Micro-PIXE Analysis of Ancient Roman Coins

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INTRODUCTION

This work is part of a wider project concerning the characterization of ancient Roman Republican coins and contemporary Celtic coins from northern Italy. In order to understand which technique could provide data useful for numismatic studies, a multi-techniques approach was used at the beginning of the project. Some coins have been sectioned to study their microstructure and especially to assess the presence or absence of corrosion layers, enriched layers and non-homogeneities between surface and bulk. Actually, the presence of a surface silver-enriched layer (from few µm up to hundreds µm) is quite common in objects made of a silver-copper alloy, and some papers in literature have already faced and discussed the topic [1-3]. Measurements presented here have been useful to understand the microstructure of the coins under analysis and helped to plan consciously further analyses.

EXPERIMENTAL

The coin presented in this work is just one of a number of different coins analysed and the results are preliminary. Like the others coins it comes from a private collection and in this case it is a victoriatus minted between the II and the I century B.C. in Rome. As a standard metallographic procedure requires, all the coins have been cut with a rotating diamond wheel in order to mount their sections in resin. Subsequently, surfaces were polished with papers having different grit and also with a diamond crystal paste (with grains 6-3-1 µm). A carbon coating has then been applied to make the surfaces conductive.

Micro-PIXE measurements were carried out at the AN2000 microbeam facility using 2 MeV protons. The beam was focused to a spot size of ~5 µm and raster-scanned over the samples. The beam current was kept between 200 and 500 pA according to the results expected. A set of reference mineral and metal standards, inserted in the vacuum chamber with the samples, has been acquired as well for further quantitative analysis by means of the Gupixwin software (version 2.1.3).

RESULTS AND DISCUSSION

Micro-PIXE analysis was carried out on areas selected according to microphotographies taken at the optical microscope (Fig. 1). As shown in Fig. 2, on the victoriatus coin, measurements were carried out on areas on the white layer close to the surface (clearly visible at the optical microscope), and in two areas of the bulk (dark reddish area and light red area).

The presence of a surface silver-enriched layer has been confirmed on the victoriatus coin, while other analysed coins do not appear to be affected by this phenomenon. Profile measurements carried out on the section of victoriatus show a different elemental distribution between surface and bulk, especially for silver and copper (Fig. 2). The silver content is clearly higher in the silver-enriched surface layer, while in the bulk its amount is lower.

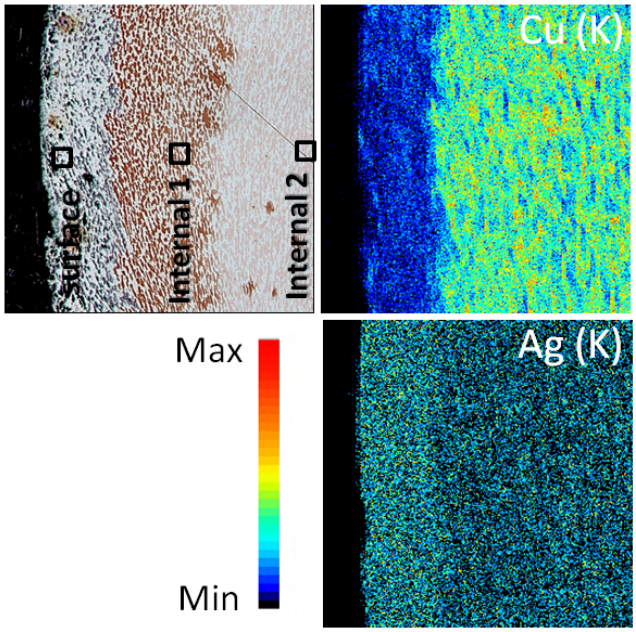

Fig. 2. Optical microscope detail with PIXE elemental maps of the same area, showing the distributions of copper and silver.

Fig. 1. Sections of an ancient Roman republican coin Victoriatus at the optical microscope (5X). Reference bar: 500 µm.

The most interesting results, however, concern the distribution of minor elements along the section (Fig. 3). Elements like chlorine and iron, commonly present in soil and water, are detected mainly in the silver enriched layer close to the surface and can be therefore linked to alteration phenomena due to the bury conditions. On the other hand, it is really interesting to observe the behaviour of nickel, zinc and gold. Gold is clearly linked to silver as it appears mostly present in the silvery layer. Nickel and zinc seem, on the contrary, to be correlated to copper, since their presence is concentrated in the bulk.

CONCLUSIONS

The elemental analysis of the ancient Roman republican coin by means of micro-PIXE showed to be useful to study the different elemental distribution between surface and bulk. A very thick silver-enriched layer (100-150 μm) has been found on the surface of the victoriatus, suggesting an intentional depletion occurred with acid chemicals during minting operations, as reported in some studies [1,3].

As concern major elements such as silver and copper, the strong different elemental distribution between surface and bulk implies that compositional analyses carried out with surface techniques on untreated surfaces on silver-copper alloys are not reliable to provide fineness of ancient coins. Minor elements seem, on the other hand, to be differentially correlated either to silver and copper. These measurements confirm also that the victoriatus coin series is strongly characterized by the presence of thick surface silver-enriched layers, as shown in recently published data [4].

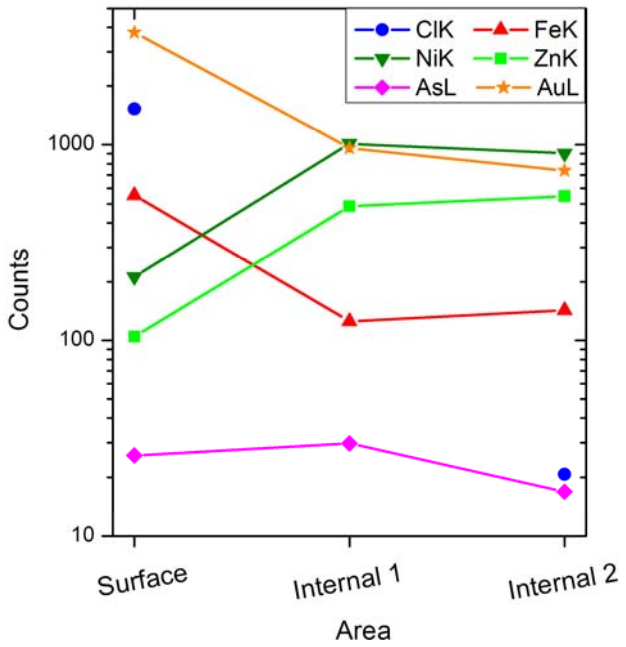

Fig. 3. Distribution of minor elements between surface and bulk areas (the analysed areas are shown in Fig. 2).

[1] L. Beck et al., Nucl. Instr. and Meth. B 226 (2004) 153.

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[4] F.J. Ager et al., Nucl. Instr. and Meth. B 306 (2013) 241.