Time-of-flight neutron diffraction for characterising archaeological ceramics and metal artefacts

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ANCIENT CHARM, an EU FP6 project with a consortium of 10 European partners, aims at developing a non-invasive neutron activation analysis method that will allow producing 3D maps of chemical elements of objects of art and archaeology. The underlying physical effect is neutron resonant capture analysis (NRCA) which was exploited in archaeological sciences only recently by the group of H. Postma (Delft University, The Netherlands) at the neutron source GELINA in Geel, Belgium [1]. The NRCA imaging method will be stepwise developed at the Institute of Isotopes in Budapest, at the IRMM in Geel, Belgium, and at the FRM-II in Munich, Germany. The final 3D-NRCA version will be set-up at ISIS at the Rutherford Appleton Laboratory, UK. ISIS is the word's most intense spallation source that produces pulses of neutrons for fundamental and applied materials research. The pulsed nature of the neutron source which is based on a proton accelerator (Fig. 1) is the important prerequisite for utilizing the NRCA effect but it is also useful for other applications in archaeological sciences.

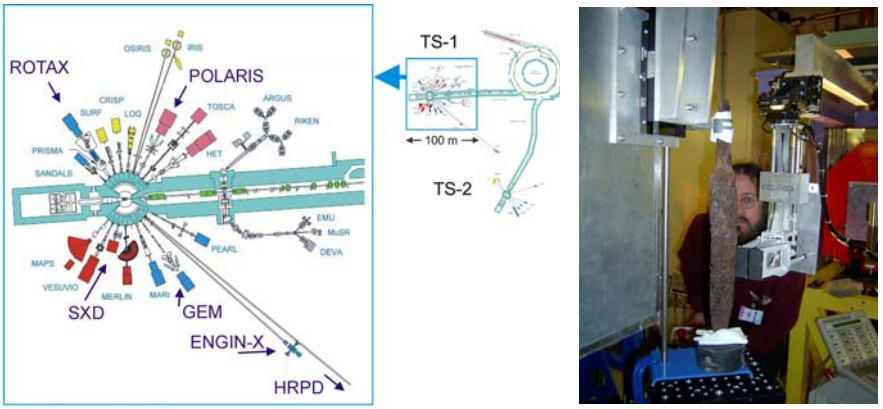

Fig. 1 Left: ISIS neutron source at the Rutherford Appleton Laboratory, UK. The diffraction stations on target station 1 (TS-1) that are of special interest for archaeometric studies are highlighted. Middle: The second target station (TS-2) is under construction. Right: Set-up of an iron sword on ENGIN-X (M. van Nie, The Netherlands).

ISIS is already involved in many archaeological studies, almost all of them being based on neutron diffraction. Diffraction is, in contrast to elemental analysis techniques, a direct method for quantitative assessment of the mineral and metal phase compositions, the crystal structures as well as the crystallographic textures and microstructures of the constituent phases. These structural features may provide important clues to the mechanical and thermal treatments during fabrication of an object, and may thus be used to confirm or refute details of the historic production steps. If the historic making techniques are known, the structure information may help to distinguish genuine from fake objects. Neutron diffraction is in some ways similar, in other ways complementary to X-ray diffraction. Neutron instruments at a spallation source are operated in a time-of-flight (TOF) mode that has particular advantages for materials studies [2,3]: (i) the experimental set-up is simple and mostly free of sample movements, (ii) the shape of the object is of minor importance, (iii) intact objects can be studied in a completely non-destructive way without prior preparation. Here we survey on recent examples of archaeological studies at ISIS, including ceramic objects and metal artefacts, in order to introduce the ISIS facility where the main objectives of ANCIENT CHARM will be accomplished in the next few years.

[1] H. Postma, P. Schillebeeckx and R.B. Halbertsma, Archaeometry 46, 635 (2004).
[2] W. Kockelmann, A. Kirfel, E. Hähnel, J. Arch.Science 28, 213 (2001).
[3] W. Kockelmann, S. Siano, L. Bartoli, D. Visser, P. Hallebeek, R. Traum, R. Linke, M. Schreiner, A. Kirfel, Applied Physics A, Material Science and Processing, in press (2006)