Diagnostic study of Durium phonographic discs on paper substrate

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Introduction

Within the Institute for Sound and Audiovisual Heritage (ICBSA) of the Italian Minister of Cultural Heritage (MiBAC) there is a collection of over 1,500 phonograph discs made of Durium, a synthetic resin spread over a cardboard base [1].

This sound recording support was invented by Hal T. Beans, a professor of chemistry at Columbia University.

In April 1929 Beans patented a brown synthetic resin, resistant to water and fire, colorless, odorless and able to harden quickly while remaining very flexible.

Initially used in other technical and product fields, this material soon became a cheaper and more easily used substitute of the shellac and bakelite used for traditional record productions.

Background

The ICBSA collection of Durium discs dated from the 30's to the 50's.

Since the Durium discs are made by coupling cardboard and plastic material they have shown over time strong deformations. These make them often unreadable with the classic turntables nowadays.

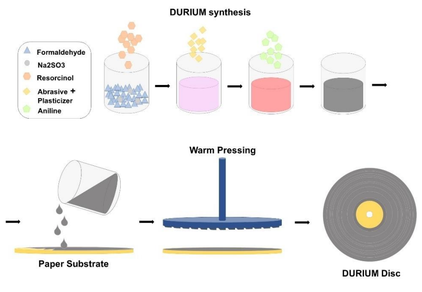
A project started aimed at recovering the sound content of the records through the characterization of the constituent materials of the discs and the experimentation of innovative procedures for their restoration and digital preservation.

A Durium disc (diameter 24 cm) labeled "Hit of the week" made in the USA in 1930. The right image shows the cardboard back side. The sound recording lasts 2 minutes and 16 seconds

Materials

The technology to produce paper based phonograph discs was based on the spreading of a large sheet of cardboard substrate with a liquid phenol formaldehyde resin.

The resin was impressed in order to form sound grooves and then dried at 230 degrees °C: this system allowed to print several discs simultaneously. The dried sheet was lacquered to avoid deformation and the label was etched directly onto the disc surface.



Durium production started from around 1930 with dance and jazz tracks of the Hit of the week label. On these supports music, advertisements or study courses were recorded.

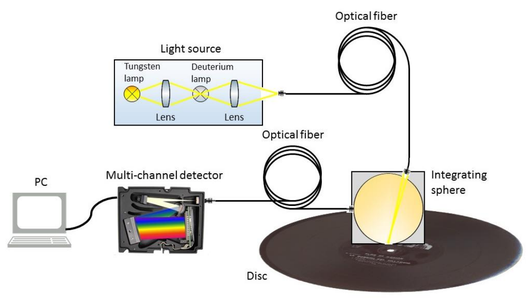
Experiments

Optical microscopy

Images were acquired in reflected light by using a STMPRO-T stereomicroscope by BEL Engineering equipped with a 3 MPixel EUREKAM 3.0 camera (magnification 30×). Images were calibrated in order to obtain quantitative information on the morphology of the discs and grooves by using ImageJ software (http://imagej.nih.gov/ij).

UV-Vis diffuse reflectance

The diffuse reflectance (R) spectra on Durium and paper substrate were measured in the 250–1050-nm range by a fiber-optics setup with integrating sphere from AvantesBV. R spectra were normalized to a Spectralon® reference standard [2].

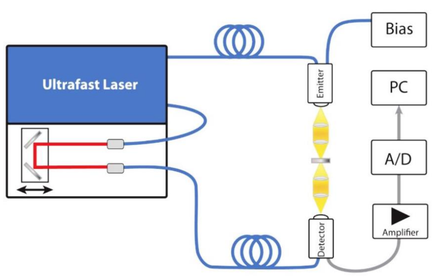


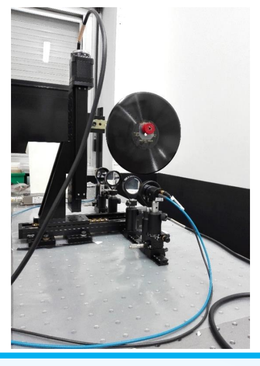
Fourier Transform Infrared (FTIR) spectroscopy

FTIR spectra were acquired by using a JASCO FTIR 410 equipped with a microscope in order to obtain non-invasive measurements in reflection mode in an area of about 100×100 μm^2. FTIR spectra were acquired by averaging 512 scans with a resolution of 4 cm^{-1}.

Terahertz time-domain imaging (THz-TDI)

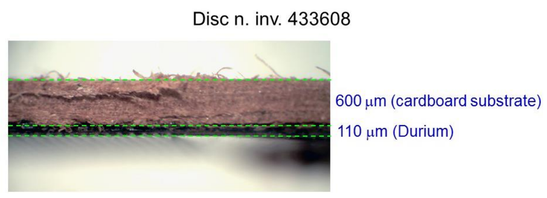
THz-TDI were acquired in transmission mode by using a Menlo Systems TERA K15 equipped with photoconductive antennas and a xy translation stage. Transmitted THz pulses E(t) propagating through the discs and through air were recorded [3,4].

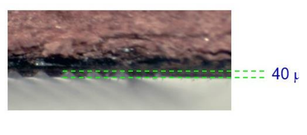


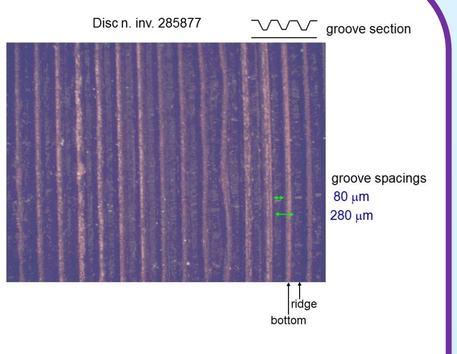


Results

One disc owned by the ICBSA in several copies was used for destructive analysis of the grooves' **morphology** (width, depth and profile) Durium and carboard substrate thicknesses.

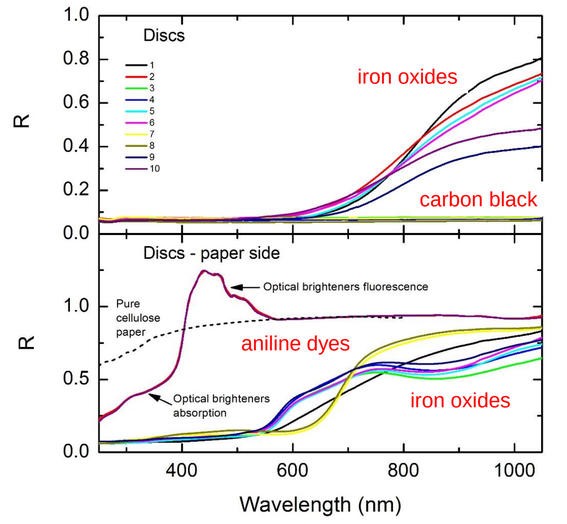




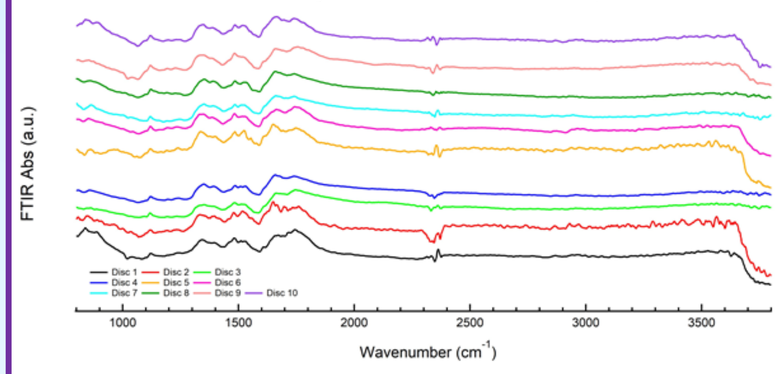


The **R** spectral trends can be divided into three groups for the Durium side and into four groups for the paper side.

Graphic mediations are likely obtained by aniline dyes, dispersed in a medium with a strong chemical affinity with the surface such as sulphonated castor oil, used for the preparation of the Durium itself.



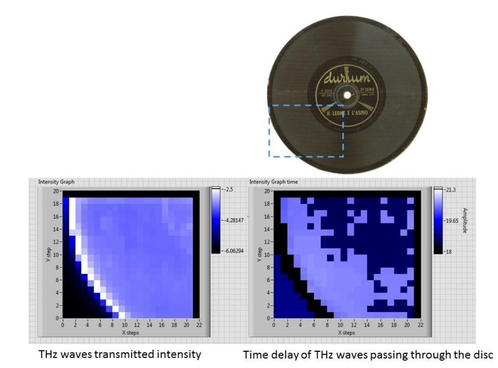
All discs show **FTIR** peaks at about 1120 cm^{-1} (C-O-C stretching), 1380 cm^{-1} (in-plane OH), 1460 and 1485 cm^{-1} (CH) and between 1500 and 1550 cm^{-1} (aromatic ring of resorcinol). This confirms the composition of the Durium layer as formed by a phenolic resin as resorcinol-formaldehyde indicated in the patent.



Peaks around 1740 cm^{-1} (carbonyls) also suggest the presence of additional components, probably rich in fatty acids (castor oil indicated in the patent).

As for the paper side, the spectra are similar to each other and show the characteristic peaks of cellulose.

Two types of images were obtained with **THz-TDI**: attenuation that pulses have when crossing the discs mainly due to the overall thickness; time delays of pulses with respect to the air. The delay is due both to the thickness and to the THz refractive index of the disc materials and it is related to their chemical characteristics [5].



References

[1] On this type of disk see also http://hitoftheweek.blogspot.com/ searching 'Hans Koert'.
[2] M. Missori, Optical spectroscopy of ancient paper and textiles, Il Nuovo Cimento C, 39, 2, (2016) 293-302.
[3] M. Peccianti, R. Fastampa, A. Mosca Conte, O. Pulci, C. Violante, J. Łojewska, M. Clerici, R. Morandotti and M. Missori, Terahertz absorption by cellulose: Application to ancient paper artifacts, Phys. Rev. Applied, 7 (2017) 064019-1-7.
[4] M. Missori, D. Pawcenis, J. Bagniuk, A. Mosca Conte, C. Violante, M.S. Maggio, M. Peccianti, O. Pulci, J. Łojewska, Quantitative diagnostics of ancient paper using THz time-domain spectroscopy, Microchem. J., 142 (2018) 54-61.
[5] R. Fastampa, L. Pilozzi, M. Missori, Cancellation of Fabry-Perot interference effects in terahertz time-domain spectroscopy of optically thin samples, Phys. Rev. A, 95, 6, (2017) 063831.

Acknowledgments

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