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Ion Microbeam Analysis in cultural heritage: application to lapis lazuli and ancient coins

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ABSTRACT
Ion Beam Analyses (IBA) techniques, for example PIXE (Particle Induced X-ray Emission) and IL (IonoLuminescence), are a powerful analytical tool used to investigate the composition and structure of materials in cultural heritage. These techniques could be applied both in vacuum, preparing the sample as in electron microscopy, and in air in a non-invasive way allowing to analyse artworks of practically any shape and dimension without sample preparation. Moreover the use of a focused beam (microbeam) permits to reach an analysis resolution of few micrometers in vacuum and ten micrometers in air.
In this work, instruments and methodologies are described and two examples of case study are reported: I) the mapping of elemental distribution in ancient roman coins; II) the trace elements measurement in lapis lazuli for provenance determination.

Section: RESEARCH PAPER

Keywords: Ion Beam Analysis; microbeam; trace elements; ancient coins; lapis lazuli

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1. INTRODUCTION

Ion Beam Analyses (IBA) are performed by using a proton beam provided by small accelerators as probe and collecting the products of the interaction between the particles and the atoms of the sample [1]. Depending on the applications and techniques, a broad beam (a few mm^2) or a micro-beam (2-20 μm in diameter) could be used as probe; a scanning system permits to map the properties of the material under investigation in an area of about 2×2 mm^2 when micro-beam is employed. The energy of protons useful for IBA techniques is around 2-3 MeV whereas the current is of the order of few hundreds of pA, low enough to avoid any damage in the majority of the materials. IBA techniques can be carried out both in vacuum, preparing the sample as in electron microscopy, and in atmosphere, allowing the non-invasive analysis of objects such as artworks of practically any shape and dimension without sample preparation. Among the most used IBA techniques RBS (Rutherford Back-Scattering), PIXE (Proton Induced X-Ray Emission), PIGE (Proton Induced Gamma-ray Emission), ERDA (Elastic Recoil Detection Analysis) and NRA (Nuclear Reaction Analysis) [1], [2] could be used in many scientific fields for elemental analysis, IL/IBIL (IonoLuminescence or Ion Beam Induced Luminescence) [3], [4] for characterization of optical properties of materials and IBIC (Ion Beam Induced Charge) [5] for the characterization of electronic properties of devices. In the cultural heritage field many of these techniques are used, though PIXE has a particular importance for the elemental composition analysis (especially for trace elements).

In this paper an application of micro-PIXE and IL (both micro-IL and broad beam) to solve outstanding archaeological issues is described. In particular two case studies are reported. The first is related to ancient silver-copper alloy coins from Roman and pre-Roman Italian cultures. The coins were studied