Applications of TOF Neutron Diffraction in Archaeometry

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Neutron radiation is a versatile diagnostic probe for collecting information from the interior of large, undisturbed museum objects or archaeological findings. Neutrons penetrate through coatings and corrosion layers deep into centimetre-thick artifacts without substantial attenuation, a property that makes them ideal for non-destructive testing for which sampling is impractical or unacceptable. A particular attraction of neutron techniques for archaeologists and conservation scientists is the prospect of locating hidden materials and structures inside objects.

Intense neutron beams are presently produced by either nuclear fission (reactors) or spallation (high-energy accelerator-driven sources). Archaeometric studies at the ISIS spallation source at the Rutherford Appleton Laboratory are based on time-of-flight (TOF) neutron diffraction which is a direct method for examining all structural aspects of cultural heritage objects [1-3]. With the existing suite of instruments at ISIS, a full structural characterisation of a wide class of materials such as pottery, pigments, marble artefacts and metal objects can be achieved. The abundance of mineral and metal phases, the crystal structure of each of the phases, the grain sizes and grain orientations, microstructures as well as micro- and macro stresses in materials can be examined. A particular promising application of neutron diffraction is texture analysis for recording the grain orientation distribution [4,5]. The crystallographic texture is critically dependent on the past mechanical and/or thermal treatment of an artefact. Thus, texture analysis provides important clues to the deformation history, and may therefore help to uncover historic production steps. Moreover, if the making techniques are known, texture maps may help to distinguish genuine from fake objects.

TOF neutron diffraction allows for a time-efficient collection of the texture maps, the pole figures. On a powder diffractometer like GEM at ISIS a large portion of orientation space is covered without sample rotations. A combined phase, structure and texture analysis of a bulky object of complex shape can be achieved in a single measurement in a matter of minutes, an important aspect if the short-term radio-activation of a unique object is to be kept to a minimum. Decay times of induced radioactivity levels, which depend on the isotopic compositions and the irradiation times, are typically in the order of minutes for ceramics and up to several days for objects containing elements such as silver or copper.

References

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