Abstract

The study of ancient metallurgy, particularly the analysis of bronze and copper alloys, plays a crucial role in understanding the technological and artistic advancements of past civilisations. In this context, neutron-based methods offer a highly promising solution for the non-invasive characterisation of the elemental, isotopic, and phase composition of the objects under study.

From a metrological point of view, the absence of reliable reference samples and standardised methodological approaches for the analysis of artefacts in the Cultural Heritage field remains an open issue. This is particularly true for neutron-based techniques, which have been relatively recently applied in Heritage Science.

This thesis is conducted within the framework of the INFN CHNet_BRONZE project, which aims to develop and quantitatively calibrate techniques that exploit neutron probes for the non-invasive characterisation of archaeological copper alloy artefacts. In particular, this dissertation focuses on the Bragg Edge Neutron Transmission (BENT) analysis technique. A key objective of this research is to define standardised procedures and create a reference set of samples that can serve as benchmarks for the analysis of real archaeological copper alloy objects. These reference samples, with known composition and structure, are used to define experimental and analytical methodologies and to aid in the interpretation of data obtained from historical bronze artefacts.

The thesis presents a structured approach to achieving these objectives. First, the creation of reference samples, including both powder and cast specimens, is detailed. Next, a methodology for processing and analysing Bragg edge neutron transmission data is described, including data correction procedures and spectral fitting techniques. Different methodologies and software are discussed, specific to the various acquisition methods adopted during the measurement campaigns. Then, the analysis of the BENT spectra, with the specific purpose of extracting elemental

composition information, is presented, including the derivation of calibration curves that correlate spectral features with elemental content inside the material. Finally, the application of these methods and calibration curves to the study of real archaeological bronzes is discussed. In particular, the methodology is applied to a set of ancient Japanese bronze arrowheads from the Yayoi period, showcasing the potential of the BENT technique for extracting compositional information from the bulk of cultural heritage artefacts in a non-invasive way.

Through the establishment of well-defined methodological approaches and the creation of a reference dataset, the accuracy and reliability of neutron-based techniques in archaeometallurgy can be improved. The work presented in this dissertation is a first step towards this final goal, showing the potential and the limitations of Bragg edge neutron transmission analysis for studying the elemental composition of copper alloy artefacts.