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Non-invasive characterization of ancient Japanese helmets through ToF-Neutron Diffraction

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In historical times, armours and weapons were generally made from the best available materials and using the best known technologies. Japanese armours have always been considered a wonderful example of the union of elegance and functionality, becoming a symbol of command and an expression of social status.
From the 15th century, with the advent of large armies of foot soldiers and the beginning of a decline in fighting on horseback, the Japanese helmet, the kabuto, became one of the most important elements among an armour's constituents, because it allowed the samurai to stand out in the battlefield. Nonetheless, scientific and technological research into this category of artefacts has scarcely developed. Very few Japanese historical armours have been thoroughly investigated, owing both to the rarity of the available armours and to their extraordinary beauty. In addition, because of their generally excellent state of preservation, the traditional (invasive) methods of analysis did not suit these objects. For these reasons, the present investigation has been carried out using a non-invasive approach, namely thermal neutron diffraction [1]. The study focussed on seven iron and steel helmets, belonging to different periods and different levels of quality, kindly provided by the Stibbert Museum in Florence and by a British private collector.
The experiments were carried out at the INES diffractometer at ISIS, the pulsed neutron source in the UK. Thanks to the small interaction of thermal neutrons with other nuclei and to the consequent high penetration power, neutrons represent the ideal probe for dense matter investigation, and can be effectively used to study the microscopic properties of metal artefacts, with thickness of several centimetres [1].
Similarly to X-ray diffraction, the present analysis has been carried out in order to determine, through Rietveld refinement of the neutron diffraction patterns [2], the phase composition of the different parts, to evaluate the quality of the steel (i.e. the carbon content level), and hence gain information on the smelting procedure and the present conservation status of the metal [3]. Moreover, the analysis of the shape and relative intensities of the main phase diffraction peaks [2] provided indirect information on the thermal treatments and shed some light on the likely working techniques [4,5].
Further neutron techniques have been applied, on a kabuto of particular value (both from the artistic and technological point of view) among the analyzed samples. The helmet has been characterized using the instrument for thermal neutron radiography and tomography NEUTRA (SINQ, Paul Scherrer Institut, CH) [6].
This work represents the starting point for the characterization of materials and technology used to make a particular class of artefacts of great interest from the point of view of anthropology, art and technology. In light of the results of this thesis work, the combined use of neutron techniques (imaging and diffraction) is one of the best approaches for a non-destructive characterization of the entire volume of metal artefacts of artistic interest.

References

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Summary

In this work we present an extensive time of flight neutron diffraction (ToF-ND) study on seven Japanese helmets (kabuto) made between the 16th and 17th Century. The experiments were carried out at the INES diffractometer at ISIS, the pulsed neutron source in the UK. By this non-invasive approach we have been able to determine quantitatively the phase composition and the micro-structural properties of these artefacts, confirming that the use of ToF-ND represents one of the most suitable non-destructive approaches for the characterization of metal archaeological artefacts.

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