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Thin layers characterization with negative muons: a case study of gilded bronzes

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Muonic X-ray Emission Spectroscopy (μXES) is a rather novel technique based upon the interaction of a negative muon beam with matter. This process leads to the production of high energy x-rays (from ~20 keV of Lithium up to ~6500 keV of Uranium), that are characteristic of the emitting atom and can be used for elemental characterization. Over the last few decades, the technique has been applied for a wide range of studies, with special attention to cultural heritage artefacts [1], [2]. Thanks to the multi-elemental range, a negligible self-absorption effect of the x-rays and very low residual activity left in the sample after irradiation, μXES has proved to be a very powerful probe for material characterization. In this work we report preliminary results of the analysis on two gilded surfaces. Along with the common elemental analysis, the technique offers the possibility of investigating the variation of the layers within a sample. By varying the energy (momentum) of the incident muon beam it is possible to perform depth profile studies. Here, the thickness of the gold layers is addressed by using Monte Carlo based simulations software [3]. The investigated sample were two small pieces of a copper alloy with a gilded surface, made as a replica of the gates of the Baptistery in Florence. The gilding was made with the mercury "amalgam"technique, and the gold layer was supposed to have a thickness between 10 to 20 microns. During the experiment, a momentum scan was performed by varying the incident muon beam energy. Each of the resulting x-ray spectra was then analysed with a data analysis software and the characteristic peaks of the different elements present in the sample were fitted with a gaussian function. Then, the normalised area values were plotted against the momentum to obtain a profile describing the variation of the elements as the penetration depth of the beam increased. The profiles, in this case for gold, were then compared with the output of the simulations, and, as reported in the figure below, a remarkably good agreement was reached. This non-destructive approach to the study of a material and the consequent data analysis shows the potential of the technique. It can be applied to many different types of samples, like the one coming from the Baptistery gate in Florence (that have been recently analysed) or freshly excavated samples coming from archaeological sites, that can be analysed without removing patinas or corrosion layers.

References

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