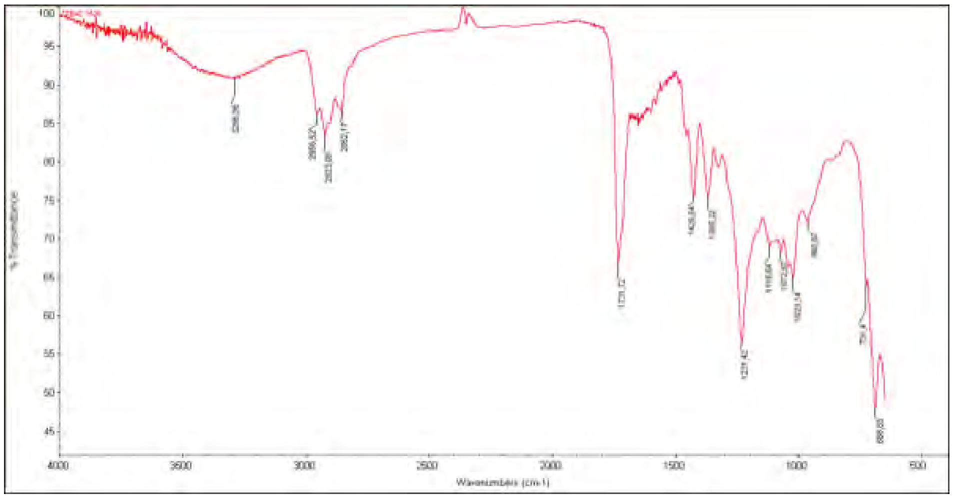
(a) Tape sample A

(b) Tape sample D

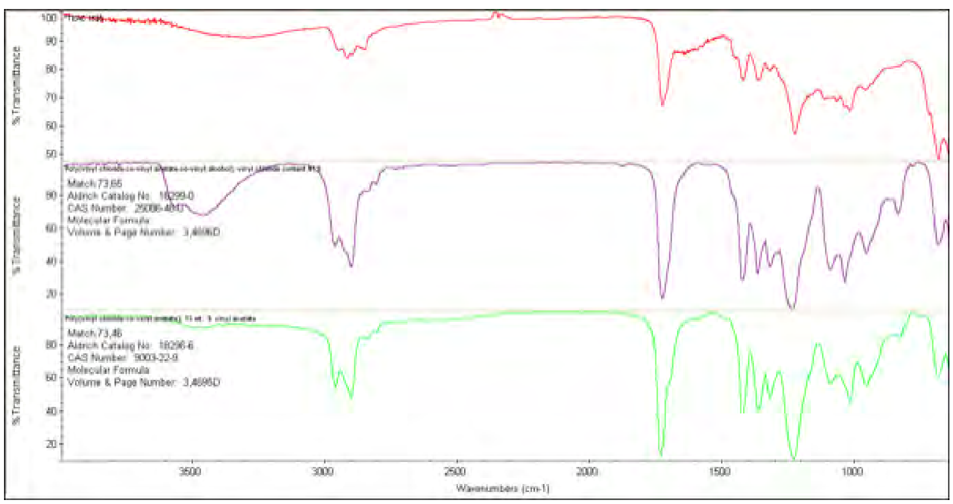
Fig. D.1: (a) Sample A: shiny side (top), identified as the base of the tape, and matt side (bottom), with the magnetic material; (b) Tape sample D: shiny side (top), with the magnetic material, and matt side (bottom), identified as the base of the tape. Please see Chapter 8 for further details on the identification, achieved by means of the FTIR spectroscopy in ATR and the ESEM analysis.

[1] `http://www.dei.unipd.it/~bressanf/tesi/tesi2013/`

D.2 FTIR spectroscopic analysis in ATR

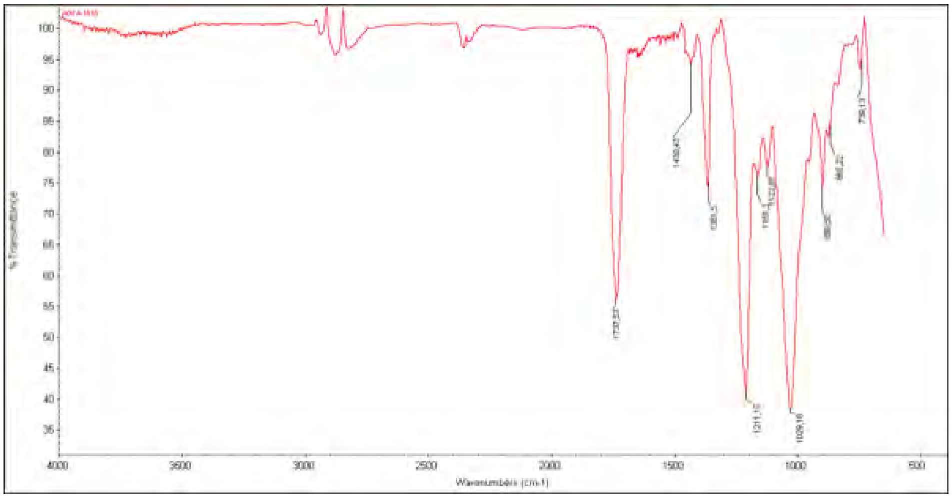


(a) Tape sample A: matt side

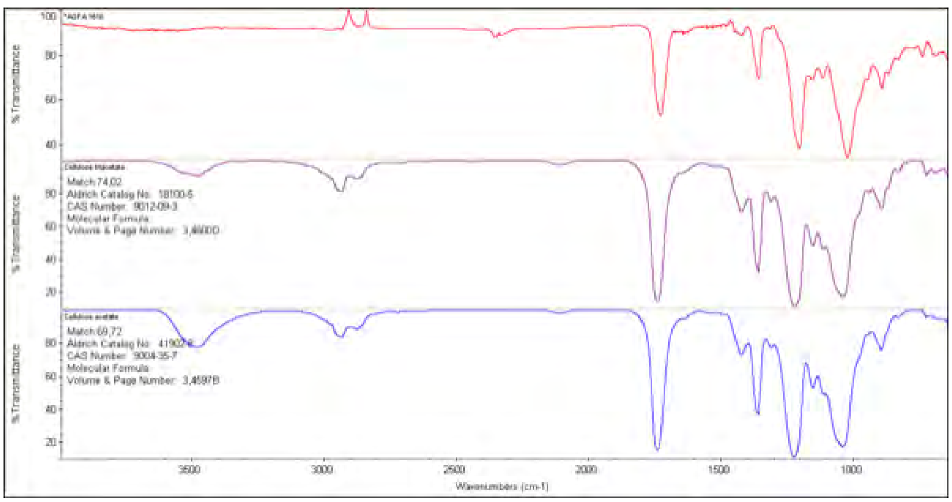


(b) Tape sample A: matt side identification

Fig. D.2: Tape sample A: (a) matt side; (b) matt side identification.

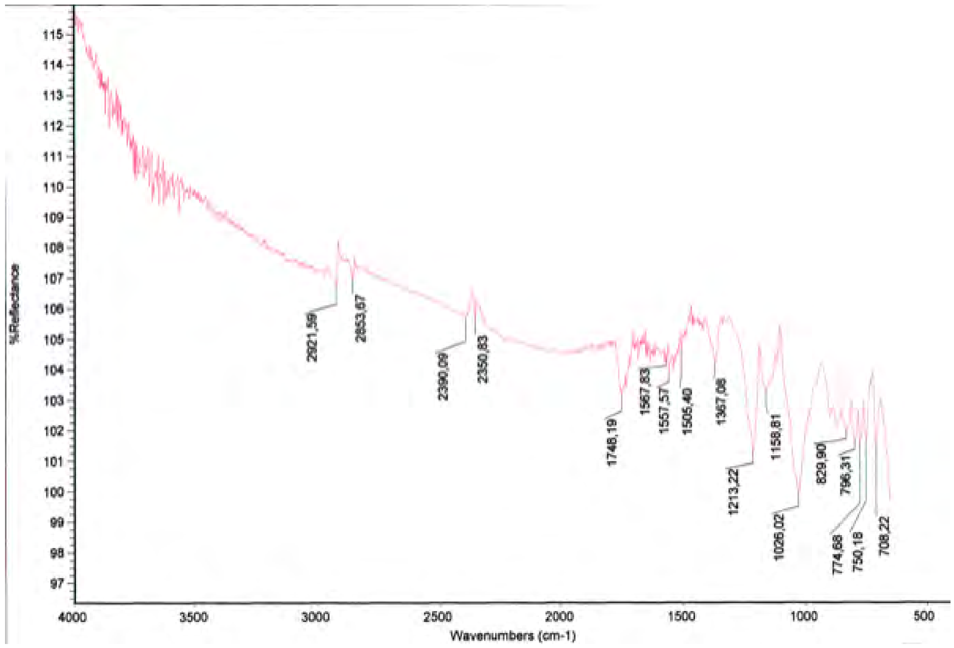


(a) Tape sample B: shiny side

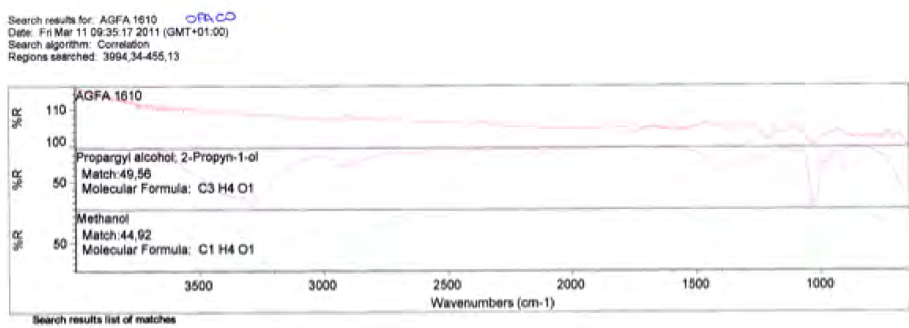


(b) Tape sample B: matt side identification

Fig. D.3: Tape sample B: (a) shiny side; (b) shiny side identification.



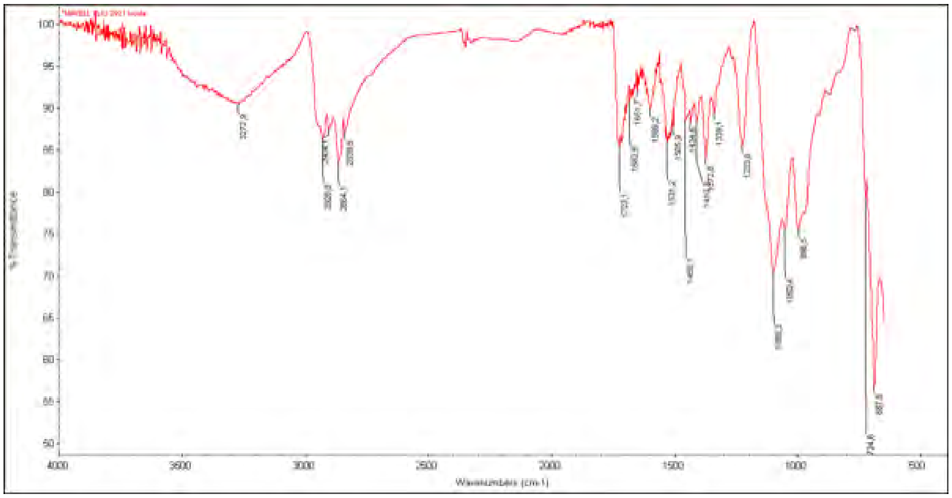
(a) Tape sample B: matt side



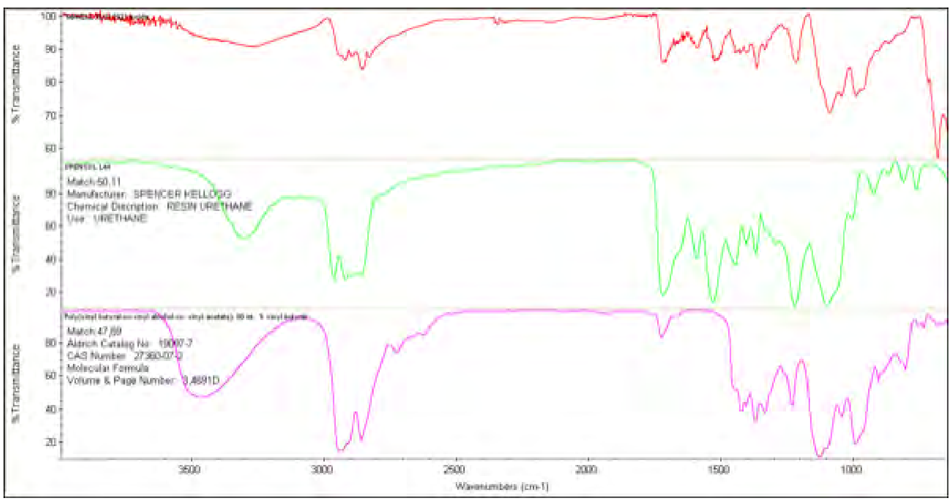
	Index	Match	Compound Name	Library Name
1	1213	49,56	Propargyl alcohol; 2-Propyn-1-ol	Hummel Polymer and Additives
2	1344	44,92	Methanol	Hummel Polymer and Additives
3	1737	43,00	2-Propyn-1-ol	Hummel Polymer and Additives
4	990	42,51	Methyl Alcohol	Coatings Technology
5	2506	41,43	Skydrol	Coatings Technology
6	1334	38,88	V-8291 Purple	Coatings Technology
7	1981	37,42	Tributyl Phosphate	Coatings Technology
8	18260	36,76	Samarium(III) nitrate hexahydrate, 99.9%	HR Aldrich FT-IR Collection Edition II
9	6581	35,76	1-Bromo-2,5-dichlorobenzene	HR Aldrich FT-IR Collection Edition II
10	1596	34,06	Tetravalent Metal Carboxyethyl Phosphonate	Coatings Technology

(b) Tape sample B: matt side identification

Fig. D.4: Tape sample B: (a) matt side; (b) matt side identification.

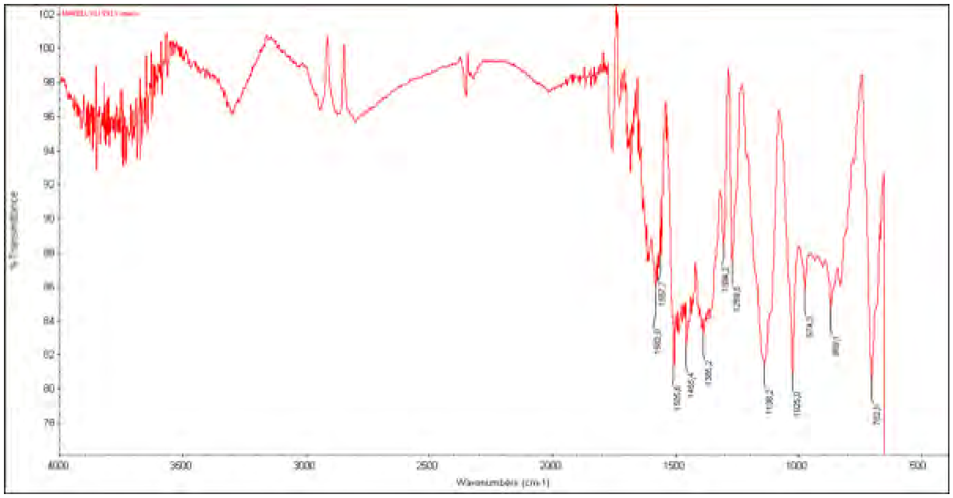


(a) Tape sample C: shiny side

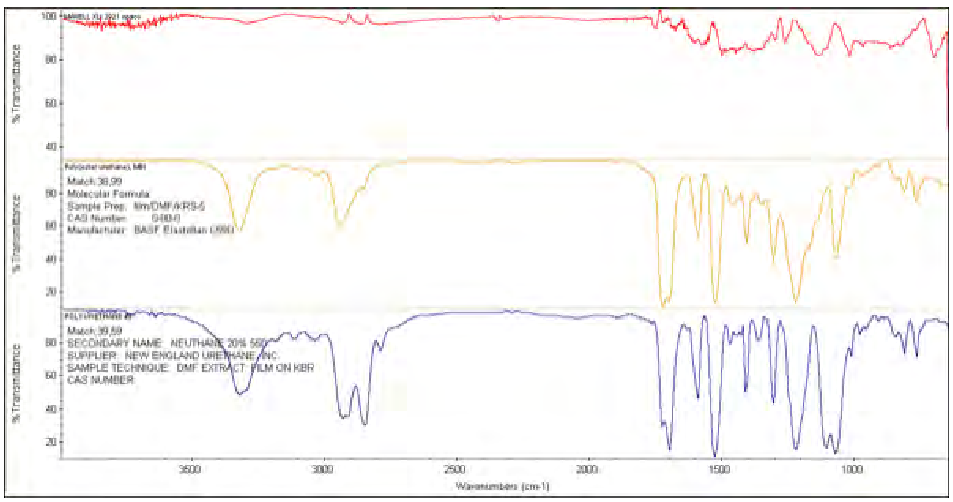


(b) Tape sample C: shiny side identification

Fig. D.5: Tape sample C: (a) shiny side; (b) shiny side identification.

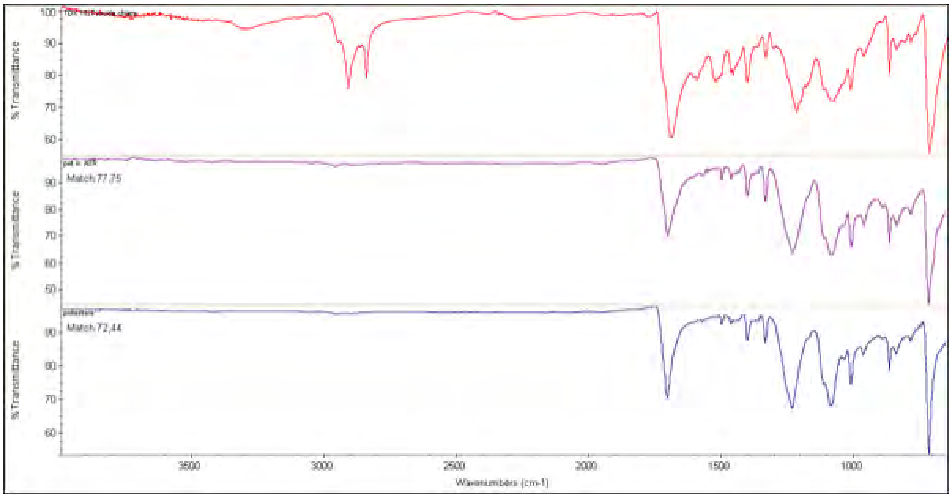


(a) Tape sample C: matt side

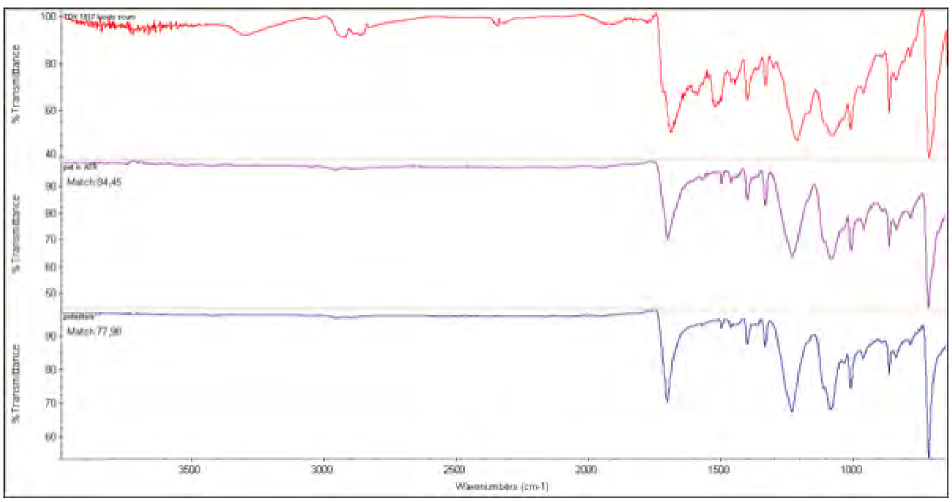


(b) Tape sample C: matt side identification

Fig. D.6: Tape sample C: (a) matt side; (b) matt side identification.

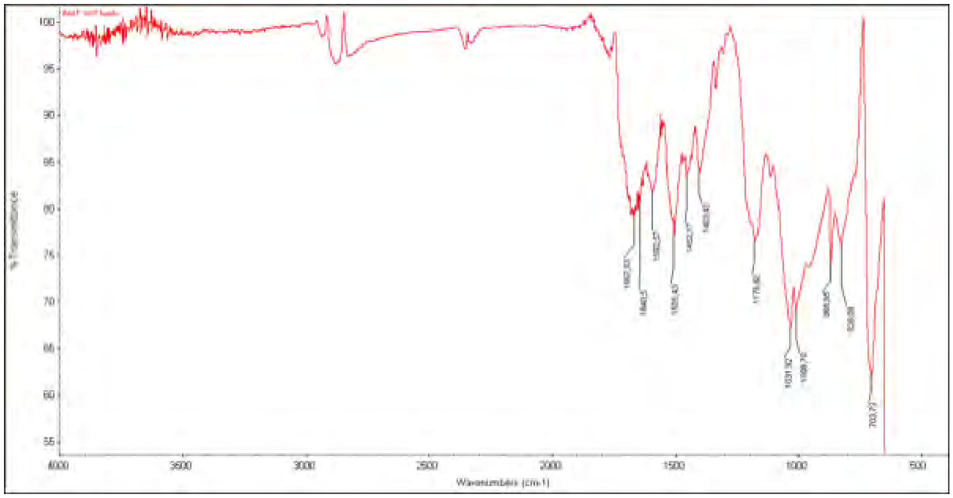


(a) Tape sample D: shiny side identification

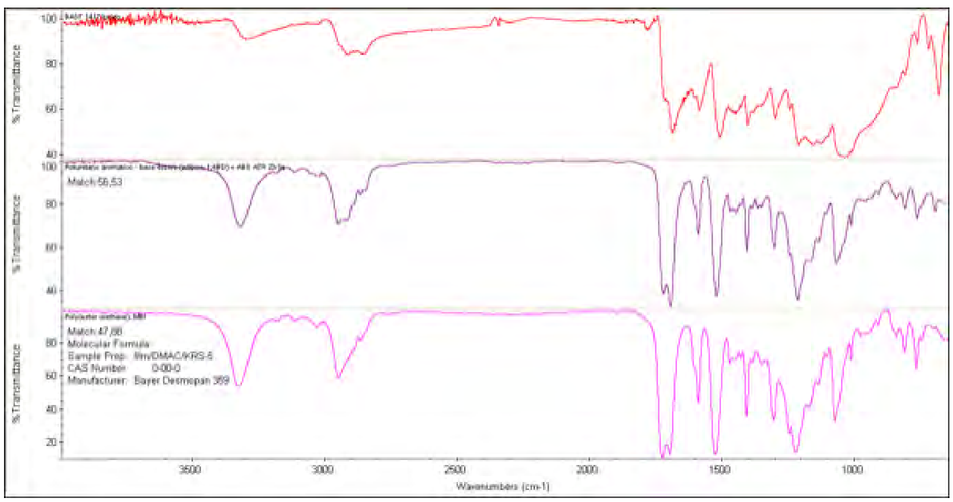


(b) Tape sample D: matt side identification

Fig. D.7: Tape sample D: (a) shiny side identification; (b) matt side identification.

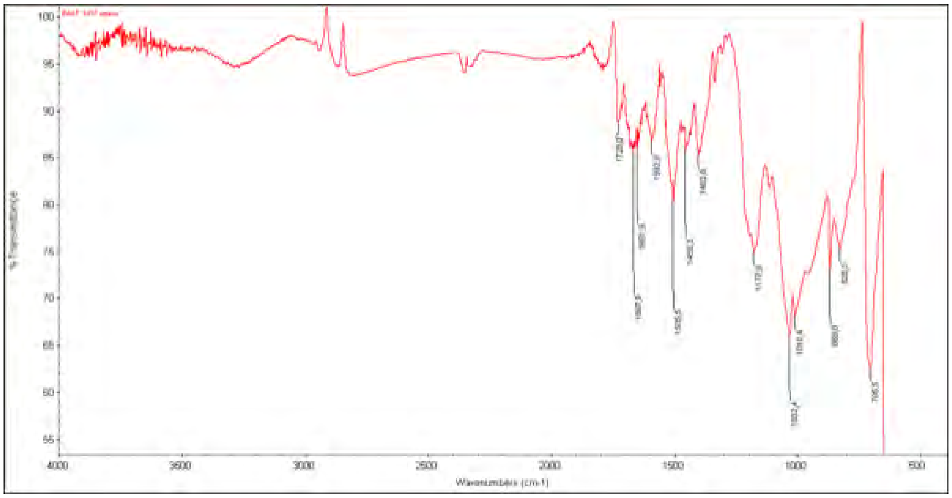


(a) Tape sample E: shiny side

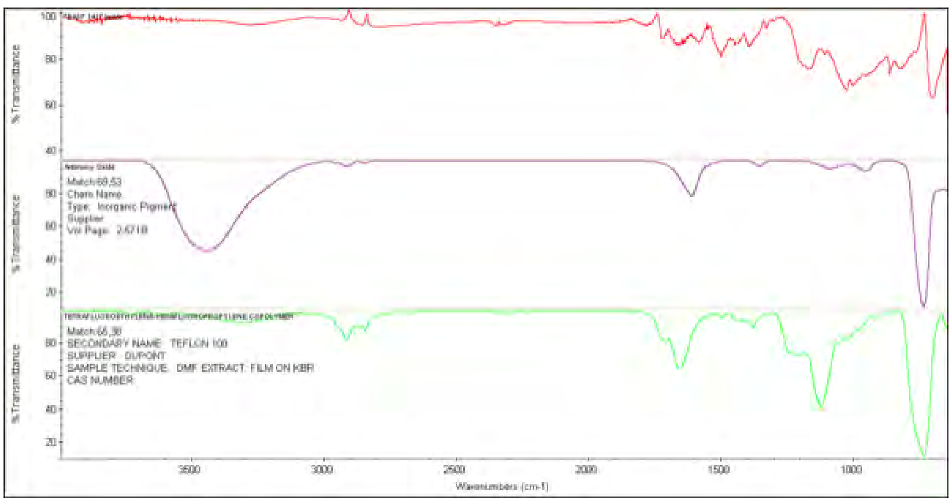


(b) Tape sample E: shiny side identification

Fig. D.8: Tape sample E: (a) shiny side; (b) shiny side identification.

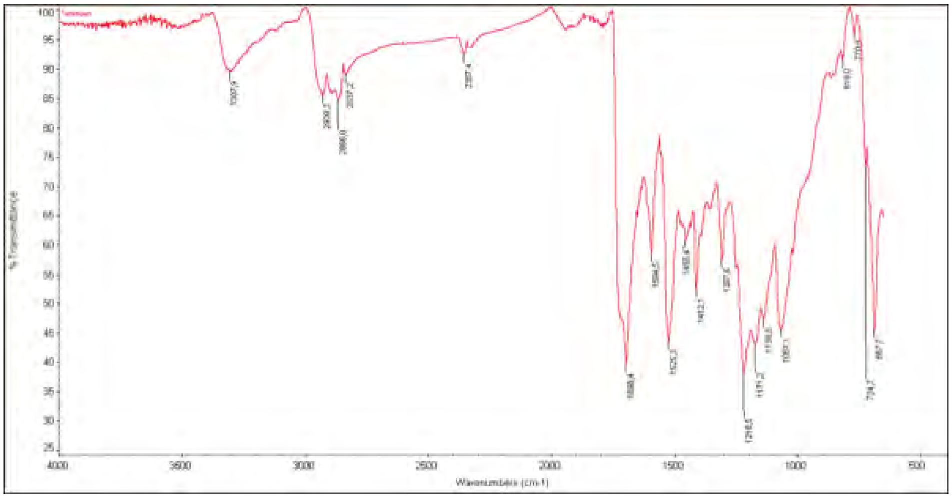


(a) Tape sample E: matt side

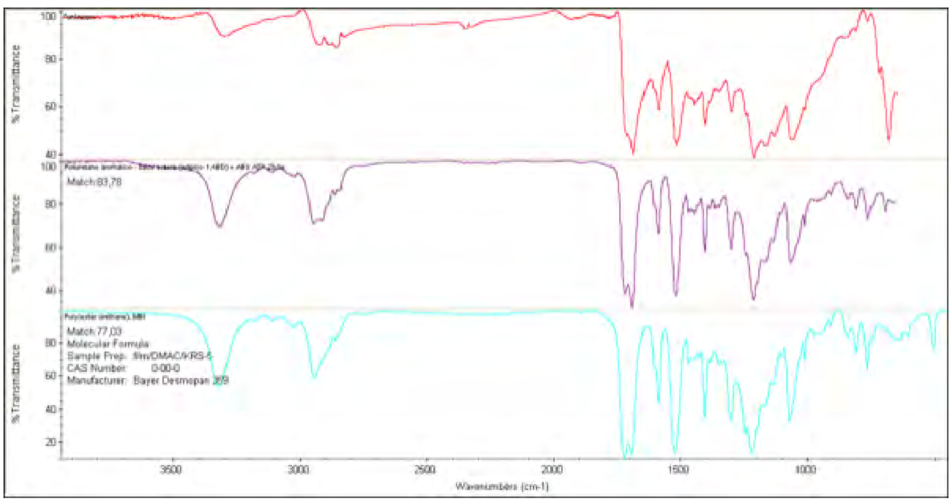


(b) Tape sample E: matt side identification

Fig. D.9: Tape sample E: (a) matt side; (b) matt side identification.

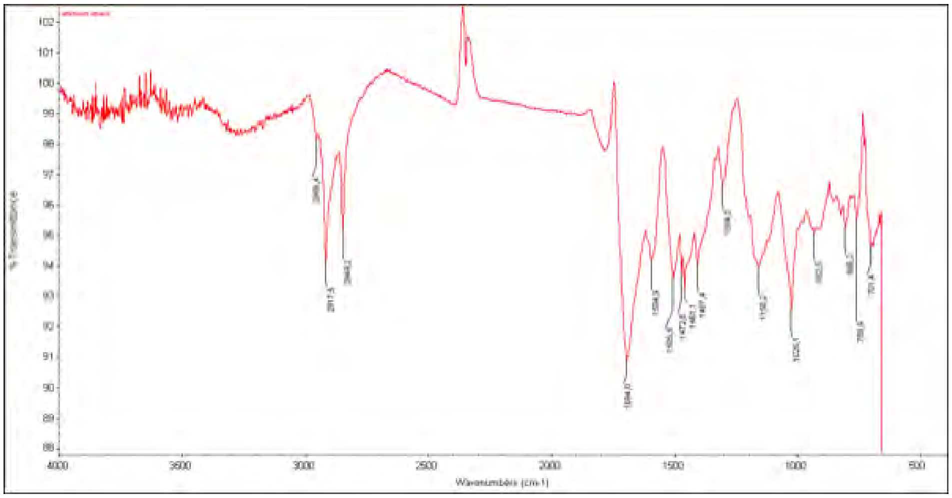


(a) Tape sample F: shiny side

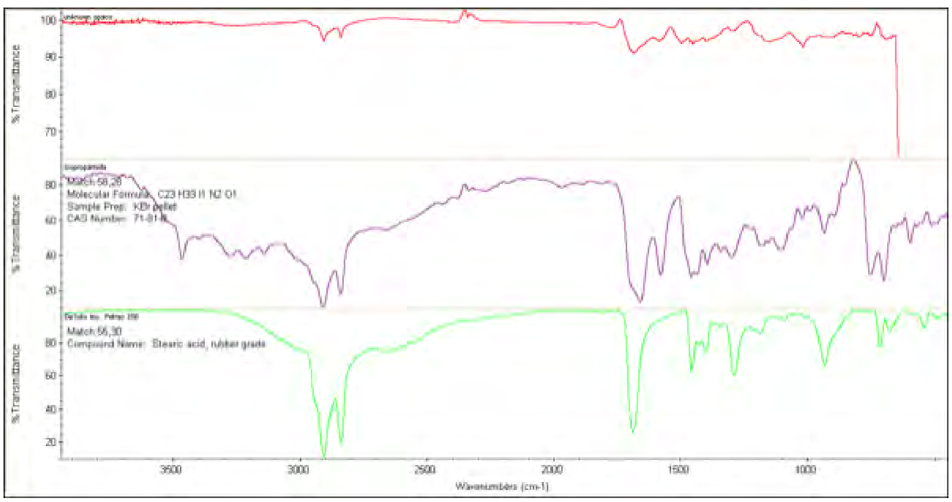


(b) Tape sample F: shiny side identification

Fig. D.10: Tape sample F: (a) shiny side; (b) shiny side identification.

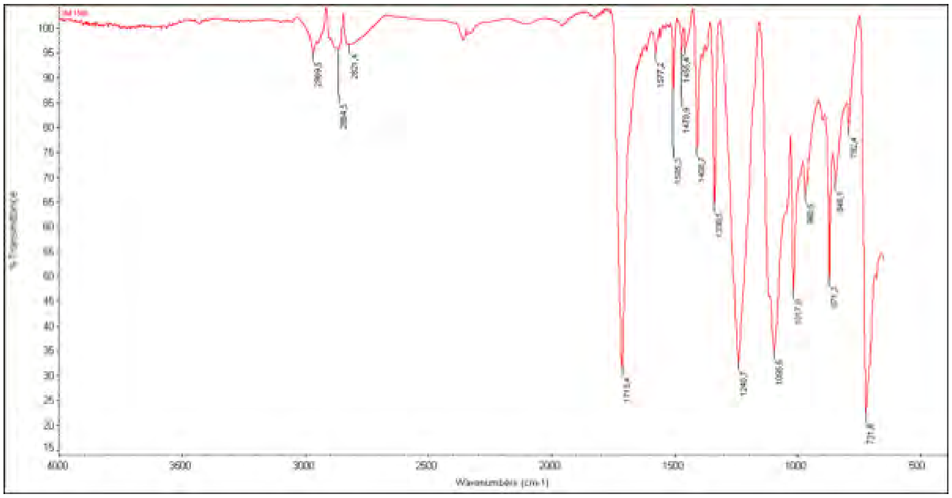


(a) Tape sample F: matt side

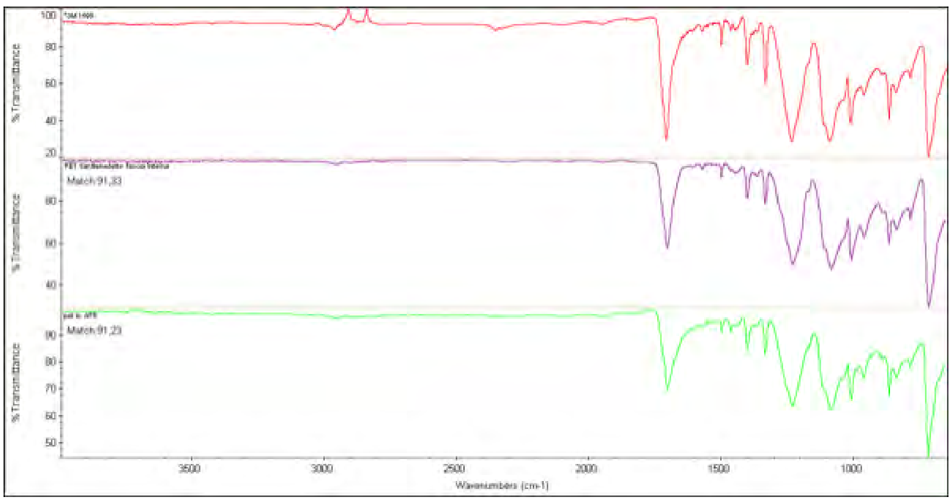


(b) Tape sample F: matt side identification

Fig. D.11: Tape sample F: (a) matt side; (b) matt side identification.

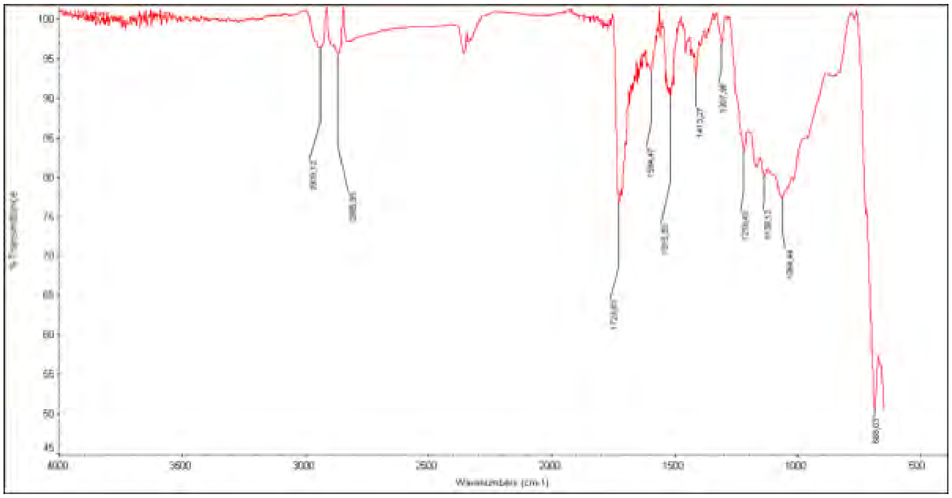


(a) Tape sample G: shiny side

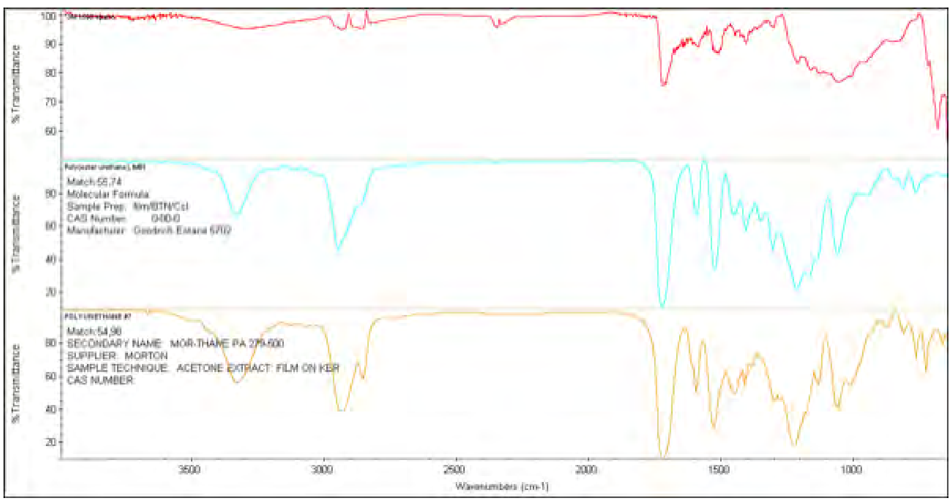


(b) Tape sample G: shiny side identification

Fig. D.12: Tape sample G: (a) shiny side; (b) shiny side identification.

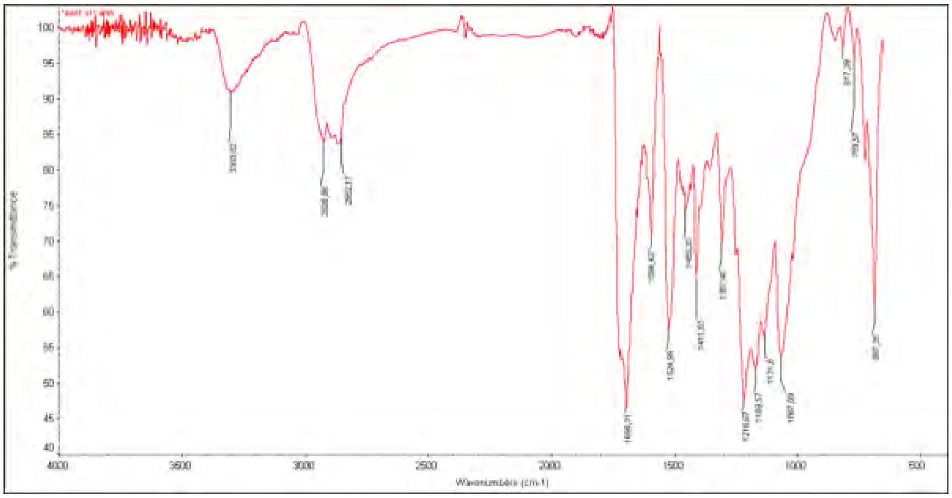


(a) Tape sample G: matt side

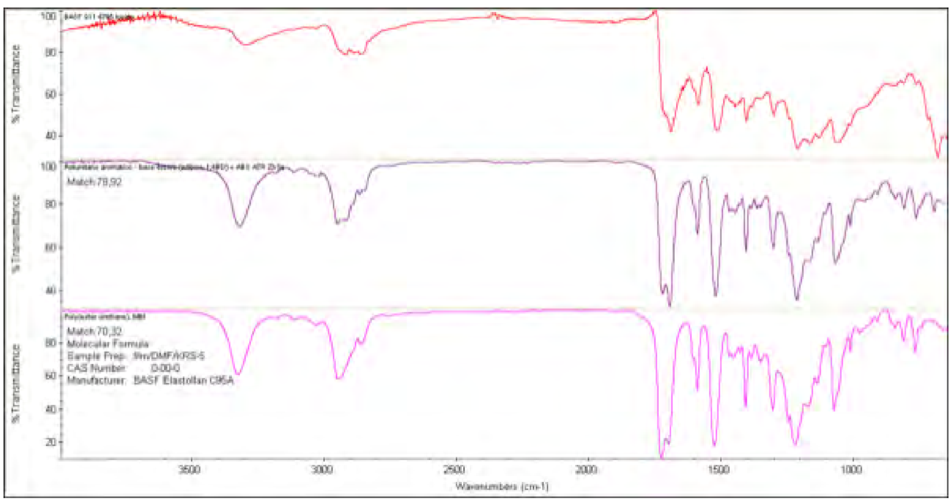


(b) Tape sample G: matt side identification

Fig. D.13: Tape sample G: (a) matt side; (b) matt side identification.

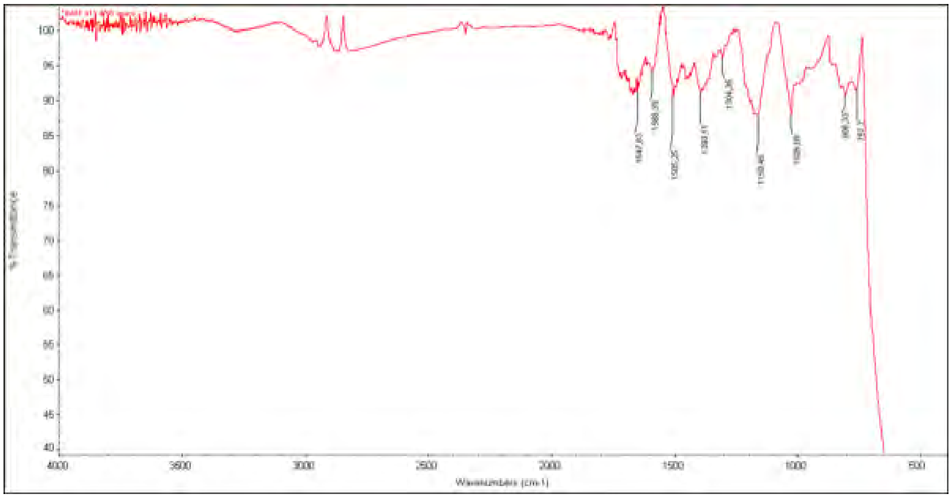


(a) Tape sample H: shiny side

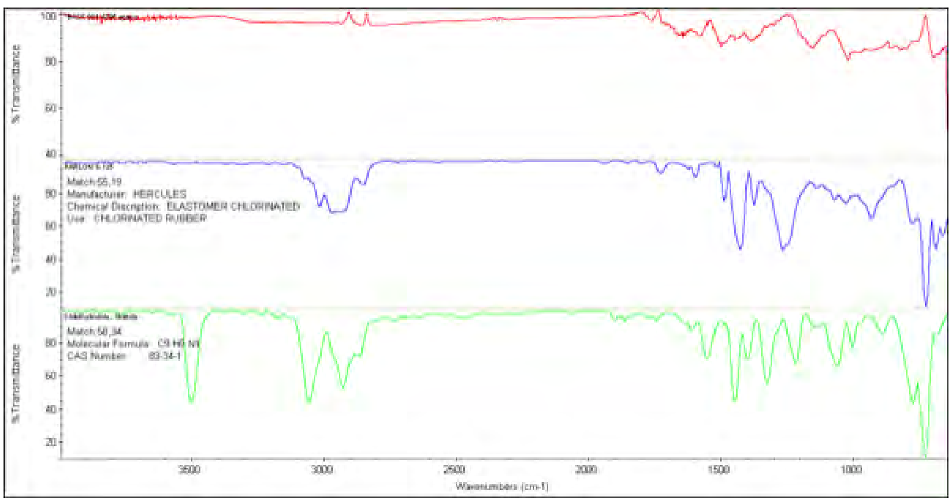


(b) Tape sample H: shiny side identification

Fig. D.14: Tape sample H: (a) shiny side; (b) shiny side identification.

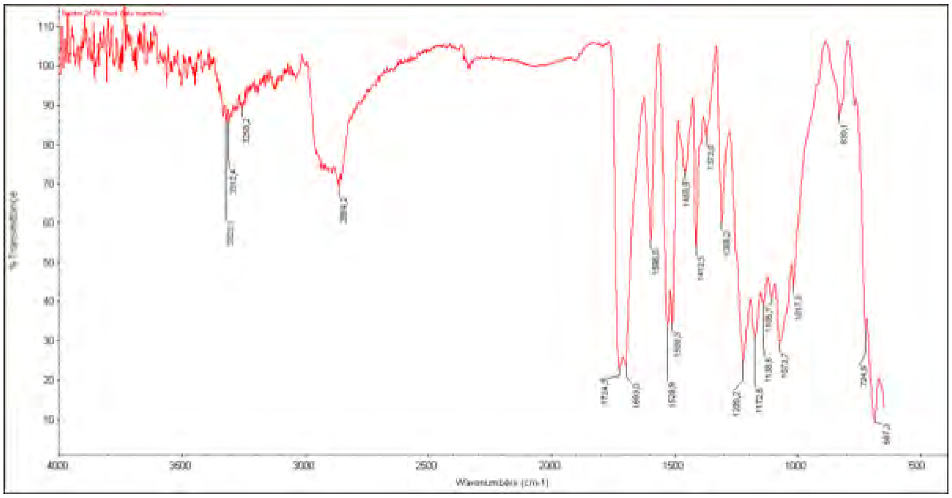


(a) Tape sample H: matt side

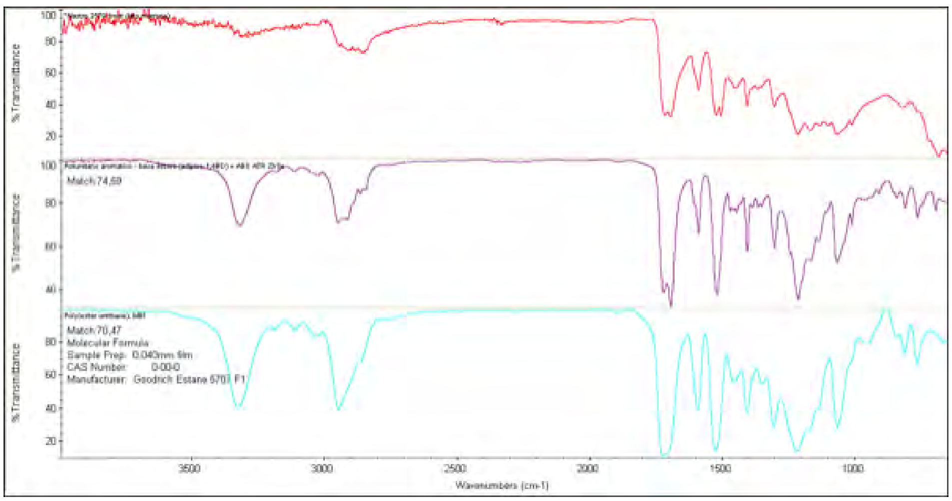


(b) Tape sample H: matt side identification

Fig. D.15: Tape sample H: (a) matt side; (b) matt side identification.

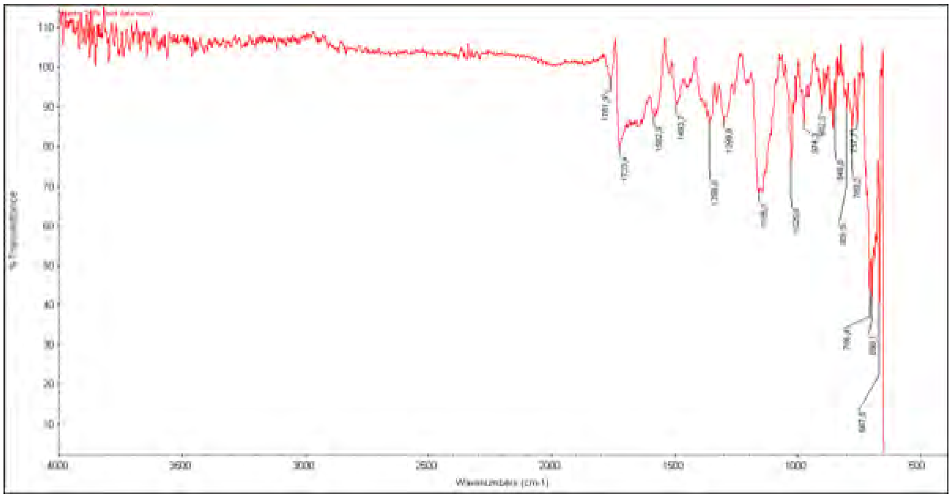


(a) Tape sample I: shiny side

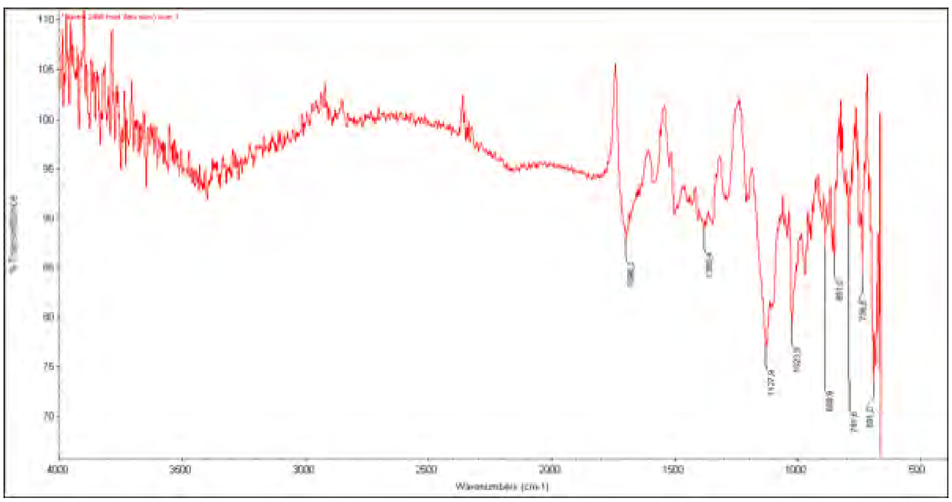


(b) Tape sample I: shiny side identification

Fig. D.16: Tape sample I: (a) shiny side; (b) shiny side identification.

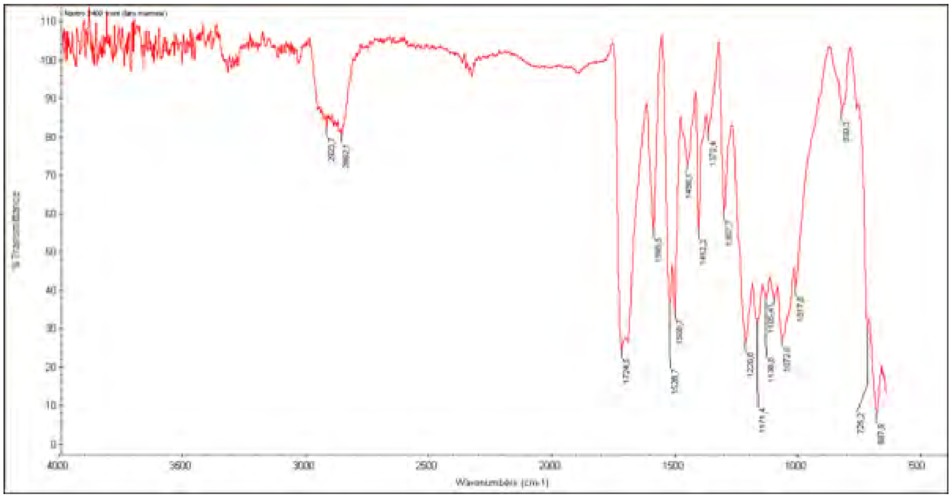


(a) Tape sample I: matt side

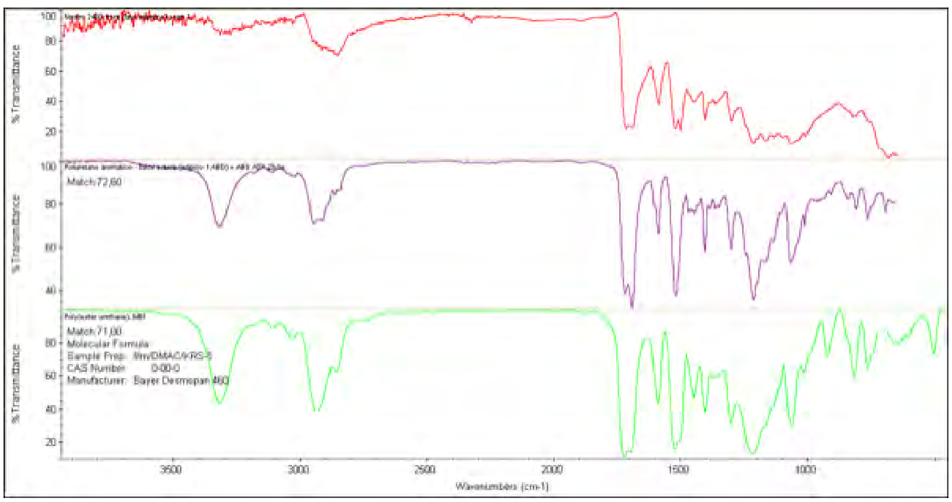


(b) Tape sample L: matt side

Fig. D.17: (a) Tape sample I: matt side. The poor quality of the analysis did not allow the identification of the material; (b) Tape sample L: matt side. The poor quality of the analysis did not allow the identification of the material.

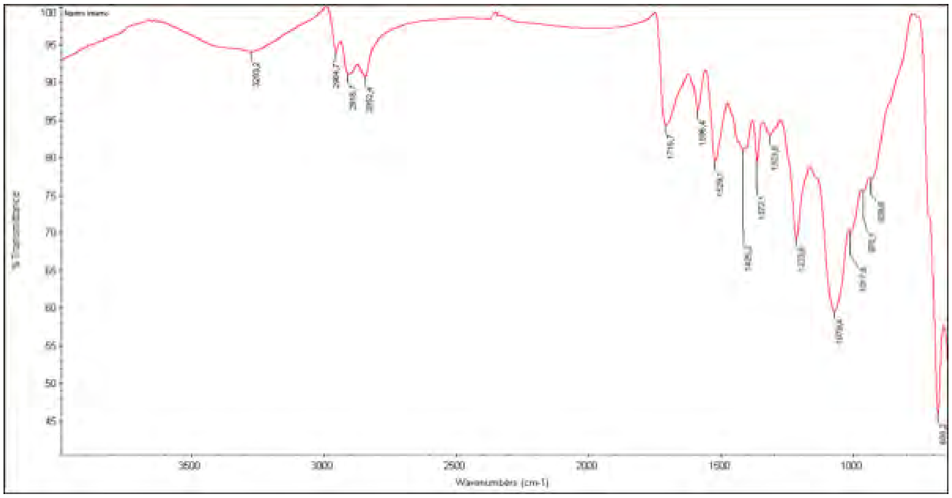


(a) Tape sample L: shiny side

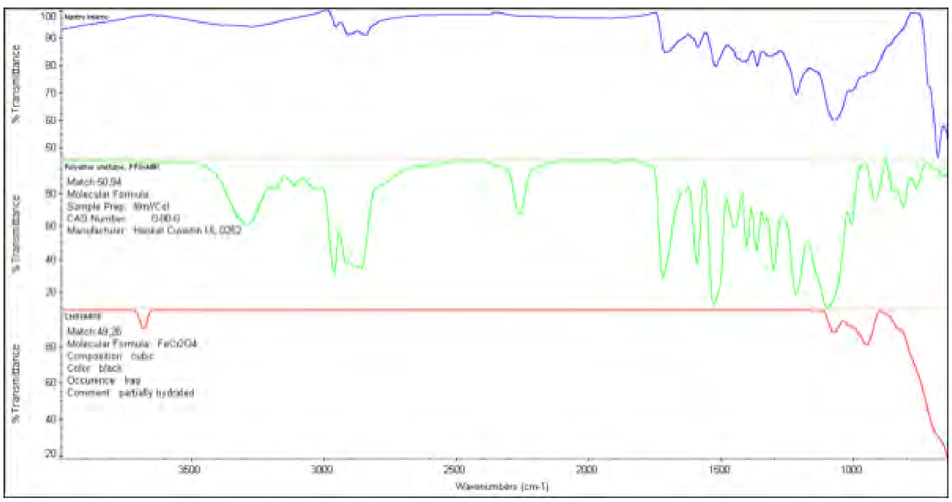


(b) Tape sample L: shiny side identification

Fig. D.18: Tape sample L: (a) shiny side; (b) shiny side identification.

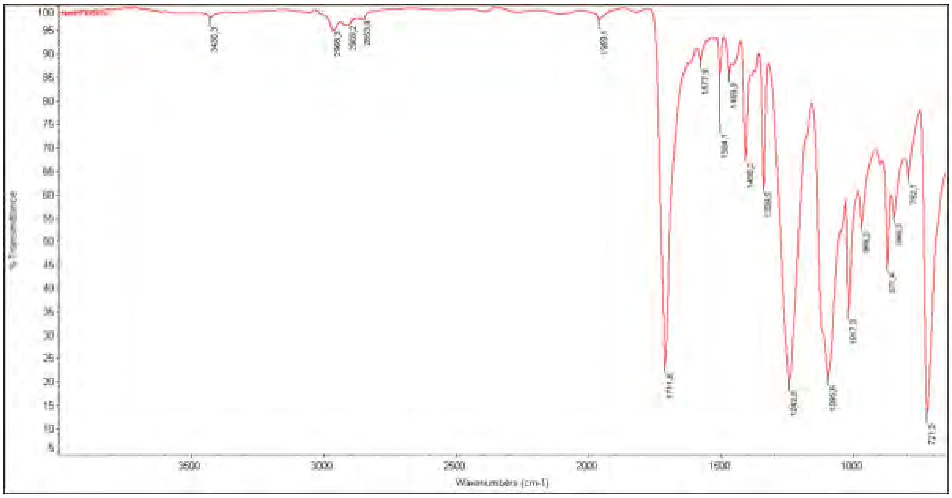


(a) Tape sample M: shiny side

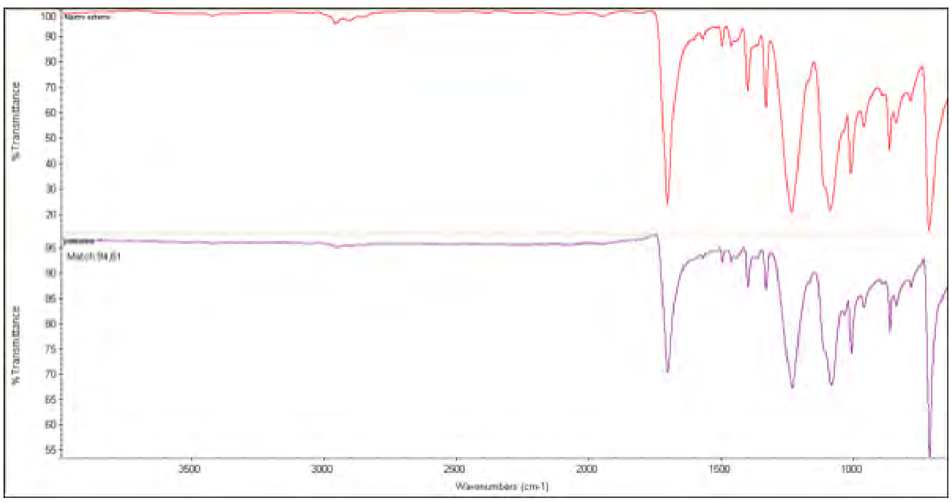


(b) Tape sample M: shiny side identification

Fig. D.19: Tape sample M: (a) shiny side; (b) shiny side identification.

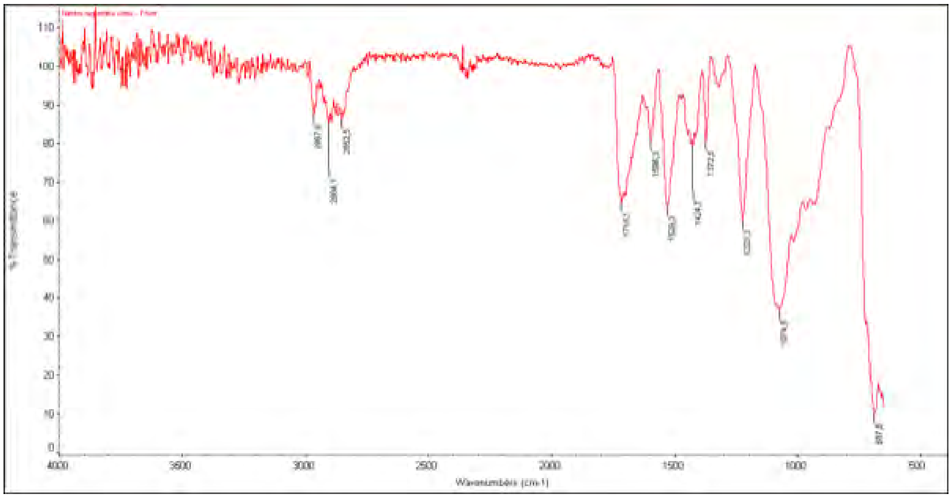


(a) Tape sample M: matt side

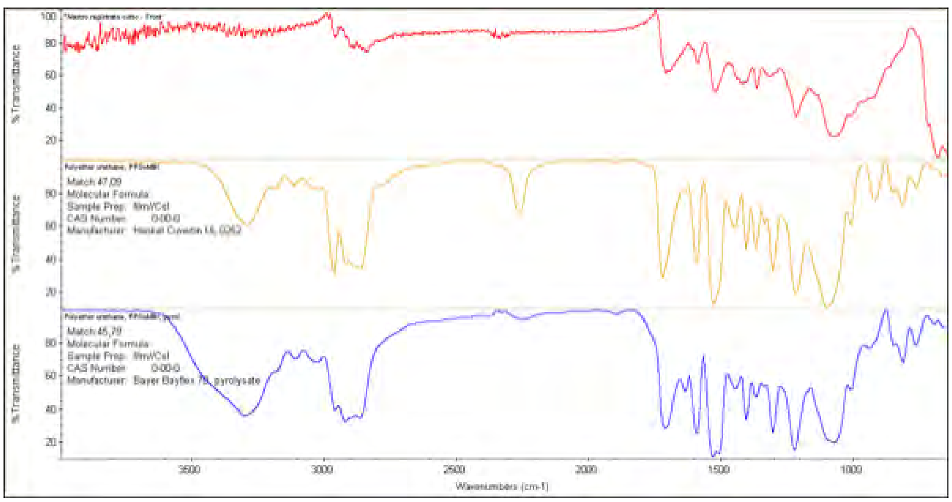


(b) Tape sample M: matt side identification

Fig. D.20: Tape sample M: (a) matt side; (b) matt side identification.

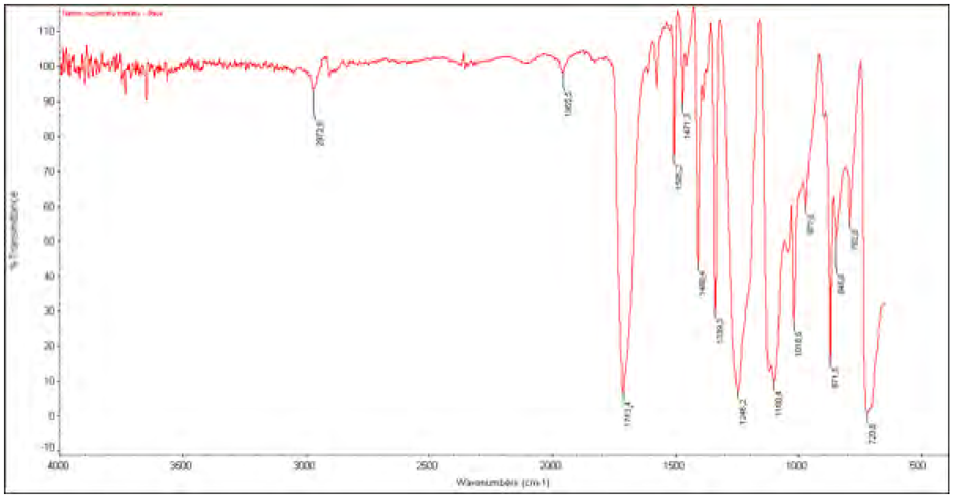


(a) Tape sample N: shiny side

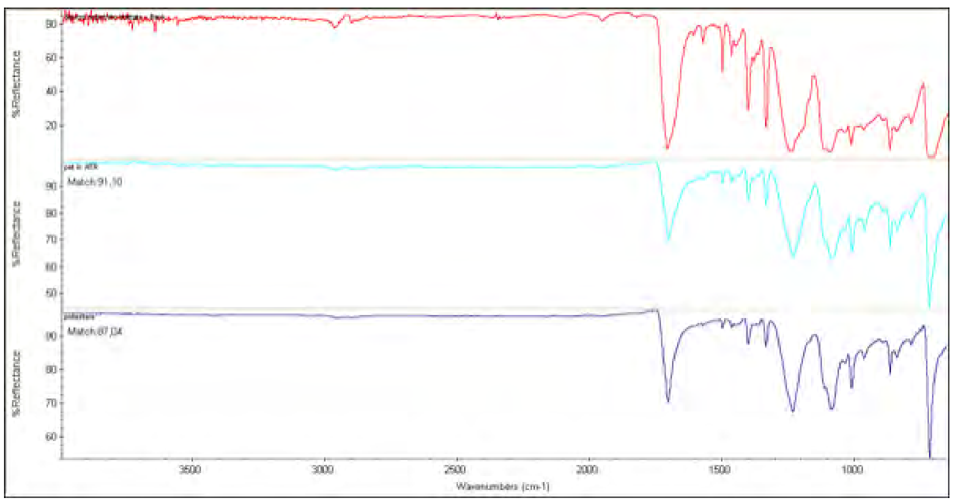


(b) Tape sample N: shiny side identification

Fig. D.21: Tape sample N: (a) shiny side; (b) shiny side identification.



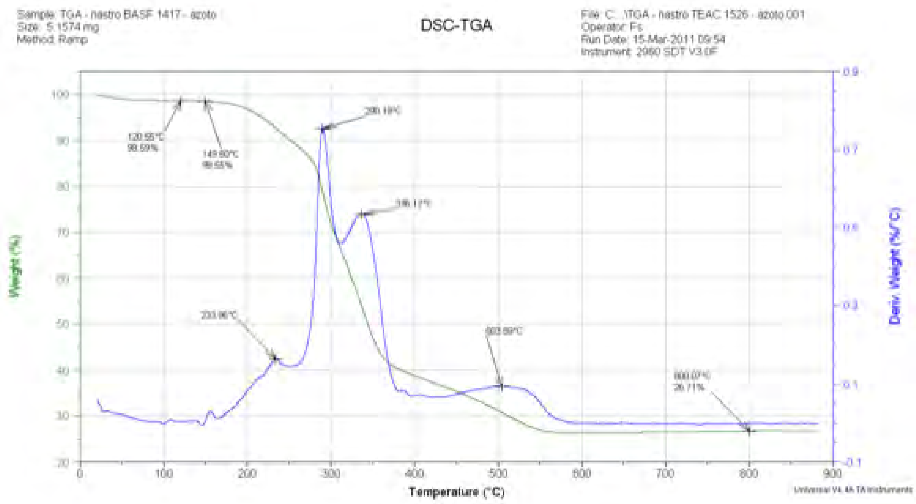
(a) Tape sample N: matt side



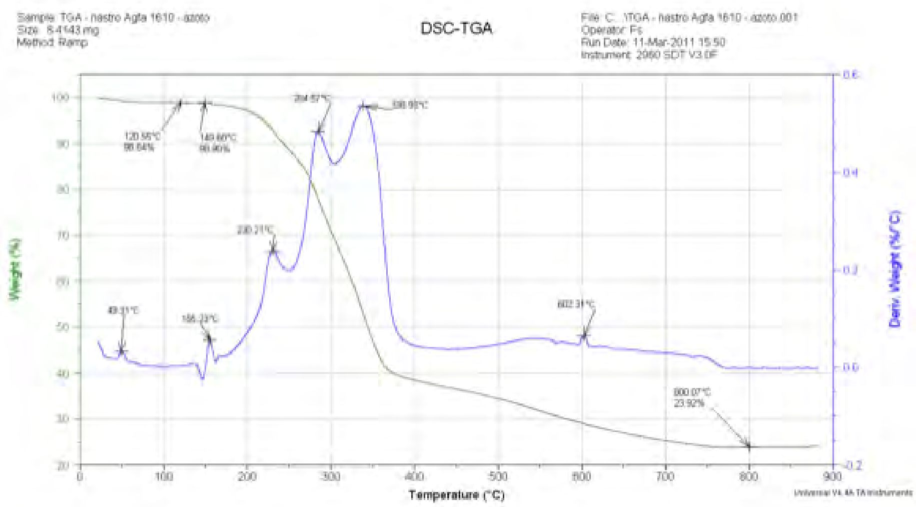
(b) Tape sample N: matt side identification

Fig. D.22: Tape sample N: (a) matt side; (b) matt side identification.

D.3 ThermoGravimetric Analysis (TGA)

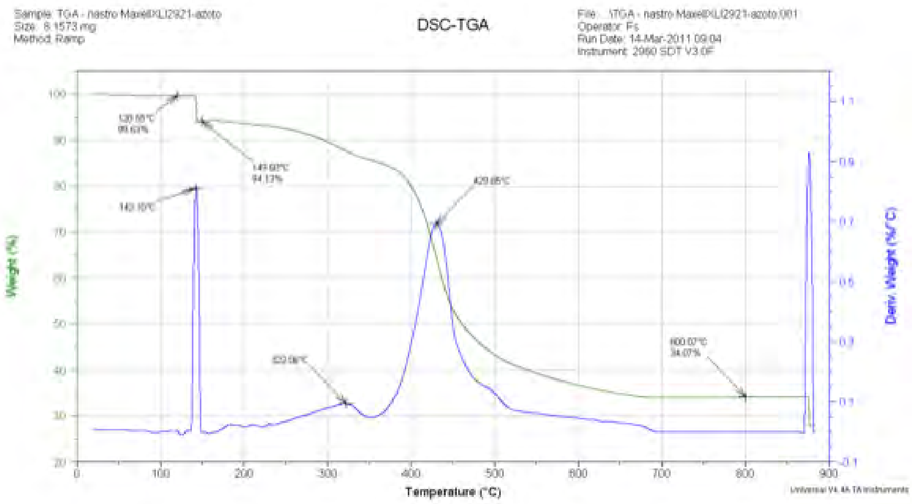


(a) Tape sample A

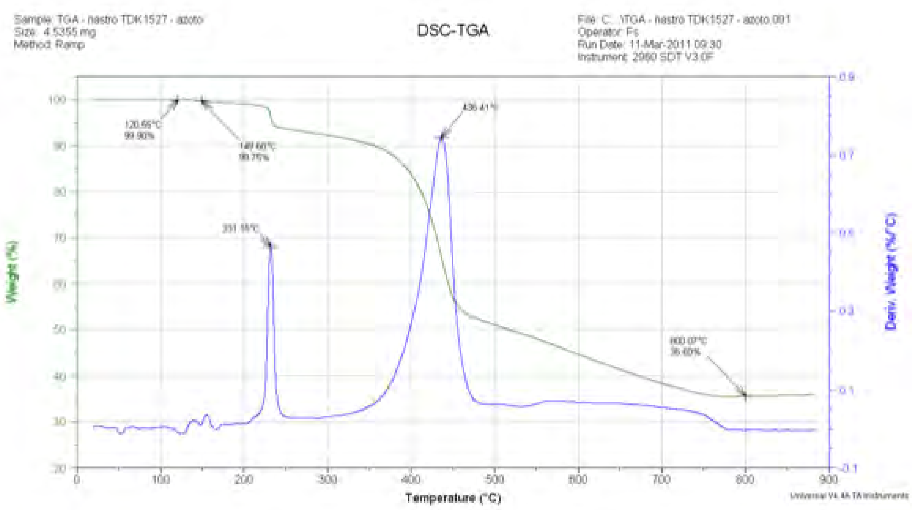


(b) Tape sample B

Fig. D.23: (a) Tape sample A; (b) Tape sample B.

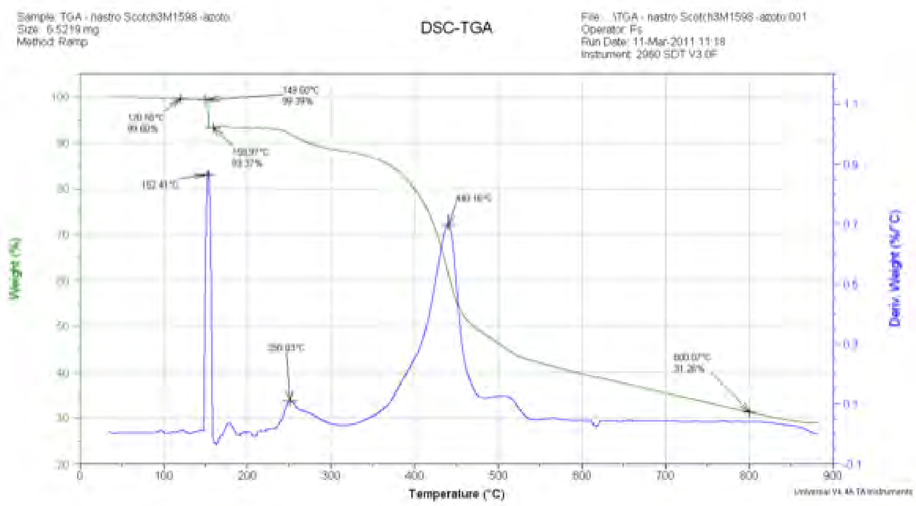


(a) Tape sample C

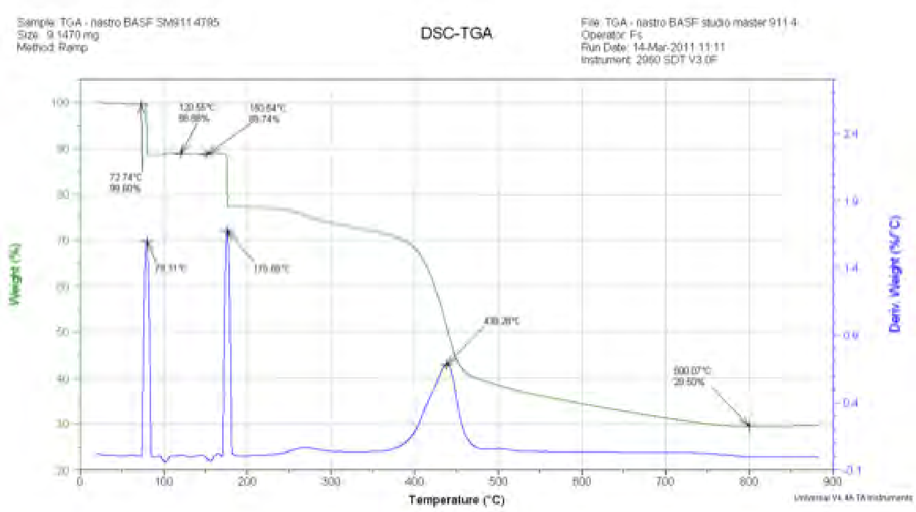


(b) Tape sample D

Fig. D.24: (a) Tape sample C; (b) Tape sample D.

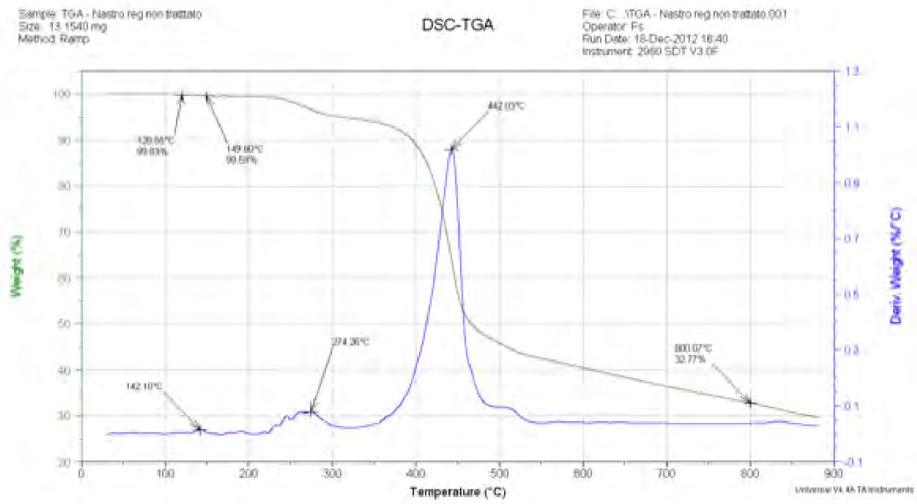


(a) Tape sample G

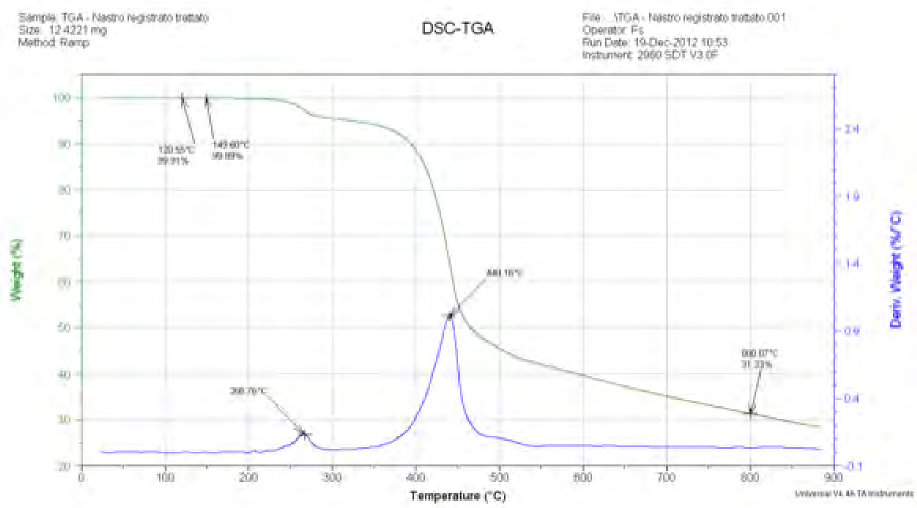


(b) Tape sample H

Fig. D.25: (a) Tape sample G; (b) Tape sample H.



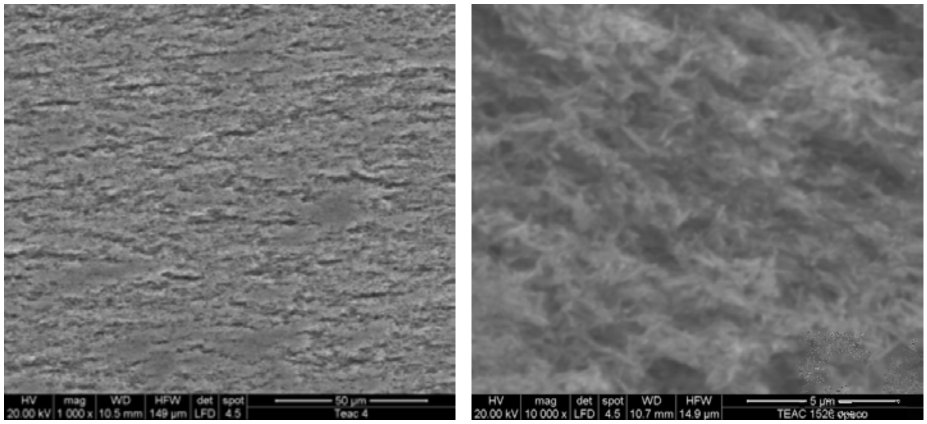
(a) Tape sample M



(b) Tape sample N

Fig. D.26: (a) Tape sample M; (b) Tape sample N.

D.3.1 ESEM



(a) Tape sample A (b) Tape sample A

Fig. D.27: Tape sample A.

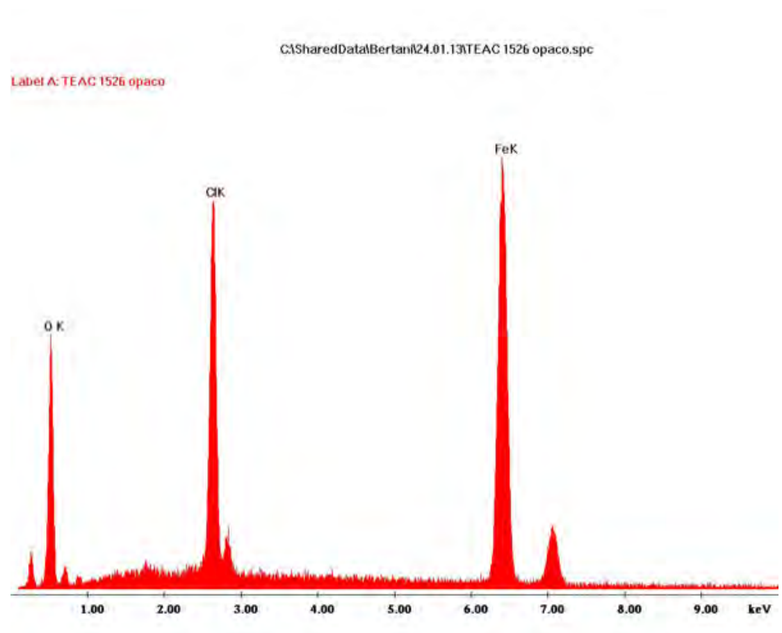
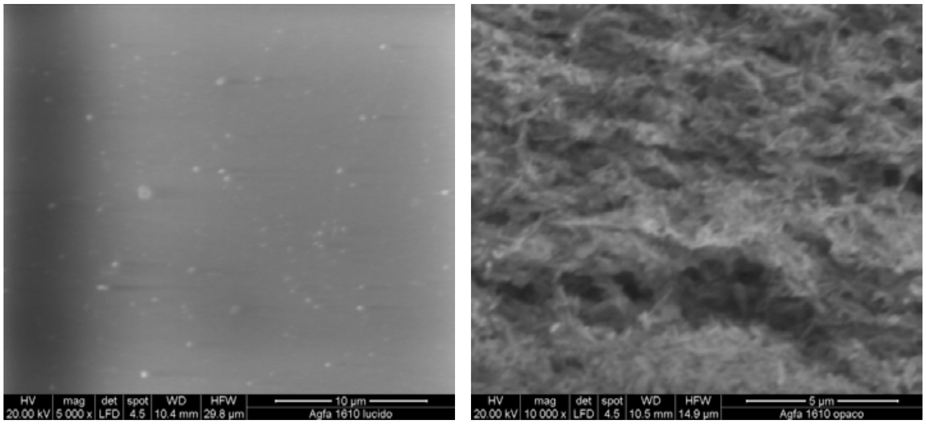


Fig. D.28: Tape sample A: elemental analysis.



(a) Tape sample B (b) Tape sample B

Fig. D.29: Tape sample B.

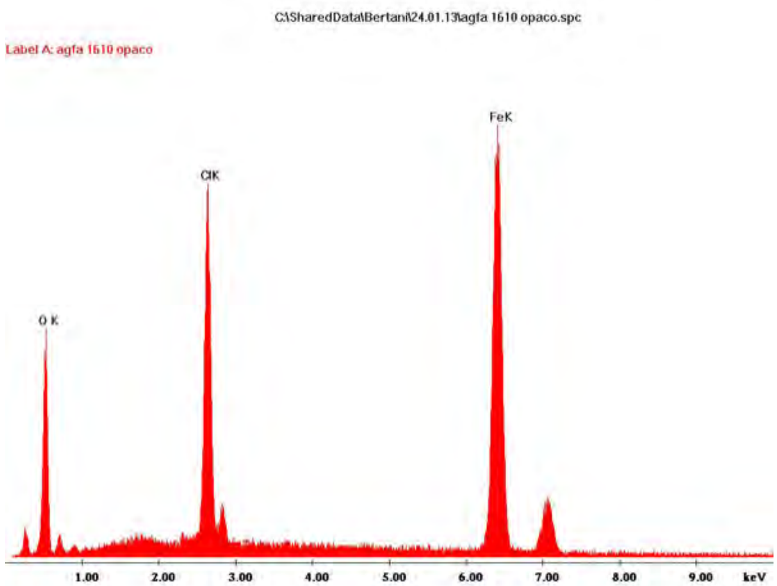
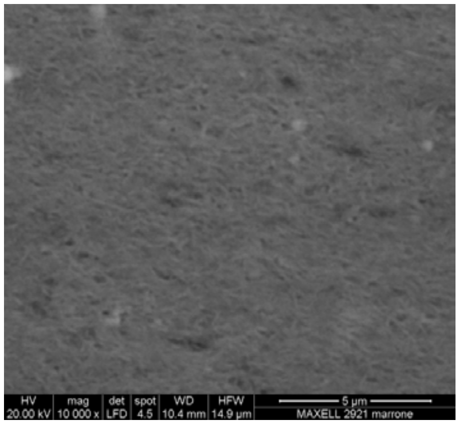
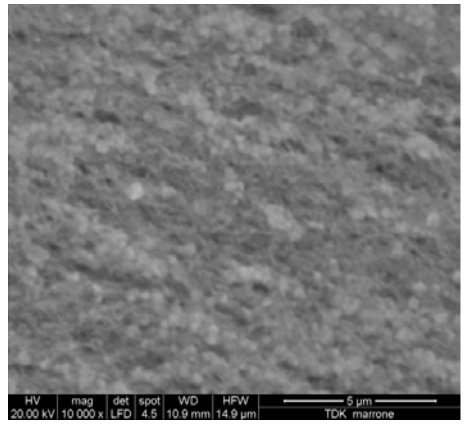


Fig. D.30: Tape sample B: elemental analysis.



(a) Tape sample C



(b) Tape sample D

Fig. D.31: (a) Tape sample C; (b) Tape sample D.

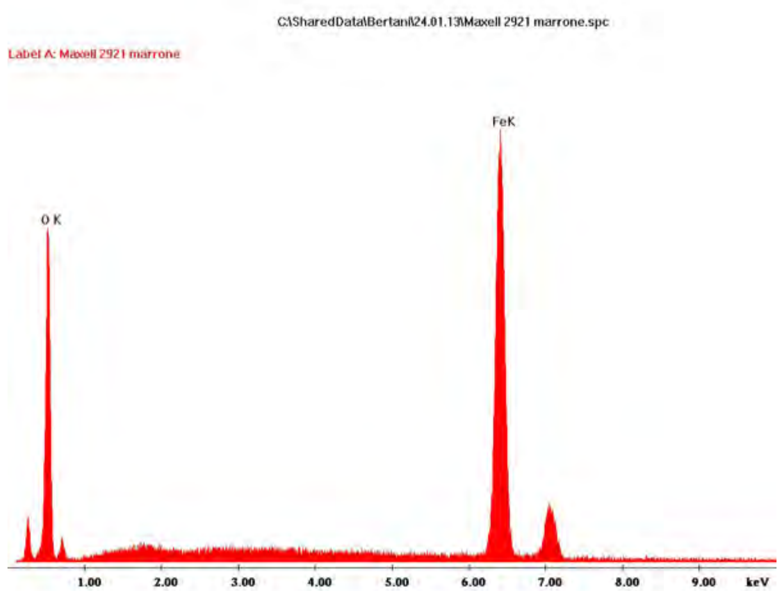


Fig. D.32: Tape sample C: elemental analysis.

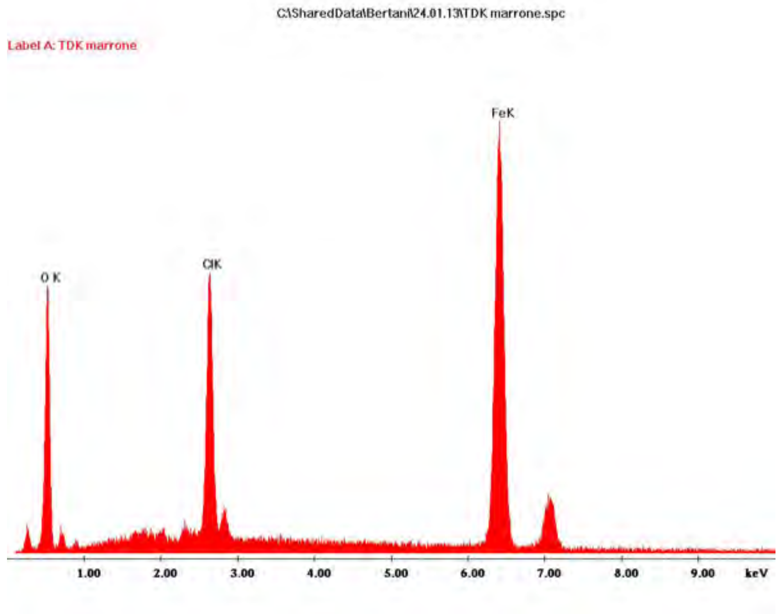
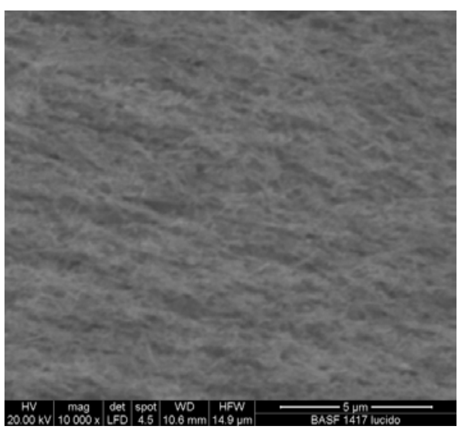
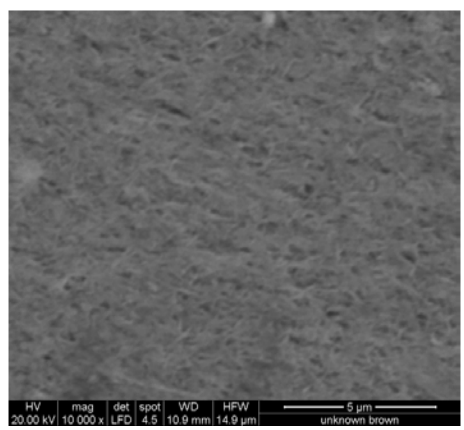


Fig. D.33: Tape sample D: elemental analysis.



(a) Tape sample E



(b) Tape sample F

Fig. D.34: (a) Tape sample E; (b) Tape sample F.

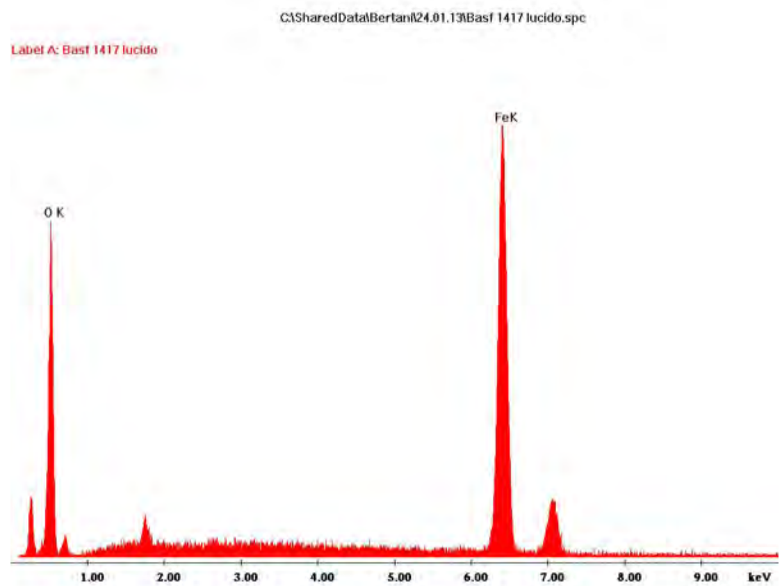
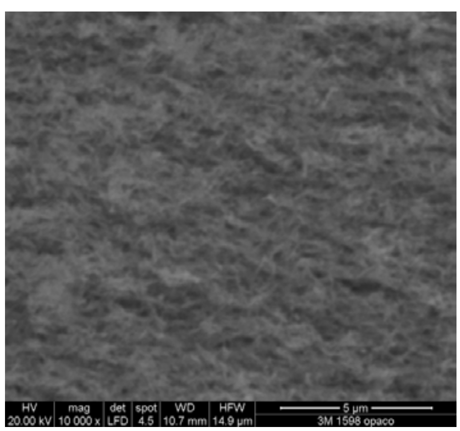
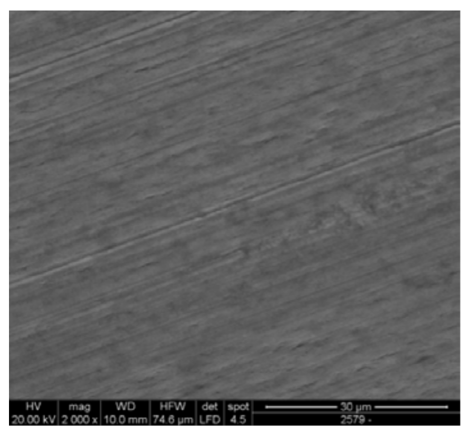


Fig. D.35: Tape sample E: elemental analysis.



(a) Tape sample G



(b) Tape sample I

Fig. D.36: Tape sample I.

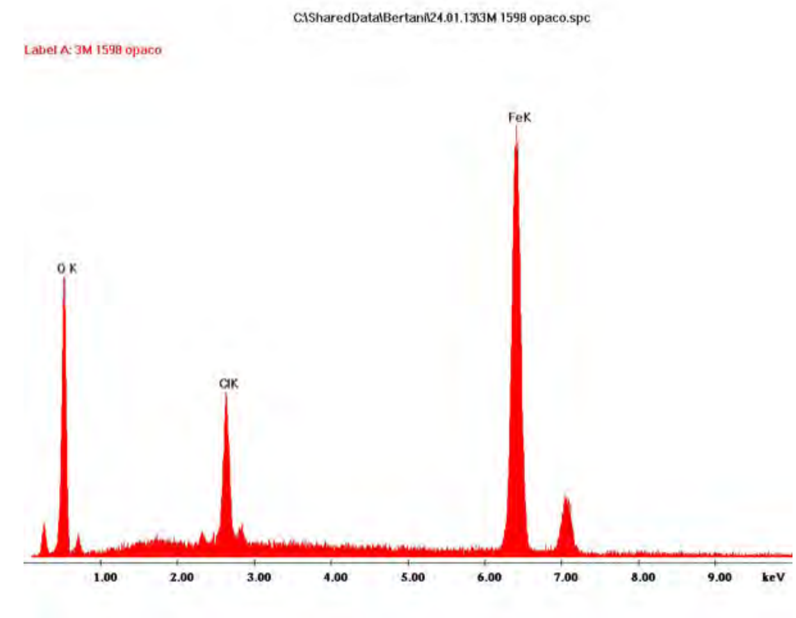
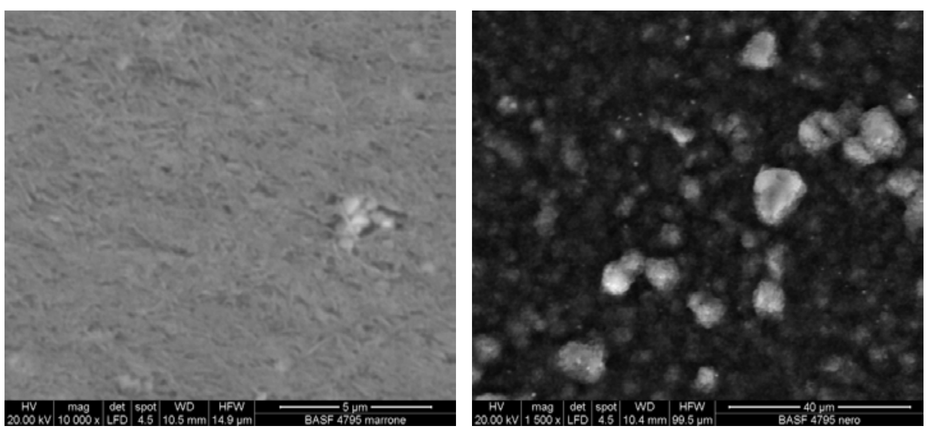


Fig. D.37: Tape sample G: elemental analysis.



(a) Tape sample H (b) Tape sample H

Fig. D.38: Tape sample H.

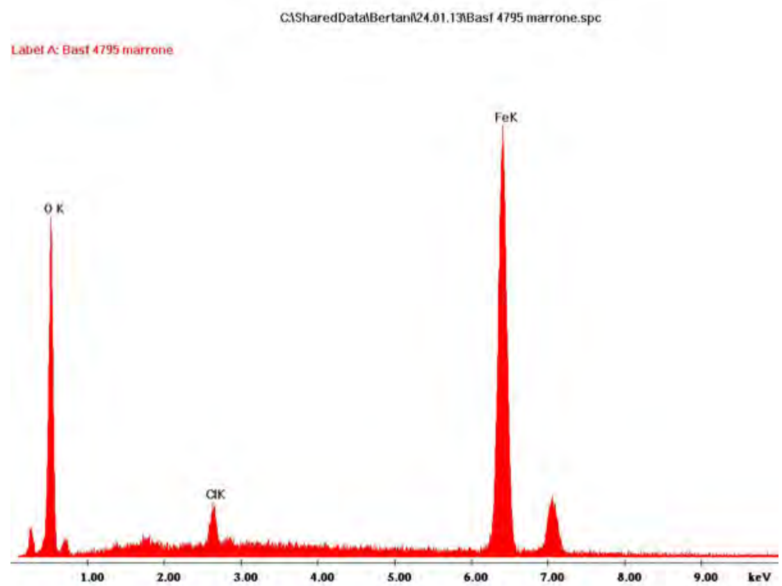
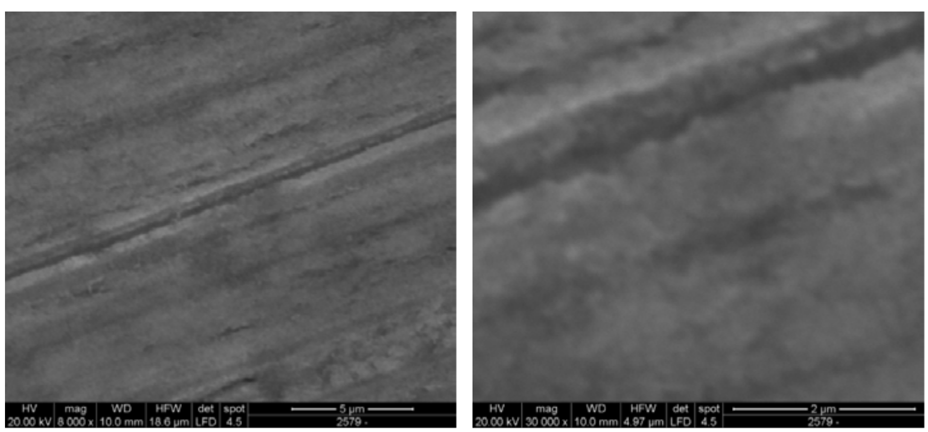


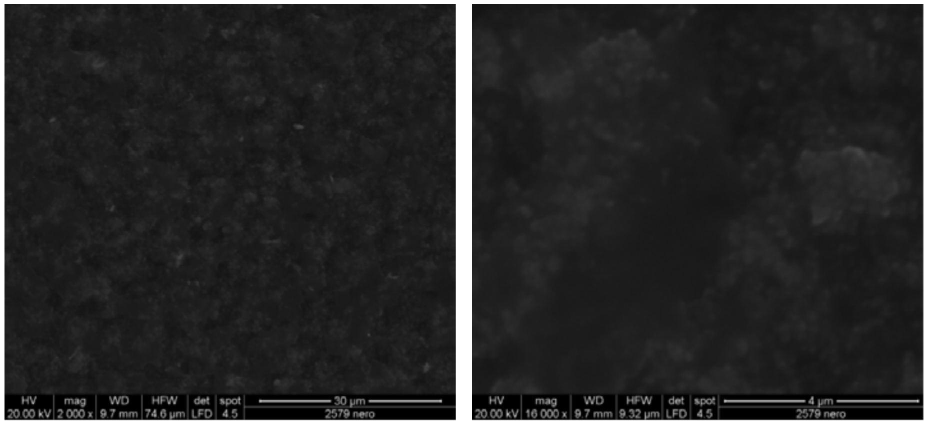
Fig. D.39: Tape sample H: elemental analysis.



(a) Tape sample I

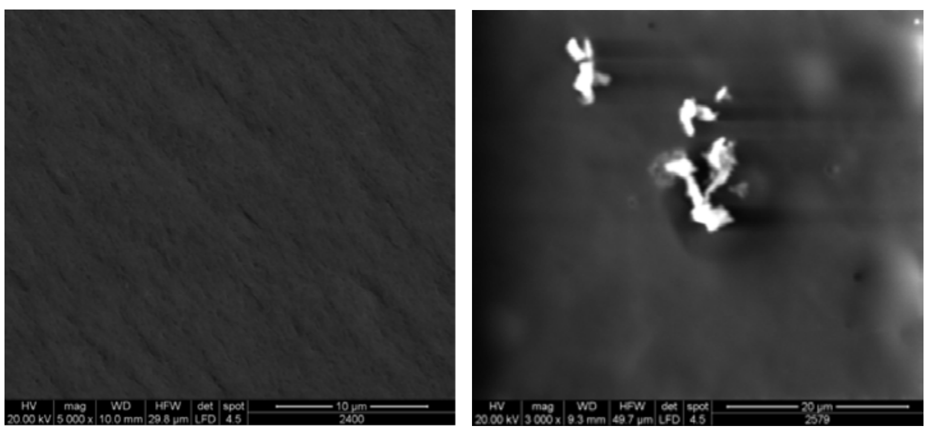
(b) Tape sample I

Fig. D.40: Tape sample I.



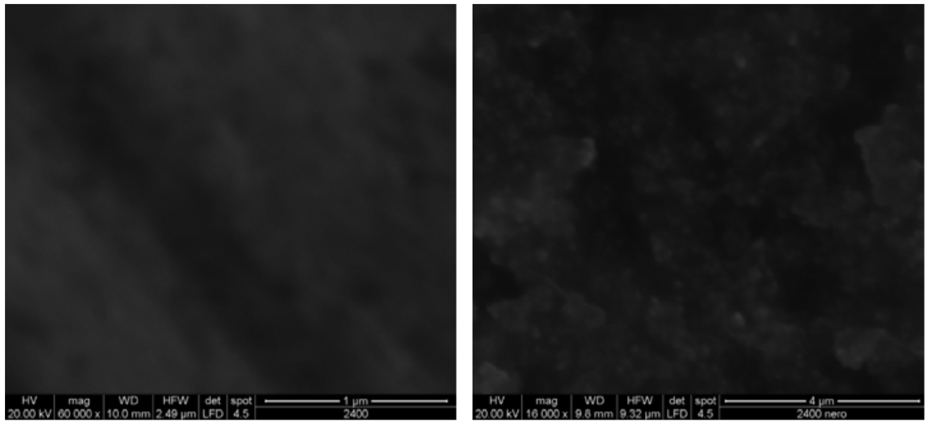
(a) Tape sample I (b) Tape sample I

Fig. D.41: Tape sample I.



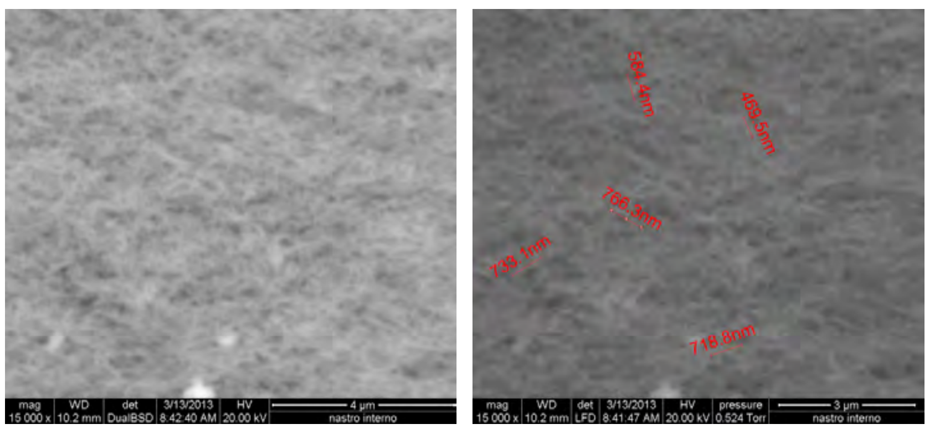
(a) Tape sample L (b) Tape sample I

Fig. D.42: (a) Tape sample L; (b) Tape sample I.



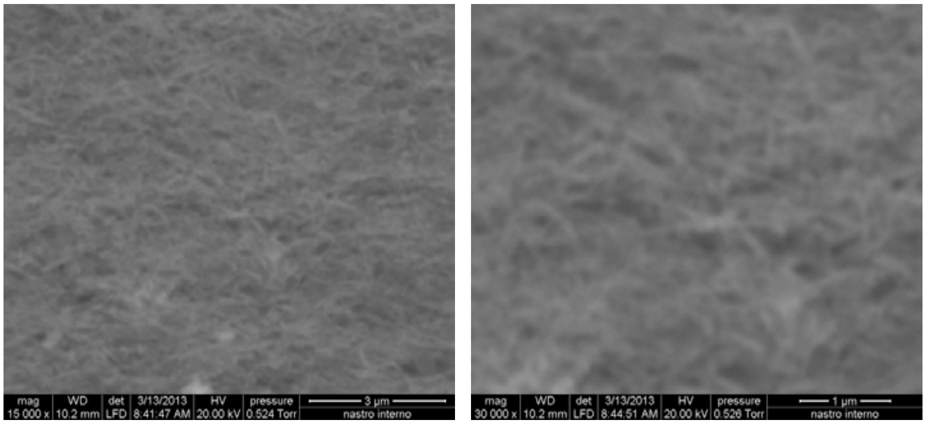
(a) Tape sample L (b) Tape sample L

Fig. D.43: Tape sample L.



(a) Tape sample M (b) Tape sample M

Fig. D.44: Tape sample M.



(a) Tape sample M (b) Tape sample M

Fig. D.45: Tape sample M.

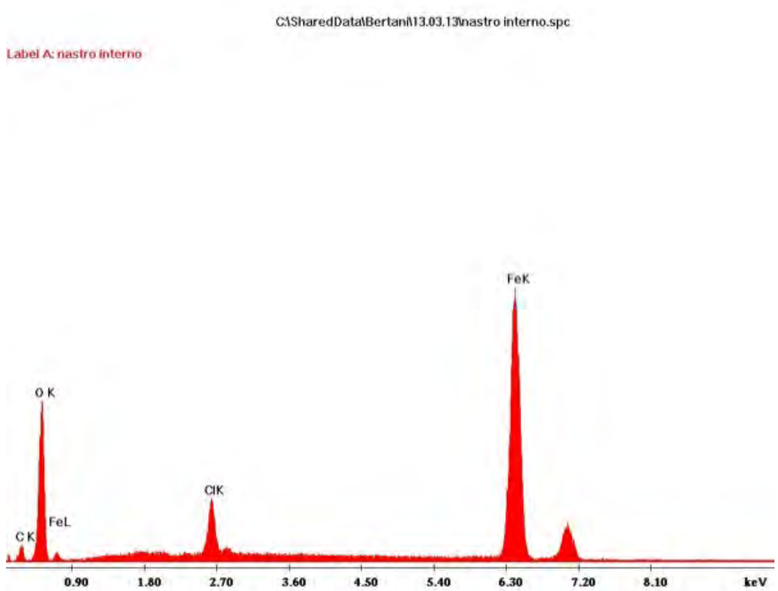
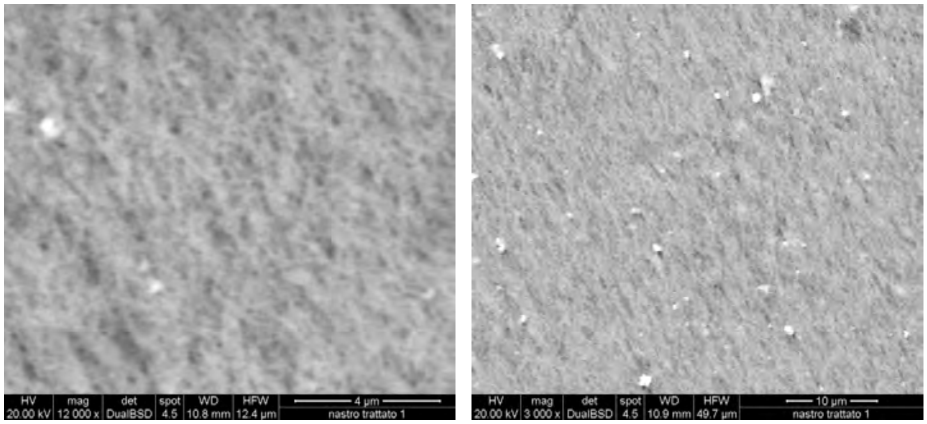


Fig. D.46: Tape sample M: elemental analysis.



(a) Tape sample N (b) Tape sample N

Fig. D.47: Tape sample N.

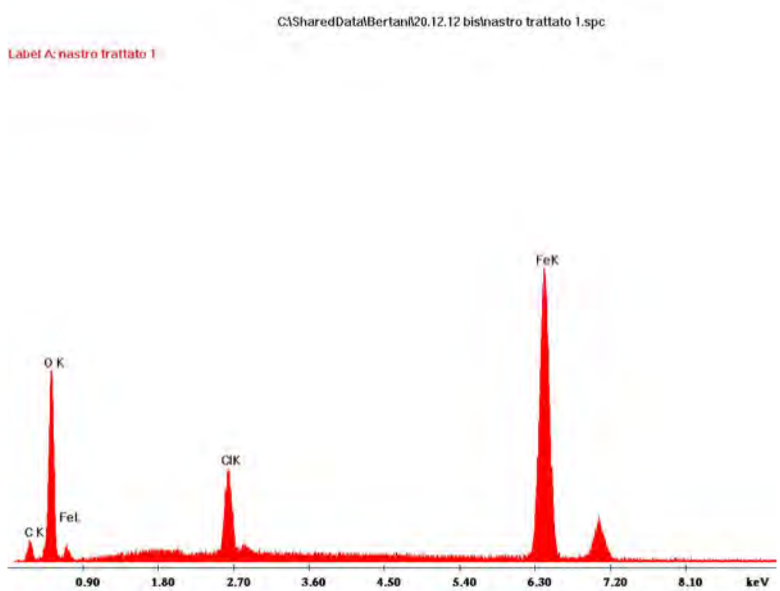
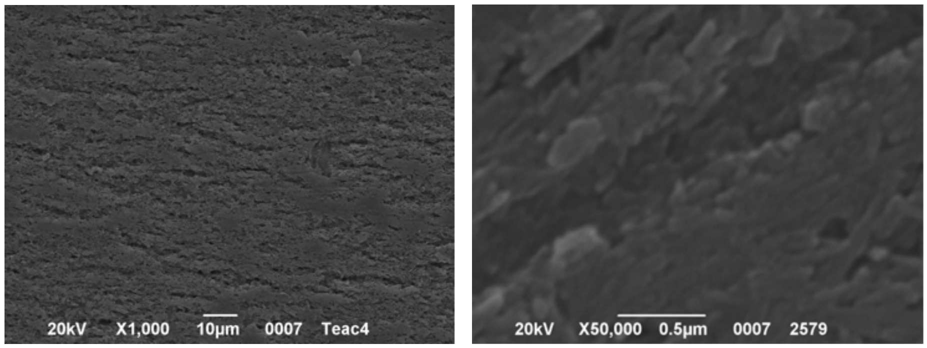


Fig. D.48: Tape sample N: elemental analysis.

D.4 Electronic Microscopy

D.4.1 SEM



(a) Tape sample A (b) Tape sample I

Fig. D.49: (a) Tape sample A; (b) Tape sample I.

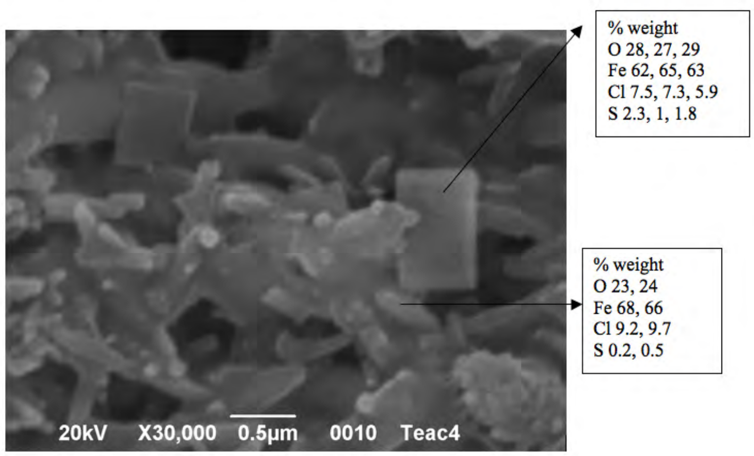
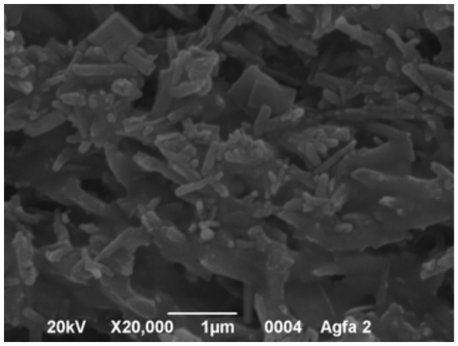
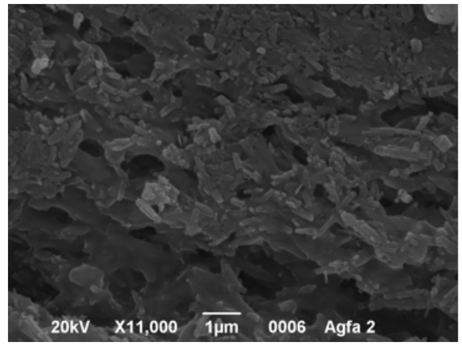


Fig. D.50: Tape sample A.

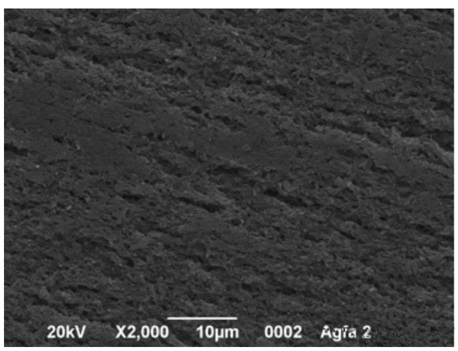


(a) Tape sample B

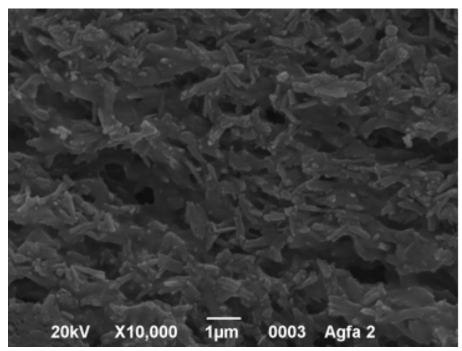


(b) Tape sample B

Fig. D.51: Tape sample B.

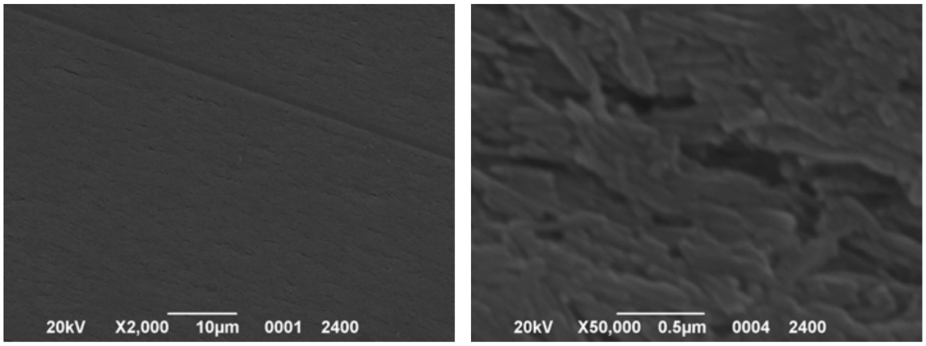


(a) Tape sample B



(b) Tape sample B

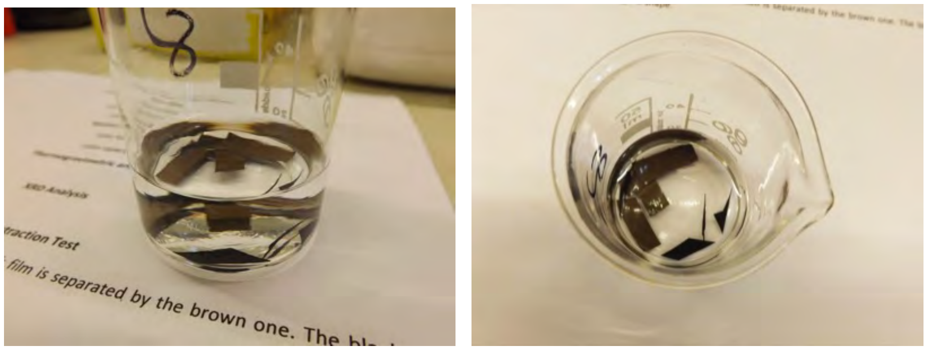
Fig. D.52: Tape sample B.



(a) Tape sample L (b) Tape sample L

Fig. D.53: Tape sample L.

D.5 Acetone extraction test

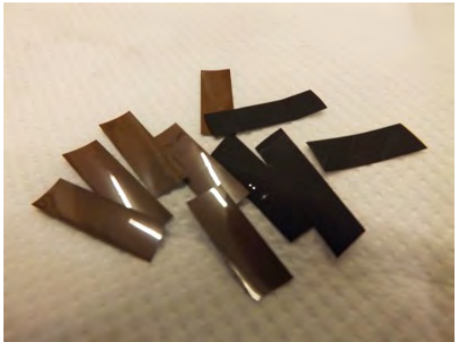


(a) Tape sample C (b) Tape sample C

Fig. D.54: Tape sample C: acetone extraction test.

(a) Tape sample D (b) Tape sample E

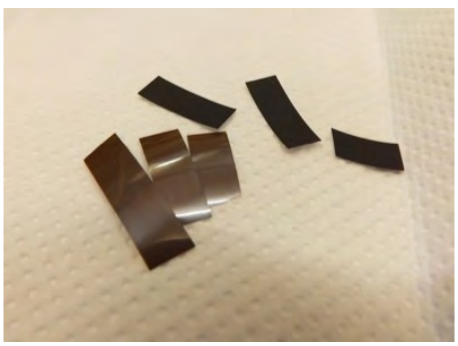
Fig. D.55: Acetone extraction test: (a) Tape sample D; (b) Tape sample E.



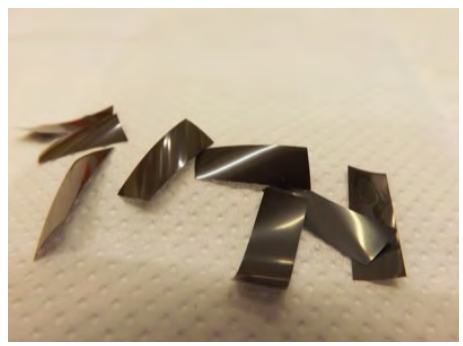
(a) Tape sample F

(b) Tape sample H

Fig. D.56: Acetone extraction test: (a) Tape sample F; (b) Tape sample H.



(a) Tape sample L



(b) Tape sample M

Fig. D.57: Acetone extraction test: (a) Tape sample L; (b) Tabe sample M.

(a) Tape sample N

(b) Tape sample N

Fig. D.58: Tape sample N: acetone extraction test.

D.6 Mechanical analysis: Tensile testing

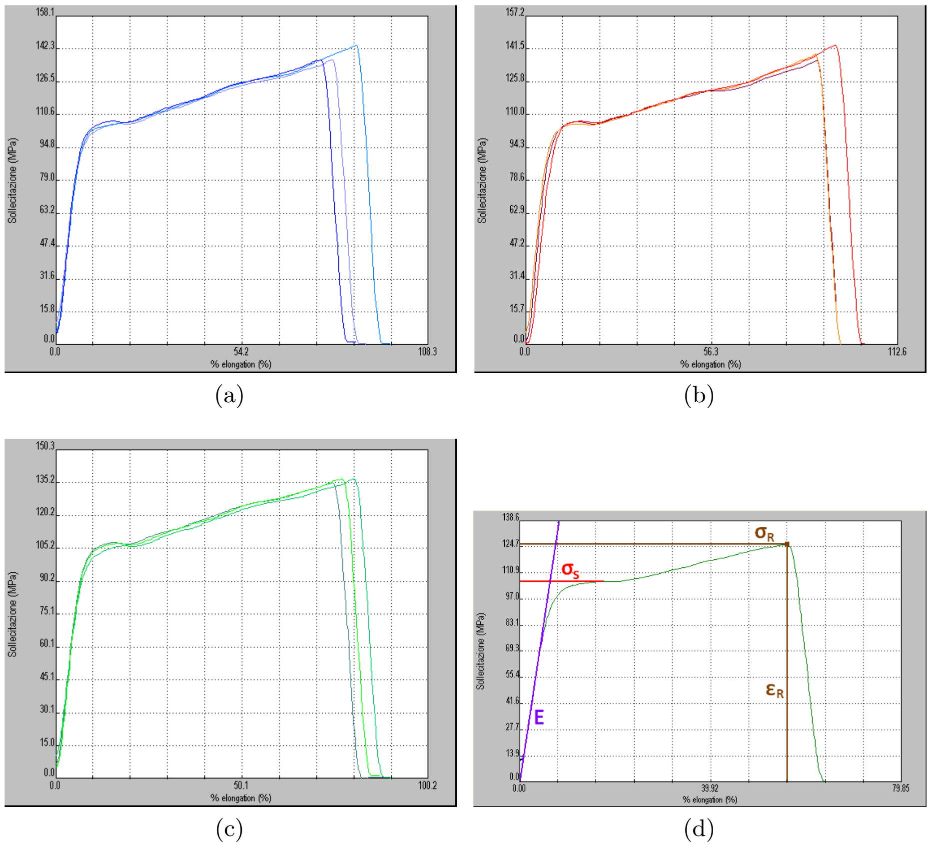


Fig. D.59: Tensile testing on magnetic tapes: comparison of the samples before treatment (a), after treatment (b), and blank tape (c); the mean values for the blank tape is shown in (d). For the mean values of the tapes before and after treatment, please see Chapter 9.

Tape sample		$\boldsymbol{E}$ **(MPa)**	σ_S **(MPa)**	σ_R **(MPa)**	ϵ_R **(%)**
Blank tape	Sample 1	1681	106.7	74.16	136.1
	Sample 2	1680	106.9	76.6	134.7
	Average	1680	106.8	74.2	135.4

Table D.1: The Table shows the results obtained with the tensile testing of the blank tape samples. For the data about the recorded tapes before and after treatment, please see Subsection 9.4.3.

E

Audio analyses

This Chapter contains all the figures that have not been included in text in Chapter 9. Additional documentation is available separately[1].

E.1 Audio feature extraction

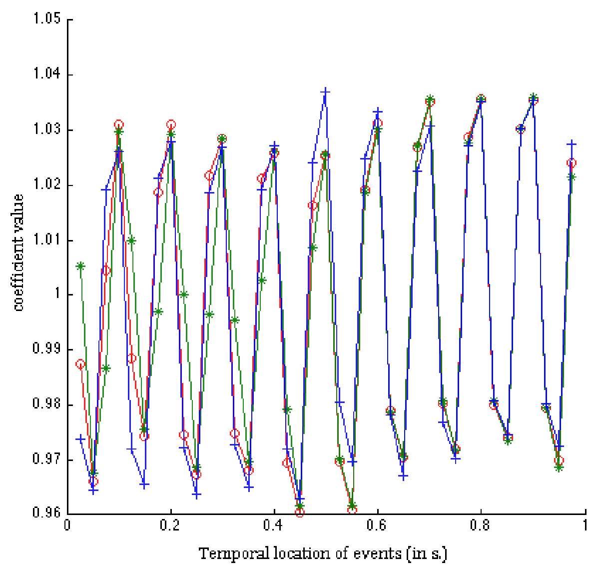


Fig. E.1: Comparison of the feature RMS of the audio files. Colors: blue indicates the signal extracted from tape before the treatment, green and red indicate the signal extracted from the tape after the treatment (respectively take 1 and take 2).

[1] `http://www.dei.unipd.it/~bressanf/tesi/tesi2013/`

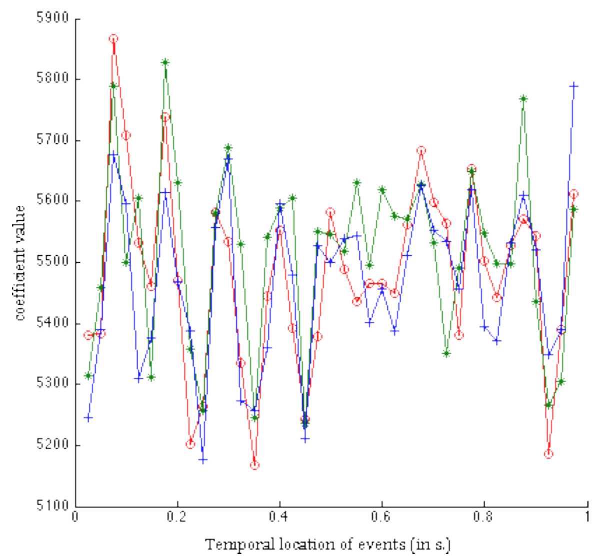


Fig. E.2: Comparison of the feature CENTROID of the audio files. Colors: blue indicates the signal extracted from tape before the treatment, green and red indicate the signal extracted from the tape after the treatment (respectively take 1 and take 2).

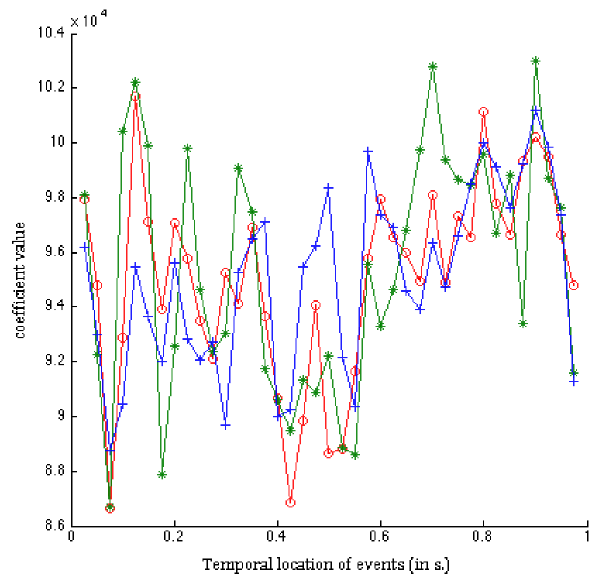


Fig. E.3: Comparison of the feature ROUGHNESS of the audio files. Colors: blue indicates the signal extracted from tape before the treatment, green and red indicate the signal extracted from the tape after the treatment (respectively take 1 and take 2).

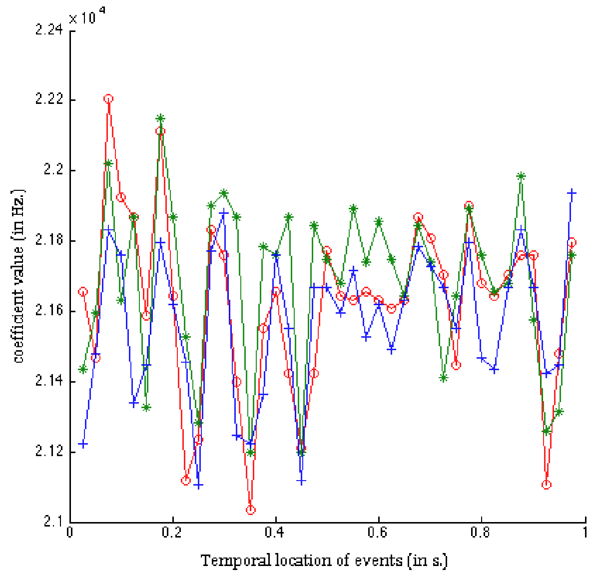


Fig. E.4: Comparison of the feature ROLLOFF95 of the audio files. Colors: blue indicates the signal extracted from tape before the treatment, green and red indicate the signal extracted from the tape after the treatment (respectively take 1 and take 2).

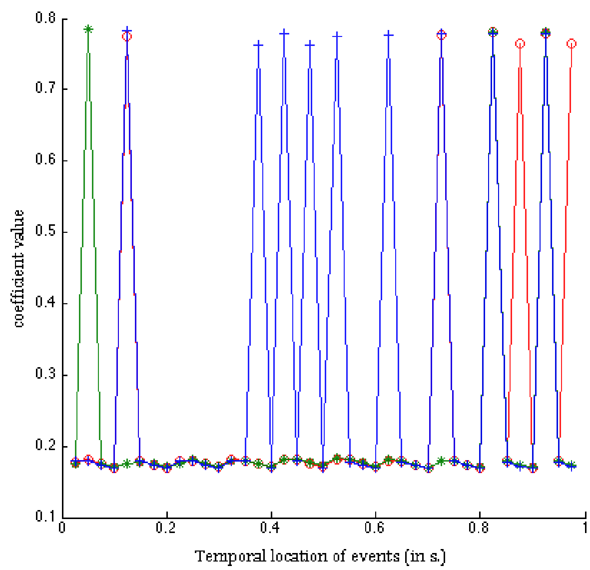


Fig. E.5: Comparison of the feature IRREGULARITY of the audio files. Colors: blue indicates the signal extracted from tape before the treatment, green and red indicate the signal extracted from the tape after the treatment (respectively take 1 and take 2).

F

Database documentation

F.1 Description of the contents

This Chapter includes the documentation of the MySQL database used by PSKit PreservationPanel and CataloguingPanel. In particular, the documentation includes the tables representing the descriptions of the linguistics audio resources, reflecting the database structure developed during the Gra.fo project at the Scuola Normale Superiore di Pisa (see Section 11.2). The version of MySQL used during the project is the 5.1.41.

The database is made of 61 tables, one of which (`path`) is a service table containing the paths to the files and folders on the users' local machines that are necessary during the execution of PreservationPanel and CataloguingPanel. For this reason, the table `path` does not reference and is not referenced by the other tables.

The names of the tables are reported in lowercase letters as they are in the database. For each table, the documentation provides (1) the list of attributes:

- `POS.`: sequential order of the column
- `NAME`: name of the column
- `TYPE`: data type associated to the column
- `SIZE`: max number of bytes allocated for the values in the column
- `UNIQUE`: YES if the value in this column is subject to a *unique* constraint, NO otherwise
- `NULLABLE`: YES if the value in this column can be NULL, NO otherwise
- `DEFAULT`: default value for this column

(2) the primary key, (3) the foreign keys, if existing, with the following attributes:

- `FK col.`: name of the column that contains the reference

- `PK table`: name of the referenced table
- `PK col.`: name of the specific column in the referenced table
- `delete rule`: action in case the record is deleted
- `update rule`: action in case the record is updated/modified

and the keys made of multiple columns, if existing (e.g., see tables `gruppointervistati` or `catalogtemp`).

F.2 Summary of the tables

This Section provides a high-level description of the content and of the function of each table in the database.

1. table `altracopia`: information on other copies, if existing, of a given audio document (see item *esistenza altre copie* in [143])
2. table `anno`: controlled vocabulary
3. table `archivio`: information on the archives
4. table `argomento`: controlled vocabulary
5. table `bitdepth`: controlled vocabulary
6. table `bitrate`: controlled vocabulary
7. table `catalogtemp`: controlled vocabulary
8. table `cc`: information on the preservation copies ('cc' stands for the Italian of preservation copy, *copia conservativa*)
9. table `codifica`: controlled vocabulary
10. table `copiaaccesso`: information on access copies
11. table `copiamontata`: information on the audio of the ARMAs[1]
12. table `copiasicurezza`: information on the backup copy of the preservation copies
13. table `custodia`: controlled vocabulary
14. table `diagnosi`: controlled vocabulary (state of preservation)
15. table `diagnosischeda`: controlled vocabulary (detailed descriptions of the symptoms on which the state of preservation is evaluated)
16. table `diametro`: controlled vocabulary
17. table `documorig`: information on the source (original) audio document
18. table `eq`: controlled vocabulary
19. table `estensione`: controlled vocabulary (file extensions, e.g., wav)
20. table `fc`: controlled vocabulary
21. table `fondo`: information on the archive sections (funds)

[1] ARMA: Audio Resource Mediated for Access

22. table `genere`: controlled vocabulary
23. table `giannelli`: controlled vocabulary (linguistic varieties[2])
24. table `giorno`: controlled vocabulary
25. table `grooveorientation`: controlled vocabulary (groove orientation for phonographic discs)
26. table `gruppointervistati`: associates the interviewees in table `persona` to the ARMAs in table `unita`
27. table `gruppointervistatori`: associated the interviewers in table `persona` to the ARMAs in table `unita`
28. table `keyword`: associates the keywords in table `parola` to the ARMAs in table `unita`
29. table `larghezzanastro`: controlled vocabulary
30. table `layersubstratematerial`: controlled vocabulary (material of the substrate of the audio carrier)
31. table `layersurfacematerial`: controlled vocabulary (material of the surface of the audio carrier)
32. table `localita`: controlled vocabulary (*provinces* and *municipalities* of Italy)
33. table `luogo`: controlled vocabulary (venue of the re-mediation)
34. table `mansione`: associates people involved in the project (table `ruolo`) to their role within the project (table `persona`)
35. table `marca`: controlled vocabulary
36. table `mese`: controlled vocabulary
37. table `mime`: controlled vocabulary (standard taxonomy for digital documents)
38. table `montaggio`: associates the ARMAs in table `unita` to the corresponding audio in table `copiamontata`
39. table `mp3mode`: controlled vocabulary
40. table `nr`: controlled vocabulary (noise reduction system)
41. table `numerolati`: controlled vocabulary
42. table `numeropiste`: controlled vocabulary
43. table `numerotracce`: controlled vocabulary
44. table `parola`: controlled vocabulary (keywords for the description of ARMAs)

[2] The name of the table derives from the first taxonomy adopted for the classification of the linguistic varieties by the research team; subsequently the group decided to adopt another taxonomy, but the name of the table remained unaltered – which is not relevant in the process of presenting or retrieving the data.

45. table `path`: service table for PSKit PreservationPanel and CataloguingPanel, containing the paths of the files and folders necessary during execution
46. table `persona`: information on the people involved or mentioned within the project
47. table `procedarchiv`: controlled vocabulary (archiving procedure)
48. table `regione`: controlled vocabulary (regions of Italy)
49. table `registrazionead`: controlled vocabulary
50. table `riavvolgimento`: controlled vocabulary
51. table `ruolo`: controlled vocabulary (roles of the people involved or mentioned in the project)
52. table `serie`: information on the archive subsections (series)
53. table `supportohdd`: controlled vocabulary
54. table `tecnicaregistrazione`: controlled vocabulary
55. table `tipo`: controlled vocabulary (types of audio carriers)
56. table `tiposegnale`: controlled vocabulary
57. table `tipotrascrizione`: controlled vocabulary
58. table `traccia`: information on the audio contained in the preservation copies (contains a reference to the table `cc`)
59. table `trascrizione`: information on the linguistic transcriptions and on the accompanying material
60. table `unita`: information on the ARMAs
61. table `velocita`: controlled vocabulary

F.3 The tables

Table altracopia

Information on other copies or duplicates, if existing, of a given audio document (see item *esistenza altre copie* in [143]). The label 'copy' does not establish a hierarchy between the documents, but simply signals a relation between them. The nature of this relation, which can also be partial, can be detailed in the notes field or, at the cataloguing staff's choice, else where, for example in the descriptive sheet of the ARMAs.

Columns (5)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	originale	INT	10	NO	NO	NONE
3	copia	INT	10	NO	YES	NULL
4	archivio	INT	10	NO	NO	NONE
5	descrizione	TEXT	65535	NO	YES	NULL

Table F.1: altracopia

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.2: Primary key altracopia

Foreign keys (3)

FK col.	PK table	PK col.	delete rule	update rule
originale	documorig	id	NoAction	NoAction
archivio	archivio	id	NoAction	NoAction
copia	documorig	id	NoAction	NoAction

Table F.3: altracopia Foreign keys

Table anno

Controlled vocabulary for the solar years from 1888 to 2012.

Columns (1)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	valore	VARCHAR	4	YES	NO	NONE

Table F.4: anno

Primary key (1)

Information about the primary key:

Position	Col. Name
1	valore

Table F.5: Primary key anno

Table archivio

Information on the archives involved in the project (an archive can be articulated in sections and subsections, according to the project working documentation [143]).

Columns (15)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	NO	NO	NONE
2	nome	VARCHAR	128	YES	NO	NONE
3	codice	VARCHAR	12	YES	YES	NONE
4	indirizzo	VARCHAR	128	NO	YES	NULL
5	regione	INT	10	NO	YES	NULL
6	provincia	INT	10	NO	YES	NULL
7	comune	INT	10	NO	YES	NULL
8	descrizione	TEXT	65535	NO	YES	NULL
9	note	TEXT	65535	NO	YES	NULL
10	proprietario	INT	10	NO	YES	NULL
11	referente	INT	10	NO	YES	NULL
12	sito	VARCHAR	128	NO	YES	NULL
13	dataadesione	VARCHAR	10	NO	YES	NULL
14	racconta	BIT	0	NO	YES	NULL
15	consultabile	BIT	0	NO	YES	NULL

Table F.6: archivio

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.7: Primary key archivio

Foreign keys (5)

FK col.	PK table	PK col.	delete rule	update rule
regione	regione	id	NoAction	NoAction
provincia	localita	id	NoAction	NoAction
comune	localita	id	NoAction	NoAction
proprietario	persona	id	NoAction	NoAction
referente	persona	id	NoAction	NoAction

Table F.8: archivio Foreign keys

Table argomento

Controlled vocabulary for the subjects (topics) associated to the ARMAs, according to [143].

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	40	YES	NO	NONE

Table F.9: argomento

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.10: Primary key argomento

Table bitdepth

Controlled vocabulary for the values of the binary word length (resolution) associated to the audio tracks.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	15	YES	NO	NONE

Table F.11: bitdepth

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.12: Primary key bitdepth

Table bitrate

Controlled vocabulary for the values of the bitrate (bit per second) associated to the audio tracks.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	10	YES	NO	NONE

Table F.13: bitrate

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.14: Primary key bitrate

Table catalogtemp

Information about the temporary cataloguing of the content of the preservation copies.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	cc	INT	10	NO	NO	NONE
2	campo	VARCHAR	264	NO	NO	NONE
3	valore	VARCHAR	516	NO	NO	NONE

Table F.15: catalogtemp

Foreign keys (5)

FK col.	PK table	PK col.	delete rule	update rule
cc	cc	id	NoAction	NoAction

Table F.16: Foreign keys catalogtemp

Unique keys (1)

Columns of the unique key: `cc`, `campo`, `valore`.

Table cc

Information on the preservation copies ('cc' stands for the Italian of preservation copy, i.e., *copia conservativa*).

Columns (13)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	segnatura	VARCHAR	128	YES	NO	NONE
3	operatore	INT	10	NO	YES	NULL
4	documorig	INT	10	YES	NO	NONE
5	datariversamento	DATE	10	NO	YES	NULL
6	notesegnale	TEXT	65535	NO	YES	NULL
7	supporto	VARCHAR	264	NO	YES	NULL
8	path	VARCHAR	128	NO	YES	NULL
9	notedilavoro	TEXT	65535	NO	YES	NULL
10	completa	BIT	0	NO	YES	NULL
11	eq	INT	10	NO	YES	NULL
12	nr	INT	10	NO	YES	NULL
13	velocita	INT	10	NO	YES	NULL

Table F.17: cc

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.18: Primary key cc

Foreign keys (5)

FK col.	PK table	PK col.	delete rule	update rule
operatore	persona	id	NoAction	NoAction
documorig	documorig	id	NoAction	NoAction
eq	eq	id	NoAction	NoAction
nr	nr	id	NoAction	NoAction
velocita	velocita	id	NoAction	NoAction

Table F.19: Foreign keys cc

Table codifica

Vocabolario controllato per i valori del tipo di codifica audio digitale.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	10	YES	NO	NONE

Table F.20: codifica

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.21: Primary key codifica

Table copiaaccesso

Information on the access copies.

Columns (10)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	cc	INT	10	NO	NO	NONE
3	segnatura	VARCHAR	128	NO	NO	NONE
4	supporto	VARCHAR	64	NO	YES	NULL
5	path	VARCHAR	128	NO	YES	NULL
6	operatore	INT	10	NO	YES	NULL
7	data	DATE	10	NO	YES	NULL
8	fc	INT	10	NO	YES	NULL
9	bitdepth	INT	10	NO	YES	NULL
10	formato	INT	10	NO	YES	NULL

Table F.22: copiaaccesso

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.23: Primary key copiaaccesso

Foreign keys (4)

FK col.	PK table	PK col.	delete rule	update rule
cc	cc	id	NoAction	NoAction
fc	fc	id	NoAction	NoAction

bitdepth	bitdepth	id	NoAction	NoAction
formato	mime	id	NoAction	NoAction

Table F.24: Foreign keys copiaaccesso

Table copiamontata

Information on the audio of the ARMAs.

Columns (20)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	nome	VARCHAR	64	YES	NO	NONE
3	unita	INT	10	NO	NO	NONE
4	supporto	VARCHAR	64	NO	YES	NULL
5	path	VARCHAR	128	NO	YES	NULL
6	operatore	INT	10	NO	YES	NULL
7	data	DATE	10	NO	YES	NULL
8	fc	INT	10	NO	YES	NULL
9	bitdepth	INT	10	NO	YES	NULL
10	nominalbitrate	VARCHAR	15	0	YES	NULL
11	formato	INT	10	NO	YES	NULL
12	durata	VARCHAR	24	NO	YES	NULL
13	size	VARCHAR	28	NO	YES	NULL
14	numerocanali	INT	10	NO	YES	NULL
15	versionmpeg	VARCHAR	24	NO	YES	NULL
16	versionlayer	VARCHAR	24	NO	YES	NULL
17	versionencoding	VARCHAR	24	NO	YES	NULL
18	firstheaderposition	VARCHAR	24	NO	YES	NULL
19	vbrscale	INT	10	NO	YES	NULL
20	mode	INT	10	NO	YES	NULL

Table F.25: copiamontata

Primary key (1)

Information about the primary key:

Foreign keys (1)

Position	Col. Name
1	id

Table F.26: Primary key copiamontata

FK col.	PK table	PK col.	delete rule	update rule
mode	mp3mode	id	NoAction	NoAction
unita	unita	id	NoAction	NoAction
operatore	persona	id	NoAction	NoAction
bitdepth	bitdepth	id	NoAction	NoAction
formato	mime	id	NoAction	NoAction
fc	fc	id	NoAction	NoAction

Table F.27: Foreign keys copiamontata

Table copiasicurezza

Information on the backup copies of the preservation copies.

Columns (4)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	cc	INT	10	NO	NO	NONE
3	supporto	VARCHAR	64	NO	YES	NULL
4	path	VARCHAR	128	NO	YES	NULL

Table F.28: copiasicurezza

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.29: Primary key copiasicurezza

Foreign keys (1)

FK col.	PK table	PK col.	delete rule	update rule
cc	cc	id	NoAction	NoAction

Table F.30: Foreign keys copiasicurezza

Table custodia

Controlled vocabulary for the types of materials of the boxes/cases of the audio carriers.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	20	YES	NO	NONE

Table F.31: custodia

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.32: Primary key custodia

Table diagnosi

Controlled vocabulary for the rating of the state of preservation of a given audio document. A description is associated to each rating.

Columns (3)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	20	YES	NO	NONE
3	descrizione	TEXT	65535	NO	YES	NULL

Table F.33: diagnosi

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.34: Primary key diagnosi

Table diagnosischeda

Controlled vocabulary for the symptoms and the signs of degradation that affect audio carriers. A description is associated to each symptom or sign of degradation, which can be rated according to a scale from zero (the symptom is absent) to four (the symptom makes the carrier unreadable/unplayable).

Columns (3)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	cc	INT	10	NO	NO	NONE
3	pack	INT	10	NO	YES	NULL
4	packdesc	VARCHAR	264	NO	YES	NULL
5	blocking	INT	10	NO	YES	NULL
6	blockingdesc	VARCHAR	264	NO	YES	NULL
7	leafing	INT	10	NO	YES	NULL
8	leafingdesc	VARCHAR	264	NO	YES	NULL
9	loose	INT	10	NO	YES	NULL
10	loosedesc	VARCHAR	264	NO	YES	NULL
11	windowing	INT	10	NO	YES	NULL
12	windowingdesc	VARCHAR	264	NO	YES	NULL
13	spoking	INT	10	NO	YES	NULL
14	spokingdesc	VARCHAR	264	NO	YES	NULL
15	dirt	INT	10	NO	YES	NULL
16	dirtdesc	VARCHAR	264	NO	YES	NULL
17	otherpart	INT	10	NO	YES	NULL
18	otherpartdesc	VARCHAR	264	NO	YES	NULL
19	liquid	INT	10	NO	YES	NULL
20	liquiddesc	VARCHAR	264	NO	YES	NULL
21	splices	INT	10	NO	YES	NULL
22	splicesdesc	VARCHAR	264	NO	YES	NULL
23	vinegar	INT	10	NO	YES	NULL
24	vinegardesc	VARCHAR	264	NO	YES	NULL

25	mold	INT	10	NO	YES	NULL
26	molddesc	VARCHAR	264	NO	YES	NULL
27	pests	INT	10	NO	YES	NULL
28	pestsdesc	VARCHAR	264	NO	YES	NULL
29	otherbio	INT	10	NO	YES	NULL
30	otherbiodesc	VARCHAR	264	NO	YES	NULL
31	powder	INT	10	NO	YES	NULL
32	powderdesc	VARCHAR	264	NO	YES	NULL
33	tears	INT	10	NO	YES	NULL
34	tearsdesc	VARCHAR	264	NO	YES	NULL
35	brittle	INT	10	NO	YES	NULL
36	brittledesc	VARCHAR	264	NO	YES	NULL
37	folds	INT	10	NO	YES	NULL
38	foldsdesc	VARCHAR	264	NO	YES	NULL
39	cupping	INT	10	NO	YES	NULL
40	cuppingdesc	VARCHAR	264	NO	YES	NULL
41	edge	INT	10	NO	YES	NULL
42	edgedesc	VARCHAR	264	NO	YES	NULL
43	backcoat	INT	10	NO	YES	NULL
44	backcoatdesc	VARCHAR	264	NO	YES	NULL
45	magnetic	INT	10	NO	YES	NULL
46	magneticdesc	VARCHAR	264	NO	YES	NULL
47	sss	INT	10	NO	YES	NULL
48	sssdesc	VARCHAR	264	NO	YES	NULL
49	sbs	INT	10	NO	YES	NULL
50	sbsdesc	VARCHAR	264	NO	YES	NULL
51	bleeding	INT	10	NO	YES	NULL
52	bleedingdesc	VARCHAR	264	NO	YES	NULL
53	curvature	INT	10	NO	YES	NULL
54	curvaturedesc	VARCHAR	264	NO	YES	NULL
55	embossing	INT	10	NO	YES	NULL
56	embossingdesc	VARCHAR	264	NO	YES	NULL
57	adhesion	INT	10	NO	YES	NULL

58	adhesiondesc	VARCHAR	264	NO	YES	NULL
59	kink	INT	10	NO	YES	NULL
60	kinkdesc	VARCHAR	264	NO	YES	NULL
61	magneticloss	INT	10	NO	YES	NULL
62	magneticlossdesc	VARCHAR	264	NO	YES	NULL
63	manufacture	INT	10	NO	YES	NULL
64	manufacturedesc	VARCHAR	264	NO	YES	NULL
65	gummy	INT	10	NO	YES	NULL
66	gummydesc	VARCHAR	264	NO	YES	NULL
67	pad	INT	10	NO	YES	NULL
68	paddesc	VARCHAR	264	NO	YES	NULL
69	shell	INT	10	NO	YES	NULL
70	shelldesc	VARCHAR	264	NO	YES	NULL
71	corrosion	INT	10	NO	YES	NULL
72	corrosiondesc	VARCHAR	264	NO	YES	NULL
73	imprinting	INT	10	NO	YES	NULL
74	imprintingdesc	VARCHAR	264	NO	YES	NULL
75	residue	INT	10	NO	YES	NULL
76	residuedesc	VARCHAR	264	NO	YES	NULL
77	discoloration	INT	10	NO	YES	NULL
78	discolorationdesc	VARCHAR	264	NO	YES	NULL
79	wax	INT	10	NO	YES	NULL
80	waxdesc	VARCHAR	264	NO	YES	NULL
81	wear	INT	10	NO	YES	NULL
82	weardesc	VARCHAR	264	NO	YES	NULL
83	scratch	INT	10	NO	YES	NULL
84	scratchdesc	VARCHAR	264	NO	YES	NULL
85	crack	INT	10	NO	YES	NULL
86	crackdesc	VARCHAR	264	NO	YES	NULL
87	warp	INT	10	NO	YES	NULL
88	warpdesc	VARCHAR	264	NO	YES	NULL
89	crazing	INT	10	NO	YES	NULL
90	crazingdesc	VARCHAR	264	NO	YES	NULL

91	peeling	INT	10	NO	YES	NULL
92	peelingdesc	VARCHAR	264	NO	YES	NULL
93	etichetta	INT	10	NO	YES	NULL
94	etichettadesc	VARCHAR	264	NO	YES	NULL
95	centrehole	INT	10	NO	YES	NULL
96	centreholedesc	VARCHAR	264	NO	YES	NULL
97	blister	INT	10	NO	YES	NULL
98	blisterdesc	VARCHAR	264	NO	YES	NULL
99	ghost	INT	10	NO	YES	NULL
100	ghostdesc	VARCHAR	264	NO	YES	NULL

Table F.35: diagnosischeda

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.36: Primary key diagnosischeda

Table diametro

Controlled vocabulary for the values of the diameter of a given audio carrier.

The term diameter refers to:
- the diameter of the flange in the case of open-reel-tapes;
- the diameter of the disc in case of phonographic discs;
- the diameter of the disc in case of Compact Discs.

Columns (3)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	20	NO	NO	NONE
3	tipo	INT	10	NO	NO	NONE

Table F.37: diametro

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.38: Primary key diametro

Unique keys (1)

Columns of the unique key: `valore`, `tipo`.

Table documorig

Information on the original document.

Columns (45)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	segnatura	VARCHAR	128	YES	NO	NONE
3	archivio	INT	10	NO	NO	NONE
4	fondo	INT	10	NO	YES	NULL
5	serie	INT	10	NO	YES	NULL
6	velocita	INT	10	NO	YES	NULL
7	consultabile	BIT	0	NO	YES	NULL
8	riavvolgimentoprima	INT	10	NO	YES	NULL
9	testonote	VARCHAR	64	NO	YES	NULL
10	allegati	VARCHAR	64	NO	YES	NULL
11	tecnicaregistrazione	INT	10	NO	YES	NULL
12	larghezzanastro	INT	10	NO	YES	NULL
13	custodiatipo	INT	10	NO	YES	NULL
14	custodiamarca	INT	10	NO	YES	NULL
15	supportomarca	INT	10	NO	YES	NULL
16	supportomodello	VARCHAR	20	NO	YES	NULL
17	flangiamarca	INT	10	NO	YES	NULL
18	proceduraarchiv	INT	10	NO	YES	NULL
19	statoconservazione	INT	10	NO	YES	NULL
20	tipo	INT	10	YES	NO	NONE
21	supportohdd	INT	10	NO	YES	NULL
22	eq	INT	10	NO	YES	NULL
23	fc	INT	10	NO	YES	NULL
24	nr	INT	10	NO	YES	NULL
25	codifica	INT	10	NO	YES	NULL
26	bitdepth	INT	10	NO	YES	NULL
27	bitrate	INT	10	NO	YES	NULL

28	formato	INT	10	NO	YES	NULL
29	numerolati	INT	10	NO	YES	NULL
30	numeropiste	INT	10	NO	YES	NULL
31	segnale	INT	10	NO	YES	NULL
32	numerotracce	INT	10	NO	YES	NULL
33	noteconservazione	TEXT	65535	NO	YES	NULL
34	matrice	VARCHAR	36	NO	YES	NULL
35	numerotake	VARCHAR	36	NO	YES	NULL
36	edito	BIT	0	NO	YES	NULL
37	annoedizione	VARCHAR	12	NO	YES	NULL
38	etichetta	VARCHAR	64	NO	YES	NULL
39	diametro	INT	10	NO	YES	NULL
40	registrazionead	INT	10	NO	YES	NULL
41	grooveorientation	INT	10	NO	YES	NULL
42	layersurfacematerial	INT	10	NO	YES	NULL
43	layersubstratematerial	INT	10	NO	YES	NULL
44	riavvolgimentodopo	INT	10	NO	YES	NULL
45	estensione	INT	10	NO	YES	NULL

Table F.39: documorig

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.40: Primary key documorig

Foreign keys (35)

FK col.	PK table	PK col.	delete rule	update rule
estensione	estensione	id	NoAction	NoAction

larghezzanastro	larghezzanastro	id	NoAction	NoAction
segnale	tiposegnale	id	NoAction	NoAction
numerolati	numerolati	id	NoAction	NoAction
numeropiste	numeropiste	id	NoAction	NoAction
supportohdd	supportohdd	id	NoAction	NoAction
numerotracce	numerotracce	id	NoAction	NoAction
eq	eq	id	NoAction	NoAction
fc	fc	id	NoAction	NoAction
nr	nr	id	NoAction	NoAction
codifica	codifica	id	NoAction	NoAction
bitdepth	bitdepth	id	NoAction	NoAction
velocita	velocita	id	NoAction	NoAction
bitrate	bitrate	id	NoAction	NoAction
flangiamarca	marca	id	NoAction	NoAction
formato	mime	id	NoAction	NoAction
supportohdd	tipo	id	NoAction	NoAction
archivio	archivio	id	NoAction	NoAction
fondo	fondo	id	NoAction	NoAction
serie	serie	id	NoAction	NoAction
registrazionead	registrazionead	id	NoAction	NoAction
registrazionead	registrazionead	id	NoAction	NoAction
diametro	diametro	id	NoAction	NoAction
riavvolgimentoprima	riavvolgimento	id	NoAction	NoAction
grooveorientation	grooveorientation	id	NoAction	NoAction
layersurfacematerial	layersurfacematerial	id	NoAction	NoAction
layersubstratematerial	layersubstratematerial	id	NoAction	NoAction
riavvolgimentoprima	riavvolgimento	id	NoAction	NoAction
riavvolgimentodopo	riavvolgimento	id	NoAction	NoAction
tecnicaregistrazione	tecnicaregistrazione	id	NoAction	NoAction
custodiatipo	custodia	id	NoAction	NoAction
supportomarca	marca	id	NoAction	NoAction
proceduraarchiv	procedarchiv	id	NoAction	NoAction
statoconservazione	diagnosi	id	NoAction	NoAction

tipo	tipo	id	NoAction	NoAction

Table F.41: Foreign keys documorig

Table eq

Controlled vocabulary for the values of the equalization curve.

Columns (3)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	tipo	INT	10	NO	NO	NONE
3	valore	VARCHAR	20	NO	NO	NONE

Table F.42: eq

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.43: Primary key eq

Unique keys (1)

Columns of the unique key: `valore`, `tipo`.

Table estensione

Controlled vocabulary for the extensions of the digital files.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	20	YES	NO	NONE

Table F.44: estensione

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.45: Primary key estensione

Table fc

Controlled vocabulary for the values of the sampling frequency.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	20	YES	NO	NONE

Table F.46: fc

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.47: Primary key fc

Table fondo

Information on the sections (funds) in which archives can be articulated. See also table `archivio`.

Columns (9)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	superiore	INT	10	NO	NO	NONE
3	nome	VARCHAR	128	YES	NO	NONE
4	codice	VARCHAR	12	YES	NO	NONE
5	descrizione	TEXT	65535	NO	YES	NULL
6	motivazione	TEXT	65535	NO	YES	NULL
7	proprietario	INT	10	NO	YES	NULL
8	referente	INT	10	NO	YES	NULL
9	note	TEXT	65535	NO	YES	NULL

Table F.48: fondo

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.49: Primary key fondo

Foreign keys (3)

FK col.	PK table	PK col.	delete rule	update rule
superiore	archivio	id	NoAction	NoAction
proprietario	persona	id	NoAction	NoAction
referente	persona	id	NoAction	NoAction

Table F.50: Foreign keys fondo

Table genere

Controlled vocabulary for the values of the genres associated to the ARMAs, according to [143].

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	240	YES	NO	NONE

Table F.51: genere

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.52: Primary key genere

Table giannelli

Controlled vocabulary for the values of the linguistic varieties associated to the ARMAs, according to [143].

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	64	YES	NO	NONE

Table F.53: giannelli

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.54: Primary key giannelli

Table giorno

Controlled vocabulary for the days in a month.

Columns (1)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	valore	VARCHAR	2	YES	NO	NONE

Table F.55: giorno

Primary key (1)

Information about the primary key:

Position	Col. Name
1	valore

Table F.56: Primary key giorno

Table grooveorientation

Controlled vocabulary for the values of the orientation of the grooves for phonographic discs.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	20	YES	NO	NONE

Table F.57: grooveorientation

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.58: Primary key grooveorientation

Table gruppointervistati

This table associates the interviewees to the ARMAs.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	unita	INT	10	NO	NO	NONE
2	persona	INT	10	NO	NO	NONE

Table F.59: gruppointervistati

Foreign keys (2)

FK col.	PK table	PK col.	delete rule	update rule
unita	unita	id	NoAction	NoAction
persona	persona	id	NoAction	NoAction

Table F.60: Foreign keys gruppointervistati

Unique keys (1)

Columns of the unique key: `unita`, `persona`.

Table gruppointervistatori

This table associates the interviewers to the ARMAs.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	unita	INT	10	NO	NO	NONE
2	persona	INT	10	NO	NO	NONE

Table F.61: gruppointervistatori

Foreign keys (2)

FK col.	PK table	PK col.	delete rule	update rule
unita	unita	id	NoAction	NoAction
persona	persona	id	NoAction	NoAction

Table F.62: Foreign keys gruppointervistatori

Unique keys (1)

Columns of the unique key: `unita`, `persona`.

Table keyword

This table associates the keywords in table `parola` to the ARMAs in table `unita`.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	unita	INT	10	NO	NO	NONE
2	parola	INT	10	NO	NO	NONE

Table F.63: keyword

Foreign keys (2)

FK col.	PK table	PK col.	delete rule	update rule
unita	unita	id	NoAction	NoAction
parola	parola	id	NoAction	NoAction

Table F.64: Foreign keys keyword

Table larghezzanastro

Controlled vocabulary for the values of the tape width, which applies to Compact Cassettes, Microcassettes, open-reel-tapes and DATs.

Columns (3)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	20	NO	NO	NONE
3	tipo	INT	10	NO	NO	NONE

Table F.65: larghezzanastro

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.66: Primary key larghezzanastro

Unique keys (1)

Columns of the unique key: `valore`, `tipo`.

Table layersubstratematerial

Controlled vocabulary for the materials of the substrate of the audio carriers (for Compact Cassettes, Microcassettes, Compact Discs, open-reel-tapes, phonographic discs and DATs).

Columns (3)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	20	NO	NO	NONE
3	tipo	INT	10	NO	NO	NONE

Table F.67: layersubstratematerial

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.68: Primary key layersubstratematerial

Unique keys (1)

Columns of the unique key: `valore`, `tipo`.

Table layersurfacematerial

Controlled vocabulary for the materials of the surface of the audio carriers (for Compact Cassettes, Microcassettes, Compact Discs, open-reel-tapes, phonographic discs and DATs).

Columns (3)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	20	NO	NO	NONE
3	tipo	INT	10	NO	NO	NONE

Table F.69: layersurfacematerial

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.70: Primary key layersurfacematerial

Unique keys (1)

Columns of the unique key: `valore`, `tipo`.

Table localita

Controlled vocabulary including all the provinces and municipalities of Italy (data source: ISTAT databases[3]).

Columns (6)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	provincia	VARCHAR	10	NO	YES	NULL
3	comune	VARCHAR	10	NO	YES	NULL
4	nome	VARCHAR	40	NO	YES	NULL
5	faprovincia	BIT	0	NO	YES	NULL
6	regione	INT	10	NO	YES	NULL

Table F.71: localita

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.72: Primary key localita

[3] `http://www.istat.it/en/products/databases` (last visited on March 24th, 2013).

Table luogo

Venue where the re-mediation process took place.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	128	YES	NO	NONE

Table F.73: luogo

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.74: Primary key luogo

Table mansione

This table associates the people involved or mentioned in the project (table `persona`) to the roles (table `ruolo`) they play in the project.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	persona	INT	10	NO	NO	NONE
2	ruolo	INT	10	NO	NO	NONE

Table F.75: mansione

Primary key (2)

Information about the primary key:

Position	Col. Name
1	persona
2	ruolo

Table F.76: Primary key mansione

Foreign keys (2)

FK col.	PK table	PK col.	delete rule	update rule
persona	persona	id	NoAction	NoAction
ruolo	ruolo	id	NoAction	NoAction

Table F.77: Foreign keys mansione

Unique keys (1)

Columns of the unique key: `persona`, `ruolo`.

Table marca

Controlled vocabulary of the brands of the audio documents (may refer to boxes/cases as well as carriers: magnetic tapes, . . .).

Columns (3)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	20	NO	NO	NONE
3	tipo	INT	10	NO	NO	NONE

Table F.78: marca

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.79: Primary key marca

Unique keys (1)

Columns of the unique key: `valore`, `tipo`.

Table mese

Controlled vocabulary for the months in a year (bilingual, Italian and English).

Columns (3)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	italiano	VARCHAR	12	YES	NO	NONE
3	inglese	VARCHAR	12	YES	YES	NULL

Table F.80: mese

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.81: Primary key mese

Table mime

Controlled vocabulary for the digital file formats according to the standard classification MIME (Multipurpose Internet Mail Extensions).

Columns (3)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	64	NO	NO	NONE
3	estensione	INT	10	NO	NO	NONE

Table F.82: mime

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.83: Primary key mime

Unique keys (1)

Columns of the unique key: `valore`, `estensione`.

Table montaggio

This table associates the audio files of the ARMAs (table `copiamontata`) to the audio files contained in the preservation copies (table `traccia`) which have been used to generate them.

This table maintains the relation between the data and the metadata produced during the re-mediation process (conservative approach) to the data and the metadata produced during the cataloguing of the resources.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	unita	INT	10	NO	NO	NONE
2	traccia	INT	10	NO	NO	NONE

Table F.84: montaggio

Foreign keys (2)

FK col.	PK table	PK col.	delete rule	update rule
traccia	traccia	id	NoAction	NoAction
unita	unita	id	NoAction	NoAction

Table F.85: Foreign keys montaggio

Unique keys (1)

Columns of the unique key: `unita`, `traccia`.

Table mp3mode

Controlled vocabulary for the types of configuration of the channels in the MP3 audio format.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	20	YES	NO	NONE

Table F.86: mp3mode

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.87: Primary key mp3mode

Table nr

Controlled vocabulary for the noise reduction systems.

Columns (3)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	20	NO	NO	NONE
3	tipo	INT	10	NO	NO	NONE

Table F.88: nr

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.89: Primary key nr

Foreign keys (1)

FK col.	PK table	PK col.	delete rule	update rule
tipo	tipo	id	NoAction	NoAction

Table F.90: Foreign keys nr

Unique keys (1)

Columns of the unique key: `valore`, `tipo`.

Table numerolati

Controlled vocabulary for the number of sides of a given audio carrier.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	2	YES	NO	NONE

Table F.91: numerolati

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.92: Primary key numerolati

Table numeropiste

Controlled vocabulary for the number of tracks (channels) characterizing a given audio signal.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	2	YES	NO	NONE

Table F.93: numeropiste

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.94: Primary key numeropiste

Table numerotracce

Controlled vocabulary for the number of tracks contained in a given audio carrier. It applies to Compact Discs, DATs and the audio files on non-audio digital carriers.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	3	YES	NO	NONE

Table F.95: numerotracce

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.96: Primary key numerotracce

Table parola

Controlled vocabulary for the keywords to associate to the ARMAs.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	255	YES	NO	NONE

Table F.97: parola

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.98: Primary key parola

Table path

This tables contains the paths to the files and folders (on the users' local machines) necessary during the execution of PSKit PreservationPanel and CataloguingPanel.

Columns (43)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	chiave	VARCHAR	20	YES	NO	NONE
2	operatore	VARCHAR	40	NO	YES	NULL
3	codiceoperatore	INT	10	YES	NO	NONE
4	fototemp	VARCHAR	200	NO	YES	NULL
5	audiotemp	VARCHAR	200	NO	YES	NULL
6	archiviotest	VARCHAR	200	NO	YES	NULL
7	sharetrascrizioni	VARCHAR	200	NO	YES	NULL
8	shareaudio	VARCHAR	200	NO	YES	NULL
9	scriptfolder	VARCHAR	200	NO	YES	NULL
10	specsfolder	VARCHAR	200	NO	YES	NULL
11	trascorto1	VARCHAR	200	NO	YES	NULL
12	trascorto2	VARCHAR	200	NO	YES	NULL
13	cc1	VARCHAR	200	NO	YES	NULL
14	cc2	VARCHAR	200	NO	YES	NULL
15	ac1	VARCHAR	200	NO	YES	NULL
16	ac2	VARCHAR	200	NO	YES	NULL
17	bwf	VARCHAR	200	NO	YES	NULL
18	jpeg	VARCHAR	200	NO	YES	NULL
19	csmd5	VARCHAR	200	NO	YES	NULL
20	cscrc32	VARCHAR	200	NO	YES	NULL
21	cssha1	VARCHAR	200	NO	YES	NULL
22	convenzioniit	VARCHAR	200	NO	YES	NULL
23	convenzionien	VARCHAR	200	NO	YES	NULL
24	fileconchiave	VARCHAR	200	NO	YES	NULL
25	iconaapp	VARCHAR	200	NO	YES	NULL

26	welcomeimagegenerica	VARCHAR	200	NO	YES	NULL
27	welcomeimagework	VARCHAR	200	NO	YES	NULL
28	welcomeimageuser	VARCHAR	200	NO	YES	NULL
29	mc	VARCHAR	200	NO	YES	NULL
30	ab	VARCHAR	200	NO	YES	NULL
31	cd	VARCHAR	200	NO	YES	NULL
32	dat	VARCHAR	200	NO	YES	NULL
33	hdd	VARCHAR	200	NO	YES	NULL
34	unknown	VARCHAR	200	NO	YES	NULL
35	registro	TEXT	65535	NO	YES	NULL
36	schemiriversamento	VARCHAR	200	NO	YES	NULL
37	schemamc	VARCHAR	200	NO	YES	NULL
38	schemaab	VARCHAR	200	NO	YES	NULL
39	schemacd	VARCHAR	200	NO	YES	NULL
40	schemamicromc	VARCHAR	200	NO	YES	NULL
41	schemadisc	VARCHAR	200	NO	YES	NULL
42	schemadat	VARCHAR	200	NO	YES	NULL
43	schemahdd	VARCHAR	200	NO	YES	NULL

Table F.99: path

Primary key (1)

Information about the primary key:

Position	Col. Name
1	chiave

Table F.100: Primary key path

Foreign keys (1)

FK col.	PK table	PK col.	delete rule	update rule
codiceoperatore	persona	id	NoAction	NoAction

Table F.101: Foreign keys path

Table persona

Information on the people involved or mentioned in the project (the "address book" of the project).

Columns (14)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	nome	VARCHAR	24	NO	NO	NONE
3	cognome	VARCHAR	24	NO	YES	NULL
4	tel	VARCHAR	24	NO	YES	NULL
5	mail	VARCHAR	64	NO	YES	NULL
6	affiliazione	VARCHAR	64	NO	YES	NULL
7	sesso	BIT	0	NO	YES	NULL
8	dataN	VARCHAR	10	NO	YES	NULL
9	scolarizzazione	VARCHAR	128	NO	YES	NULL
10	professione	VARCHAR	128	NO	YES	NULL
11	regione	INT	10	NO	YES	NULL
12	provincia	INT	10	NO	YES	NULL
13	comune	INT	10	NO	YES	NULL
14	note	TEXT	65535	NO	YES	NULL

Table F.102: persona

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.103: Primary key persona

Foreign keys (3)

FK col.	PK table	PK col.	delete rule	update rule
regione	regione	id	NoAction	NoAction
provincia	localita	id	NoAction	NoAction
comune	localita	id	NoAction	NoAction

Table F.104: Foreign keys persona

Table procedarchiv

Controlled vocabulary for the archiving procedures of the audio carriers.

Columns (3)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	20	YES	NO	NONE
3	tipo	INT	10	YES	NO	NONE

Table F.105: procedarchiv

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.106: Primary key procedarchiv

Foreign keys (1)

FK col.	PK table	PK col.	delete rule	update rule
tipo	tipo	id	NoAction	NoAction

Table F.107: Foreign keys procedarchiv

Unique keys (1)

Columns of the unique key: `valore`, `tipo`.

Table regione

Controlled vocabulary for the regions of Italy. See also table `localita`.

Columns (5)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	24	YES	NO	NONE
3	codicefipsun	VARCHAR	4	YES	NO	NONE
4	codiceiso3166	VARCHAR	5	YES	NO	NONE
5	codiceistat	VARCHAR	2	YES	NO	NONE

Table F.108: regione

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.109: Primary key regione

Table registrazionead

Controlled vocabulary for the types of recording (analog or digital).

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	12	YES	NO	NONE

Table F.110: registrazionead

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.111: Primary key registrazionead

Table riavvolgimento

Controlled vocabulary for the winding of the tape before and after the remediation process.

Columns (3)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	20	YES	NO	NONE
3	tipo	INT	10	YES	NO	NONE

Table F.112: riavvolgimento

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.113: Primary key riavvolgimento

Foreign keys (1)

FK col.	PK table	PK col.	delete rule	update rule
tipo	tipo	id	NoAction	NoAction

Table F.114: Foreign keys riavvolgimento

Unique keys (1)

Columns of the unique key: `valore`, `tipo`.

Table ruolo

Controlled vocabulary for the roles played by the people within the project.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	64	YES	YES	NONE

Table F.115: ruolo

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.116: Primary key ruolo

Table serie

Information on the archive subsections (series) in which archives sections (funds) can be articulated (see also table `archivio`).

Columns (9)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	superiore	INT	10	NO	NO	NONE
3	nome	VARCHAR	128	YES	NO	NONE
4	codice	VARCHAR	12	YES	YES	NONE
5	descrizione	TEXT	65535	NO	YES	NULL
6	motivazione	TEXT	65535	NO	YES	NULL
7	proprietario	INT	10	NO	YES	NULL
8	referente	INT	10	NO	YES	NULL
9	note	TEXT	65535	NO	YES	NULL

Table F.117: serie

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.118: Primary key serie

Foreign keys (3)

FK col.	PK table	PK col.	delete rule	update rule
superiore	fondo	id	NoAction	NoAction
proprietario	persona	id	NoAction	NoAction
referente	persona	id	NoAction	NoAction

Table F.119: Foreign keys serie

Table supportohdd

Controlled vocabulary for the types of digital non-audio carriers.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	64	YES	YES	NONE

Table F.120: supportohdd

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.121: Primary key supportohdd

Table tecnicaregistrazione

Controlled vocabulary for the recording techniques (e.g., optical, magnetic, mechanical, . . .).

Columns (3)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	24	NO	NO	NONE
3	tipo	INT	10	NO	NO	NONE

Table F.122: tecnicaregistrazione

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.123: Primary key tecnicaregistrazione

Foreign keys (1)

FK col.	PK table	PK col.	delete rule	update rule
tipo	tipo	id	NoAction	NoAction

Table F.124: Foreign keys tecnicaregistrazione

Unique keys (1)

Columns of the unique key: `valore`, `tipo`.

Table tipo

Controlled vocabulary for the types of audio carrier.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	18	YES	NO	NONE

Table F.125: tipo

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.126: Primary key tipo

Table tiposegnale

Controlled vocabulary for the types of audio signal (mono, stereo, unknown). Si tratta di una valutazione qualitativa dell'operatore.

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	20	YES	NO	NONE

Table F.127: tiposegnale

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.128: Primary key tiposegnale

Table tipotrascrizione

Controlled vocabulary for the types of linguistic transcriptions.
This table has been adapted to meet the new requirements expressed by the linguistics research team at an advanced stage of the project, therefore its name remained `tipotrascrizione` although now it includes the descriptions of the accompanying materials (not only ortographic/phonetic transcriptions).

Columns (2)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	valore	VARCHAR	40	YES	NO	NONE

Table F.129: tipotrascrizione

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.130: Primary key tipotrascrizione

Table traccia

Information on the audio tracks contained in the preservation copies.

Columns (22)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	nome	VARCHAR	128	YES	NO	NONE
3	cc	INT	10	YES	NO	NONE
4	durata	VARCHAR	24	NO	YES	NULL
5	mime	INT	10	NO	YES	NULL
6	size	VARCHAR	28	NO	YES	NULL
7	status	VARCHAR	64	NO	YES	NULL
8	profile	VARCHAR	64	NO	YES	NULL
9	codifica	INT	10	NO	YES	NULL
10	byteorder	VARCHAR	64	NO	YES	NULL
11	encoding	VARCHAR	64	NO	YES	NULL
12	compression	VARCHAR	64	NO	YES	NULL
13	firstsampleoffset	VARCHAR	32	NO	YES	NULL
14	checksumcrc32	VARCHAR	8	NO	YES	NULL
15	checksummd5	VARCHAR	32	NO	YES	NULL
16	checksumsha1	VARCHAR	40	NO	YES	NULL
17	fc	INT	10	NO	YES	NULL
18	bitdepth	INT	10	NO	YES	NULL
19	bitrate	INT	10	NO	YES	NULL
20	note	TEXT	65535	NO	YES	NULL
21	numeropiste	INT	10	NO	YES	NULL
22	estensione	INT	10	NO	YES	NULL

Table F.131: traccia

Primary key (1)

Information about the primary key:

Foreign keys (2)

Position	Col. Name
1	id

Table F.132: Primary key traccia

FK col.	PK table	PK col.	delete rule	update rule
cc	cc	id	NoAction	NoAction
mime	mime	id	NoAction	NoAction
codifica	codifica	id	NoAction	NoAction
fc	fc	id	NoAction	NoAction
bitrate	bitrate	id	NoAction	NoAction
bitdepth	bitdepth	id	NoAction	NoAction
numeropiste	numeropiste	id	NoAction	NoAction
estensione	estensione	id	NoAction	NoAction

Table F.133: Foreign keys traccia

Table trascrizione

Information on the ortographic and phonetic transcriptions of the ARMAs. This table has been adapted to meet the new requirements expressed by the linguistics research team at an advanced stage of the project, therefore its name remained `trascrizione` although now it includes the accompanying materials along with the ortographic/phonetic transcriptions.

Columns (5)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	nome	VARCHAR	64	NO	NO	NONE
3	tipo	INT	10	NO	YES	NULL
4	operatore	INT	10	NO	YES	NULL
5	unita	INT	10	NO	NO	NONE

Table F.134: trascrizione

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.135: Primary key trascrizione

Foreign keys (3)

FK col.	PK table	PK col.	delete rule	update rule
tipo	tipotrascrizione	id	NoAction	NoAction
unita	unita	id	NoAction	NoAction
operatore	persona	id	NoAction	NoAction

Table F.136: Foreign keys trascrizione

Unique keys (1)

Columns of the unique key: `nome`, `tipo`, `unita`.

Table unita

Information on the ARMAs.

Columns (39)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	segnatura	VARCHAR	128	YES	NO	NONE
3	operatore	INT	10	NO	YES	NULL
4	archivio	INT	10	NO	YES	NULL
5	fondo	INT	10	NO	YES	NULL
6	serie	INT	10	NO	YES	NULL
7	regione	INT	10	NO	YES	NULL
8	provincia	INT	10	NO	YES	NULL
9	comune	INT	10	NO	YES	NULL
10	ubicazione	INT	10	NO	YES	NULL
11	note_ubicazione	TEXT	65535	NO	YES	NULL
12	titolo	VARCHAR	256	NO	YES	NULL
13	titoloalt	VARCHAR	128	NO	YES	NULL
14	abstract	TEXT	65535	NO	YES	NULL
15	controllato	BIT	0	NO	YES	NULL
16	cantato	BIT	0	NO	YES	NULL
17	formalizzato	BIT	0	NO	YES	NULL
18	finalita	TEXT	65535	NO	YES	NULL
19	giannelli	INT	10	NO	YES	NULL
20	genere	INT	10	NO	YES	NULL
21	argomento	INT	10	NO	YES	NULL
22	descrizionematerialecorredoa	TEXT	65535	NO	YES	NULL
23	descrizionematerialecorredob	TEXT	65535	NO	YES	NULL
24	descrizioneallegati	TEXT	65535	NO	YES	NULL
25	tipoambientazione	BIT	0	NO	YES	NULL
26	materialesensibile	BIT	0	NO	YES	NULL
27	descrizioneambientazione	TEXT	65535	NO	YES	NULL

28	bibliografia	TEXT	65535	NO	YES	NULL
29	notelocalita	TEXT	65535	NO	YES	NULL
30	note	TEXT	65535	NO	YES	NULL
31	datadal	VARCHAR	10	NO	YES	NULL
32	dataal	VARCHAR	10	NO	YES	NULL
33	notedata	TEXT	65535	NO	YES	NULL
34	contenutain	INT	10	NO	YES	NULL
35	minutaggioda	VARCHAR	12	NO	YES	NULL
36	minutaggioa	VARCHAR	12	NO	YES	NULL
37	mammafiglia	VARCHAR	45	NO	YES	NULL
38	datacreazione	VARCHAR	12	NO	YES	NULL
39	parzriservato	TEXT	65535	NO	YES	NULL

Table F.137: unita

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.138: Primary key unita

Foreign keys (11)

FK col.	PK table	PK col.	delete rule	update rule
genere	genere	id	NoAction	NoAction
operatore	persona	id	NoAction	NoAction
contenutain	unita	id	NoAction	NoAction
argomento	argomento	id	NoAction	NoAction
giannelli	giannelli	id	NoAction	NoAction
archivio	archivio	id	NoAction	NoAction
fondo	fondo	id	NoAction	NoAction

serie	serie	id	NoAction	NoAction
regione	regione	id	NoAction	NoAction
provincia	localita	id	NoAction	NoAction
comune	localita	id	NoAction	NoAction

Table F.139: Foreign keys unita

Table velocita

Controlled vocabulary for the values of the tape transfer rate (cm/s) and the revolutions of a disc (rpm).

Columns (3)

POS.	NAME	TYPE	SIZE	UNIQUE	NULLABLE	DEFAULT
1	id	INT	10	YES	NO	NONE
2	tipo	INT	10	NO	NO	NONE
3	valore	VARCHAR	40	NO	NO	NONE

Table F.140: velocita

Primary key (1)

Information about the primary key:

Position	Col. Name
1	id

Table F.141: Primary key velocita

Foreign keys (1)

FK col.	PK table	PK col.	delete rule	update rule
tipo	tipo	id	NoAction	NoAction

Table F.142: Foreign keys velocita

Unique keys (1)

Columns of the unique key: `valore`, `tipo`.

G

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H

Abstract (Italian translation)

This Chapter contains the abstract of the thesis in Italian language, as requested by the Department of Computer Science of the University of Verona.

H.1 Sommario

Il contributo della scienza informatica al settore della conservazione dei beni culturali ha prodotto notevoli risultati negli ultimi anni, ad esempio traducendo una profonda comprensione delle potenzialit dello stato dell'arte tecnologico in applicazioni innovative, guadagnando in cambio un forte impulso per l'avanzamento della ricerca sul fronte della multimedialit e dei sistemi interattivi. In questo vivace scenario, il collegamento con l'universo degli archivi sonori appare piuttosto debole, nonostante la Comunità Europea abbia promosso attivamente la salvaguardia della memoria collettiva e del patrimonio culturale *intangibile*.
Questa tesi riassume il lavoro svolto dall'autore negli ultimi quattro anni, i quali sono stati interamente dedicati allo sforzo di stabilire una connessione tra le tante discipline coinvolte nella conservazione dei documento sonori, vivendo esperienze di prolungata permanenza in istituzioni archivistiche e in dipartimenti di ricerca, a contatto quotidiano con gli esperti del settore. Il risultato un composito bagaglio di conoscenza che viene presentato in questa sede all'interno di una metodologia scientifica, la base comune della quale costituita da un approccio informatico al controllo della qualit nel processo di conservazione.
Lo scenario in cui si colloca l'oggetto di studio viene presentato nel capitolo introduttivo della tesi, la quale organizzata in cinque parti. La prima parte introduce il mondo della conservazione, con particolare attenzione agli aspetti etici e filologici coinvolti, riportando il pensiero dei pi autorevoli esponenti della comunità archivistica internazionale a partire dagli anni Ottanta del secolo scorso. Alla luce di queste posizioni, l'autore propone una propria metodologia di conservazione, dettagliandone il protocollo operativo in cui

sono riflessi i principî teorici. La seconda parte descrive un insieme originale di strumenti informatici che l'autore ha sviluppato con l'obiettivo di massimizzare il controllo sulla qualit del processo di conservazione, assistendo e automatizzando le operazioni coinvolte. La terza parte riporta i risultati delle analisi chimiche, meccaniche e audio che sono state condotte per aumentare la comprensione di uno dei metodi pi comuni per il ripristino delle funzionalit fisiche dei nastri magnetici: il trattamento termico. La quarta parte offre una descrizione dei progetti di ricerca all'interno dei quali si svolta grande parte del lavoro riportato in questa sede. Gli archivi coinvolti sono stati un insostituibile banco di prova per la metodologia in fase di definizione, permettendo all'autore di perfezionare le procedure grazie al confronto quotidiano con i problemi degli archivi reali. Infine, la quinta parte getta uno sguardo a uno dei settori pi avanzati della conservazione, quello che si occupa delle installazioni multimediali interattive. In questo caso il suono è solo uno degli elementi che contribuiscono alla realizzazione dell'esperienza estetica, e anche se il problema della sua conservazione si avvantaggia naturalmente della conoscenza maturata con gli archivi sonori, rimane da affrontare l'aspetto non banale della molteplicità di media e dell'interazione in tempo reale. L'appendice, di dimensioni considerevoli, che chiude questo lavoro include un elenco dei sintomi e degli indicatori di degrado che affligge le diverse tipologie di supporti sonori; l'elenco è stato compilato incrociando diverse fonti e allineando le definizioni talvolta contraddittorie o intersecanti. Lo scopo dell'elenco è quello di iniziare a fornire un vocabolario di riferimento per colmare la lacuna che esiste nel campo degli strumenti diagnostici delle collezioni di documenti sonori.