Genuine or fake? Neutron diffraction for non-destructive testing of museum objects

W Kockelmann, A Kirfel *(Universität Bonn, Germany),* **R Linke, M Schreiner** *(Akademie der bildenden Künste Wien, Austria),* **R Traum** *(Kunsthistorisches Museum Wien, Austria),* **E Pantos** *(Daresbury Laboratory),* **R Garner** *and* **A J N W Prag** *(University of Manchester)*

Neutron diffraction, an established diagnostic tool for materials analysis and non-destructive testing of engineering components, can also be used to characterise archaeological artefacts and museum objects. The phase and microstructural information obtained – without damaging an object of value – can help answer questions of authenticity, as recent investigations of 16th-century silver/copper coins and an obviously repaired 7th-century BC Greek bronze helmet show.

NZ 205491

Fig. 1: *16th-century Ag/Cu 'Ferdinand-Taler' coin (Münzkabinett, KHM Wien). The coin has a diameter of about 40 mm.*

Neutron diffraction is a rather new diagnostic tool for studying archaeological materials. Neutrons easily penetrate through thick coatings or corrosion layers and provide information from the bulk rather than from surface areas; sampling techniques such as coring or even powdering for analysis some portion of a museum object can therefore be avoided. The large neutron beams generally used illuminate a considerable volume portion of the object and, as a result, average and representative structural information is obtained – the problems associated with the single-spot analysis of many conventional archaeometric techniques are therefore avoided.

Neutron diffraction provides information on the mineral and metal phase compositions or corrosion products in objects, on the crystal structures of the constituent phases and on the microstructures. In the material sciences it is widely used for volume texture analysis, i.e. determination of the orientations of the crystallites in polycrystalline material. Many processes such as primary crystallisation or plastic deformations impose a characteristic texture on the material which means that, for example, details of the production method may be imprinted in the microstructure. Mapping grain orientation distributions – a technique called texture analysis – reveals the creation and deformation history of an object. The crystallite distribution can be displayed via 'pole figures', 2D projections of the spatial orientation distribution function that are obtained by recording diffraction patterns for a multitude of sample orientations. The structure and texture information can therefore provide clues on the type of material and the manufacturing techniques used by the ancient craftsmen. In cases where the production techniques are known, pole figures can be used as fingerprints to distinguish genuine from fake objects.

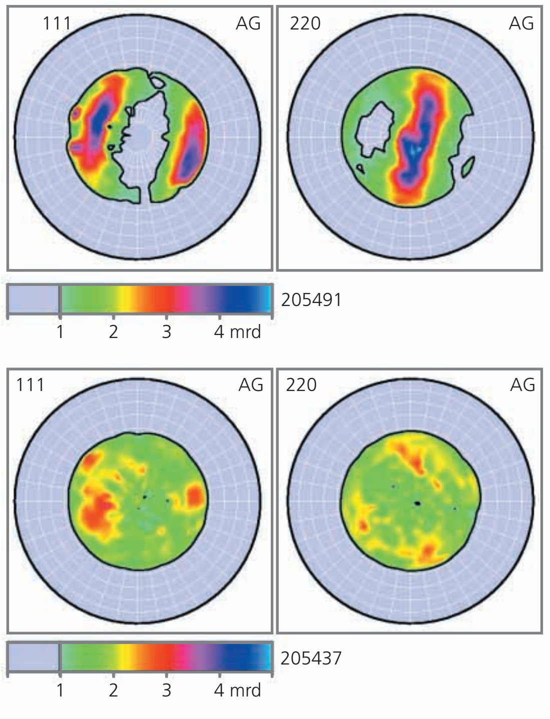

Fig. 2: *Experimental Ag pole figures, (111) and (220), of (top) a genuine minted Ag/Cu coin and (below) a cast Ag/Cu coin.*

Six 16th-century silver coins from the Kunsthistorisches Museum Wien were examined by time-of-flight neutron diffraction to distinguish between minted (genuine) and cast (fake) coins on the basis of the microstructures of the silver copper phases. The coins investigated included minted coins issued by Archduke Ferdinand and coins supposed to be cast copies. It is well known that the original coins were minted by cold-rolling the two coin faces onto a Ag/Cu metal sheet of 90/10 wt% composition. Neutron diffraction can recognise the plastic deformations caused by that minting process and the diffraction data can also be used to determine the metal composition in the bulk of the coin. Figure 1 shows the coin NZ205491 which has, according to the neutron data, silver and copper contents of 89.5 and 10.5 wt%, respectively.

The first set of incomplete experimental pole figures of Ag(111) and Ag(220) (fig. 2) clearly show the hallmarks of a rolling texture, so this coin is very likely genuine. In contrast, the second set of pole figures in figure 2 shows the typical irregular grain distribution of a cast coin (NZ205437) which is obviously fake. The data corroborated the suspicion that three out of the six coins are originals and three, with high copper contents, are cast and have to be considered fakes.

Fig. 3: Corinthian-type bronze helmet being put into position on the ROTAX instrument by Roy Garner from The Manchester Museum.

Neutron diffraction data were also collected from a 7th-century BC Greek bronze helmet of Corinthian type (fig. 3), displayed in The Manchester Museum. It was the custom for victorious Greek cities to dedicate *tropaia*, 'trophies' of armour from the defeated, in the sanctuary of one of the gods. When the trophy collapsed from age or when the sanctuary became too full the armour was buried, but first it was 'killed' as part of the process of offering it to the gods: the cheekpieces were bent back and the noseguard turned up to render the helmet useless in this world. The finder of the helmet – probably in the 19th century and in order to sell it – straightened out the cheekpieces, which cracked at the edges and left a clear fold-line running across each of them. It is also clear that the noseguard had come off altogether, probably during similar cosmetic straightening by the finder, for there is a clear overlapping join at the bridge of the nose.

So is the noseguard original or a modern replacement?

Comparing the neutron diffraction patterns collected from the noseguard and the right temple of the helmet clearly shows a shift of the alloy's Bragg peak positions (fig. 4). The bronze compositions of the helmet and the noseguard are obviously different. The lattice parameters of the bronzes were determined by Rietveld analysis and translated into Cu/Sn weight fractions on the basis of a Vegard-type calibration curve for Cu-Sn. Accordingly, the tin content of the noseguard is about 5 wt%, whereas the temple exhibits a classical bronze composition of 90/10 wt% for copper and tin, respectively. One has to assume that the noseguard, being made of a different material, is most likely not part of the original helmet but is a later replacement. This confirms the suggestion of Dr Alastar Jackson of Manchester University, who is studying the helmet from the archaeological standpoint, and noted that the noseguard shape is unusual – the present angle at which it is set is impractical and not authentic, and the edges of the noseguard itself and of the holes for fixing the lining are much sharper than on the rest of the helmet.

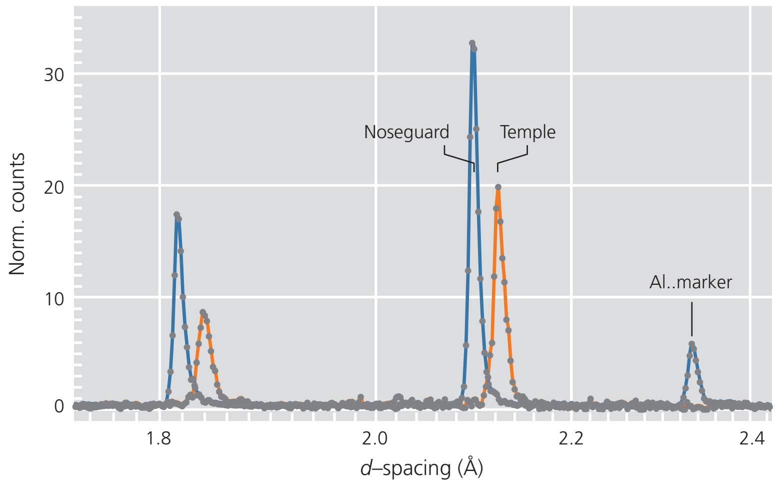

Fig. 4: Diffraction patterns collected from the right temple and the noseguard of a 7th-century Greek bronze helmet. Note the systematic peak shifts indicating bronzes of different compositions.

Contact: *Dr W Kockelmann.*
Tel: +44 (0)1235 446731. Email: w.kockelmann@rl.ac.uk
Further reading: *W Kockelmann et al., Physics Education (2004).*

CCLRC