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ScienceDirect

Procedia Materials Science 9 (2015) 31 – 47

Procedia Materials Science

www.elsevier.com/locate/procedia

International Congress of Science and Technology of Metallurgy and Materials, SAM – CONAMET 2014

Materials surface science applied to the investigation of cultural heritage artefacts

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Abstract

The skill of ancient artisans manufacturing artistic or everyday artworks surprises the modern material scientists. We show, through the study of archaeological pieces, how laboratory research instruments use enlightens the fabrication processes of unique items at antic periods. The specificity of surface science research favouring non-invasive means for investigations on museum objects is emphasised. The examples concern:

- Nanostructured layers on ceramic surface to obtain the so-called *lustre* effect, invented by ancient Islam potters;
- Intentional coloration of metallic objects by chemical patination, attested in Egypt on 2nd millenary BC and still applied by Japanese artisans;
- The history of gilding objects: leaf gilding, mercury gilding, and other processes;
- The Fresco technique, a perennial wall painting, known by ancient Roman and propagated through centuries.

The examples open new fields belonging to the modern materials science, to understand the mechanism involved in processes with the constraint that one does not know all the fabrication steps.

Peer-review under responsibility of the Scientific Committee of SAM–CONAMET 2014

*Keywords:*Cultural heritage; Surface science; Ion beam analyses; Lustered ceramic; Metal patination; Metal gilding; Fresco

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Peer-review under responsibility of the Scientific Committee of SAM–CONAMET 2014
doi:10.1016/j.mspro.2015.04.005

1. Introduction

The scientific investigation on cultural heritage items in materials laboratory has suffered very important developments during the last decades, due to the growing interest of the general public together with the demand of collection and museum keeper for a better understanding of the archaeological, artistic and technical history of those items.

Meanwhile the quality and performance of the research equipment available in these materials laboratories has been drastically improved, leading to the possibility to obtain more and more information on the objects. However the investigation on unique artistic or archaeological objects is subject to specific constraints to be kept in mind:

- The first is to favour as much as possible, especially for museum items, the non-destructive or non-intrusive measurement means;
- The second is to gather as much as possible existing information about the item history: date of production, period and conditions of use or exhibition, eventual abandonment and conditions of conservation, preservation in collection or museum, possible ancient or modern intervention of repair or restoration, etc.
- The third is to conclude a collaboration agreement with the item "keeper", archaeologist, museum curator, collection owner, about the aims and the limits of the undertaken laboratory investigation: is it for documentation only or for preparing a restoration or as a part of a general research program?, has it to be fully non-invasive?, is microsampling allowed?, etc.

The consequence of those constraints is that the dominating scientific domain to be applied to cultural heritage objects laboratory investigation is *surface science*. That scientific domain underwent quite recently very spectacular developments in its application to patrimonial items (Aucouturier and Ceretti 2007). In particular the performances of available research instruments used in the devoted laboratories underwent impressing improvements, especially in the field of the non-invasive measurements: X-ray fluorescence (XRF), X-ray diffraction (XRD), Raman or infrared micro-spectrometry, ion beam analyses (IBA), etc. (Janssens and Van Grieken 2004).

The present paper will try to illustrate the results and the limits of that specific approach, through examples taken from several research programs conducted on more or less ancient objects. We shall not consider the material of easel paintings and focus the examples only on three dimensional objects constituted of various materials: ceramic, metal, gilded metal and wall fresco.

ere introduce the paper, and put a nomenclature if necessary, in a box with the same font size as the rest of the paper. The paragraphs continue from here and are only separated by headings, subheadings, images and formulae. The section headings are arranged by numbers, bold and 10 pt. Here follows further instructions for authors.

2. Glazed ceramics with metallic lustre

In the 9th century, during the most brilliant period of Islamic civilisation in Mesopotamia, under the Abbasid caliphate, appeared an outstanding technique of ceramic decoration: lustre, a precursory nanotechnology, a true alchemy which is able to transform simple earth into infinitely precious objects, giving them magnificent shine, including the appearance of gold (Caiger-Smith 1985). That kind of decoration is related to a very sophisticated process which creates on the surface of a glazed ceramic a layer of vitreous matter with sub-micron thickness containing metallic particles (copper and silver) with a nanometric diameter (Kingery and Vandiver 2004,Perez-Aranteguy et al. 2001). It confers upon the surface a particular coloured aspect, often metallic in specular reflection but still shining in different directions.

The fabrication and use of lustred ceramics were propagated across the Islamic world (Egypt, Syria, Iran, Maghreb countries) as far as Spain, leading to the creation of the Italian lustred majolica in the Renaissance period (fig. 1).