

Editorial

Special Issue: Application of Materials Science in the Study of Cultural Heritage

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1. Introduction

The application of advanced techniques to the study of ancient materials has been increasingly demonstrating to be fundamental to a deeper knowledge of artistic and historic artefacts, contributing to their conservation and restoration. The number of scientific methodologies applied to the Cultural Heritage is huge and difficult to be listed. However, it can be noted that an important role is played by Materials Science: scientific techniques developed in Materials Science allow to contribute a multidisciplinary approach in Archaeology, History of Art, and Conservation Science. By studying the materials that constitute the artefact, deeper information can be reached, relatively to the work of art, such as the elements and compounds by which it was made and their level of degradation over time. The final goal is the possibility of determining the chronology of the making of the various part of the work of art, its provenance, the techniques of realization, the attribution to an author, and the way of intervention for restoration. Materials Science offers many different scientific methodologies in order to investigate ancient materials and artefacts. The current Special Issue collects papers dealing with the applications of Materials Science to the different types of human artefacts such as ceramics, glass, paintings, metal objects. This Special Issue includes six papers that were accepted through a stringent reviewing process and they are summarized in the following section. The contributions topics range from instrumentation and technical developments to case studies, and to methodological innovations. The authors have exploited many characteristic analytical methods of Materials Science: imaging techniques (IRR, RX, tomography); traditional as well as innovative dating techniques like various luminescence methods; spectroscopic techniques (PIXE, Raman, FTIR, UV-vis reflectance spectroscopy), and their synergic association.

2. Review of Issue Contents

Artefacts studies are concerned with the investigation of the overall life cycle from the acquisition and processing of the raw materials through production and distribution, to use, reuse, and discard. Thus, Material Science is involved in the reconstruction of how the artefacts were made, where they were made and distributed, and how they were used.

For ceramics, in this Special Issue, Pèrez-Arantegui et al. [1] have contributed a study of Islamic ceramic manufacture in northern al-Andalus (the Muslim part of the Iberian Peninsula) with the aim to improve general knowledge of small production centres and add new insights into medieval ceramic technology in the Peninsula. This work characterised nearly one hundred ceramic fragments, dated since the 11th century CE from archaeological sites in Albarracin, all of them decorated, although only the results of glazed pottery are discussed. Most of them belonged to the tableware group (bowls, beakers, and dishes); the ceramic bodies were analysed by Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES), whereas the glazes were examined with Optical Microscopy (OM), Scanning Electron Microscopy (SEM), and Inductively Coupled Plasma-Quadrupole Mass Spectrometer (ICP-QMS). The obtained results allowed the characterisation of the



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pottery production from Albarracin Taifa in the 11–12th centuries CE, and established differences and similarities with Islamic productions manufactured in other Taifa kingdoms of the Iberian Peninsula during the same period. The analyses carried out on the ceramic bodies confirmed that the selection of raw materials depended on the decoration to be applied afterward.

Always remaining in the ceramics world, but moving in time and in space, Angelini et al. [2] reported the study of very unusual ceramic dice found in Castello d'Annone (Alessandria, Italy), bearing Etruscan letters and randomly distributed dots. They are a *unicum* and confirmed their exceptional importance both for the large quantity of recovered finds and for the reconstruction of the social and cultural context of an "emporium". Based on the measured data and the archaeological information, it was proposed that the ceramic pieces, in the form of washers, spheres, and uninscribed cubes, were used as counters in board games.

The contribution that Materials Science has made to the understanding of ancient glassmaking is unquestionable, as research undertaken in recent decades has extensively demonstrated. Archaeological glass is far from being a homogeneous class of materials, encompassing objects made for different uses, manufactured in different periods and geographic areas, and with a variety of tools and working techniques. If all these factors are not adequately considered when approaching the study of ancient glasses from an archaeometric perspective, data obtained by analyses can incur the risk of being less informative or even misinterpreted. Moving from previously performed research, the paper by Fiorentino et al. [3] is focused on the potential of synergistic approaches for the study of archaeological glasses, based on the interrelation among different disciplines and fostering the integration of archaeological and historical knowledge with data-driven scientific analyses.

The obsidians are a very particular subset of archaeological glasses: they are igneous glassy rocks, formed during volcanic eruptions during the past 20 million years. While elemental analyses were used for identifying specific sources starting in the 1960s, the development of non-destructive and especially portable X-ray fluorescence spectrometers has revolutionized the number of artifacts tested since 2010, allowing statistically significant numbers for potential comparisons based on variables including time period, open-water distance, visual and physical properties, and cultural contexts. Tykot in his paper [4] illustrates the importance of this kind of study, highlighting one overall accomplishment: the documentation of long-distance travel routes, based on the distribution proportions and quantity of obsidian artefacts from the different geological sources.

The ability of luminescence techniques (TL and OSL) to provide dating if applied to ceramics or sediments is known worldwide, but not everyone knows that in some cases it is possible to obtain an indirect dating of the bronze statues by dating the clay core. The basic idea of dating by TL can be applied, in principle, to the material remaining in the interior of a bronze statue after its casting, the so-called clay core. In favourable cases, this material behaves like a ceramic, and the procedures used for dating ceramics can be also applied to clay cores. This is extremely important, considering that, with very few exceptions that are not treated in the Martini and Galli paper [5], metal objects cannot be dated by absolute techniques. In [5], the application of TL dating to clay cores was introduced and the specific difficulties deriving from the characteristics of this material, together with the complex determination of the radiation environment, are commented on.

The systematic application of complementary analytical methods typical of Material Science proved essential for a deeper understanding of such complex and extremely valuable artworks. The paper of Dal Fovo et al. [6] is an example of how the optical techniques (e.g., multispectral reflectography in the visible (Vis) and near-infrared (NIR) and optical coherence tomography), due to their non-invasive characteristic, are the best practice to approach to extremely fragile drawings on the paper. The authors report on the application of non-invasive multi-modal optical analysis on a double-side drawn sheet by Leonardo,

Drawing 8P from the Uffizi Gallery of Florence, Italy, offering a useful contribution to the literature on the drawing technique used by Leonardo in his early production.

3. Conclusions

This Special Issue highlights how Materials Science usefully participates in the study of Cultural Heritage allowing researchers to deeply understand the history of works of art, and how material processing influences their structure, properties, and performances.

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