

Ion Beam Analysis for the Investigation of a Polychrome Wooden Statuette from Ancient Egypt

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INTRODUCTION

A large production of wooden statuettes can be included among Ancient Egypt treasures. The wooden surfaces are often decorated with painted layers of different colors, whose specific sequence had not only aesthetic purpose, but also a ritual meaning, since the figurines were frequently part of grave goods [1].

Such kind of statuettes have gained increasing interest for archaeometrical studies, with the application of different techniques, such as SEM-EDX, XRF and Raman spectroscopy, and possibly with non-invasive or non-destructive methods [2,3].

In this work a preliminary qualitative characterization with both PIXE and ionoluminescence (IL) was achieved for the study of the different layers and pigments, thanks to the availability of small fragments spontaneously detached from the surfaces of a heavily damaged statuette, dated back to 1100-1300 BCE. In order to clearly discriminate the different painted layers, in this kind of study a very small beam size is needed, generally in the order of few microns.

The simultaneous acquisition of PIXE and IL signals from the same area allows to collect both elemental and structural information on the material under analysis. Moreover, the very low values for limit of detection reachable with PIXE permit as well to quantitatively determine the concentration of trace elements, useful in future investigations on the material provenance.

EXPERIMENTAL

The two fragments retrieved from the wooden statuette (C1 and C2) were prepared as cross sections: they were firstly embedded in resin, then polished until the sequence of painted layer was exposed. Preliminary observations were obtained with optical microscopy and SEM, producing images useful as reference for subsequent measurements. The cross sections surfaces were later carbon-coated to avoid the charge of the material during ion beam analysis.

μ -PIXE and μ -IL measurements were carried out at the AN2000 microbeam facility using 2 MeV protons. The focused beam was about 5 μ m in size and the current detected on sample during acquisitions was \sim 1 nA.

The IL signal was acquired via a collecting lens fixed inside the analytical chamber and connected to a QEPro Ocean Optics cooled spectrometer through two optical fibres, one inside and one outside the chamber, and a

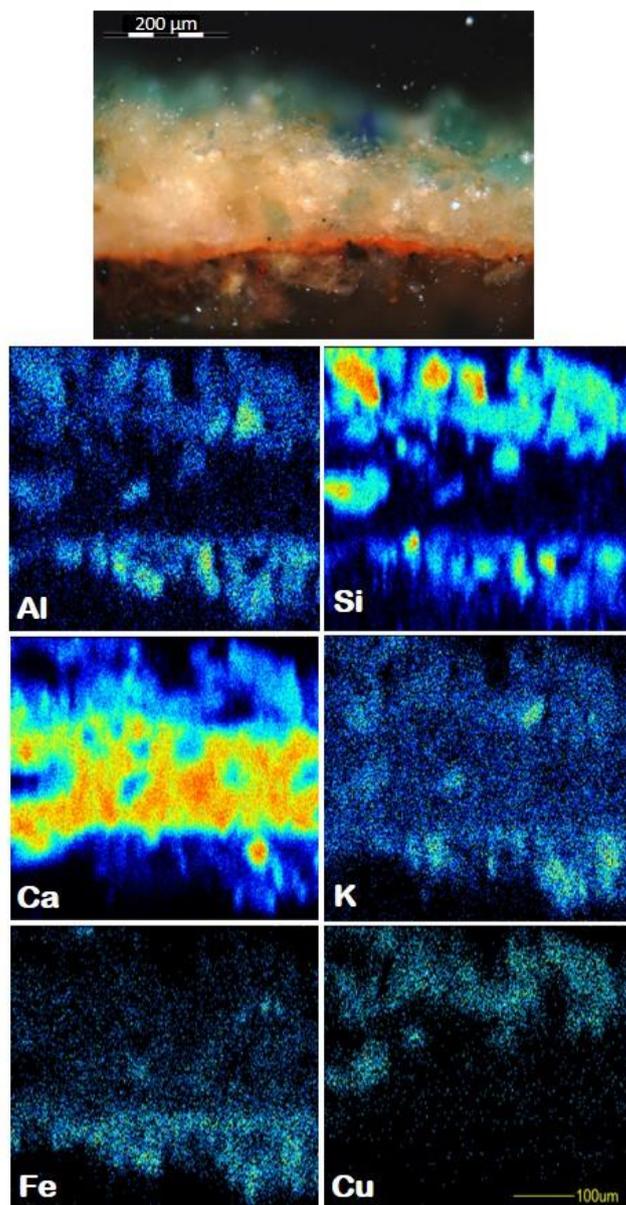


Fig. 1. Optical microscope image of the sample C1 in cross section (top) and μ -PIXE acquisitions on a $500 \times 500 \mu\text{m}^2$ scanned area. All reported PIXE maps are equally scaled in dimension and highlight the layering sequence. Color scale is from black (minimum value) to red (maximum value).

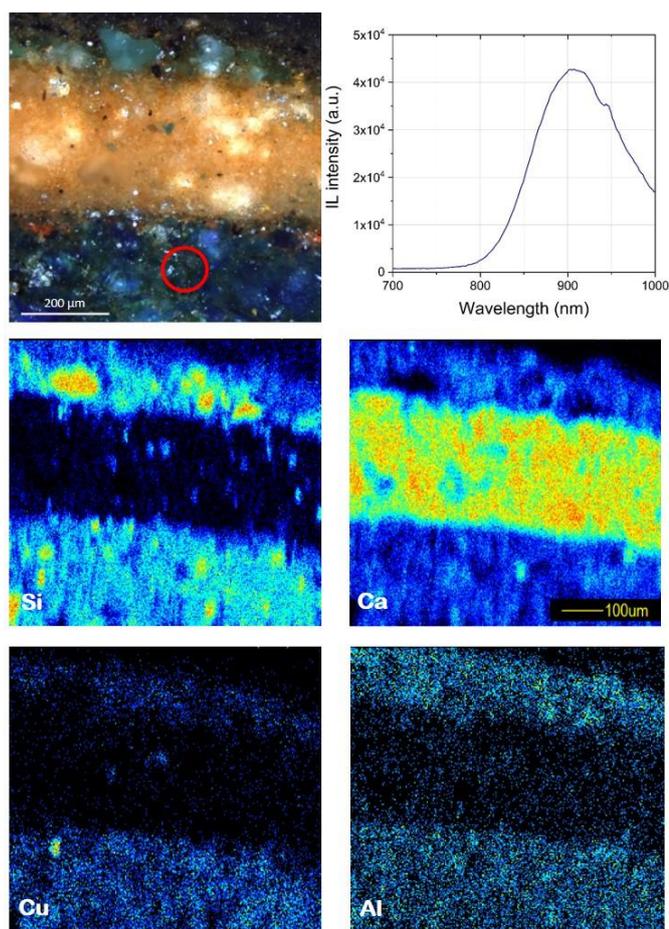


Fig. 2. Optical microscope image of the sample C2 in cross section (top left), μ -IL spectrum acquired from the blue layer (top right, the analyzed area is identified by the red circle) and μ -PIXE acquisitions on a $750 \times 750 \mu\text{m}^2$ scanned area. All reported PIXE maps are equally scaled in dimension; color scale is from black (minimum value) to red (maximum value).

vacuum feed-through. Integration time was set at 60 s and measured spectra were corrected for the spectral response of the instrument, using an intensity-calibrated lamp as reference.

For each cross section several PIXE elemental maps were acquired, from a general overview with dimensions of $2.5 \times 2.5 \text{ mm}^2$ to smaller areas with $150 \times 150 \mu\text{m}^2$ size, inside each layer or around each interface. IL signal was particularly investigated in the smaller areas of single layers, to better identify the pigments employed in the palette.

RESULTS AND DISCUSSION

The preliminary investigation by means of elemental μ -PIXE maps (figures 1 and 2) revealed a slightly different stratigraphy for the two samples.

Both samples show a central layer rich in Ca, probably

due to a calcium carbonate white (CaCO_3); in sample C2 the layer is less homogeneous, with some crystals richer in Ca if compared to the surrounding material (these are the same crystals that appear whiter in optical microscopy). This might be due to alterations of the pigment or differences in the drying phase over different areas of the statuette.

The elemental composition of the blue layers reveals the presence of Si, Al and Cu, suggesting as pigment the use of cuprorivaite ($\text{CaCuSi}_4\text{O}_{10}$), also called Egyptian blue. This hypothesis is further confirmed by the acquisition of μ -IL spectra from several areas within the blue layers. A very strong band centered at $\sim 910 \text{ nm}$ is visible (figure 2), corresponding to the fingerprint for Egyptian blue [4,5]. According to the literature, this is the first time that the band is detected using ionoluminescence, instead of more widespread techniques such as photoluminescence.

Moreover, the green crystals are as well composed by Si, Al and Cu in addition to Ca, suggesting as pigment the use of green frit, that was introduced in Ancient Egypt starting from 18th Dynasty. In particular, it can be seen from figure 2 that the big green crystal in the upper part of the optical image is characterized by a lesser quantity of Cu and a higher quantity of Ca than Egyptian blue, as a consequence of the different production procedure [6].

In addition, only in sample C1 is present a thick layer (up to $100 \mu\text{m}$ thickness), reddish-brown under visible light, that is rich in Fe, Al, Si and K. These ingredients lead to an hypothesis of the use of red ochre (Fe_2O_3) mixed with other earth pigments [7].

CONCLUSION

The simultaneous μ -PIXE and μ -IL measurements allowed to investigate the different layers constituting the polychrome decoration of an Ancient Egyptian statuette. Identification of the main pigments used was achieved and some hypotheses on the painting technique were advanced.

Additional analyses of single crystals contained in the layers performed from a quantitative point of view might provide further insights on alterations and origin of the constitutive materials.

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