MICRO-XRF

Analysis of a Roman sword with the M4 TORNADO

Application Note # XRF 443

Introduction

Archaeometric objects are unique and very sensitive to changes in their consistency. This must be taken into account when examining them. Their examination is necessary for the preparation of their restoration and for understanding the technologies of their manufacture. For this purpose, only small parts of an object are usually analyzed. Especially for elemental analysis, micro X-ray fluorescence is a fast and frequently used analytical method that permits sensitive and non-destructive examination.

This report describes the analysis of parts of a Roman sword. After removing the corrosion layers, the sword was analyzed with Bruker's micro-XRF spectrometer M4 TORNADO.

The sample

The examined object is a Roman sword of a type called Gladius (see Figure 1). It was found in the north-east of Germany, close to the town of Pasewalk. Several manufacturing features indicate that the sword was not manufactured in this region. It was most likely carried by Germanic warriors, who broke it and sacrificed it to the gods. The sword was highly corroded.

Figure 1
Image of the Roman sword showing the remaining corrosion patina after cleaning.

Examination of the material structure

The first examination step took place at the University of Applied Sciences HTW Berlin (Hochschule für Technik und Wirtschaft Berlin), where X-ray imaging analysis was performed on the sample. Figure 2 (left) shows a sandwich structure of carbon rich and carbon poor regions in the upper part of the sword. This is known as damascene steel, a steel type that combines hardness with elasticity.

The X-ray image of the area close to the handle shows two pieces of inlaid work, one on each side of the blade as it can be seen in Figure 2 (right).

The inlaid work shows on one side Victoria, the flying goddess of victory and the tutelary goddess of the Roman emperor. On the other side of the blade is an eagle, the symbol of the Roman legion (see Figure 3).

From this point on, the examination focused on the elemental composition of the inlaid work and the blade, as well as on the reconstruction of the shape of the inlaid work by using an elemental imaging system.

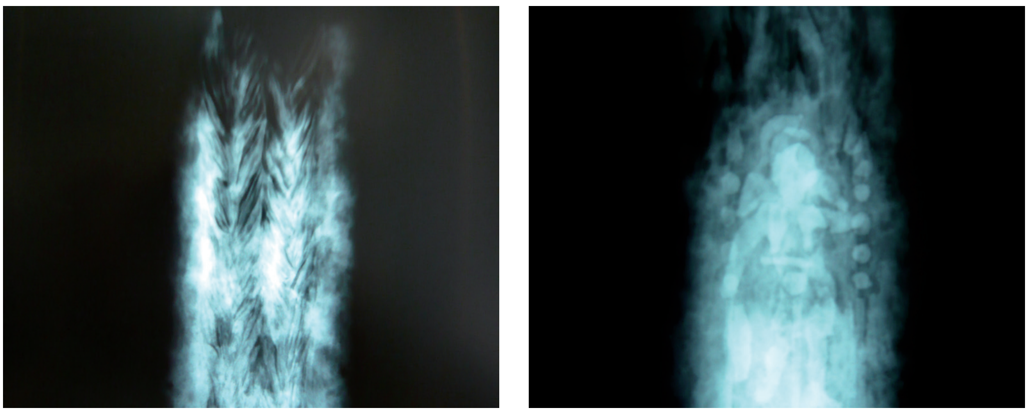

Figure 2
The X-ray absorption images show the damascene structure of the steel and the inlaid work.

Instrumentation

The examination was performed using the micro-XRF analysis method in Bruker's M4 TORNADO. The following measurement conditions were used:

- Measurement in air
- Excitation with 50 kV, 600 µA
- Distribution analysis with HyperMap in an area of approx. 22 x 16 mm (450 x 330 pixel)
- Acquisition time per pixel: 10 ms
- Total measurement time: approx. 30 min

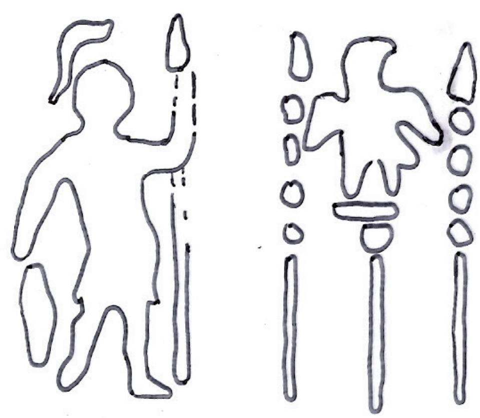

Figure 3
Drawing of the inlaid work showing the goddess Victoria and the eagle

Analytical results

The results of the distribution analysis are presented in Figure 4. The small mapped area shows the shape of the head of Victoria. The inlaid work seems to be made of a Cu-Znalloy containing Ni; as expected, the blade is made of steel.

Single spectra were accumulated of different locations on the inlaid work (see Figure 6). The HyperMap function permits to summarize the spectra of several pixels with the same composition. The measured locations are highlighted on the mixed image of all detected elements.

Interpretation of the analytical results

The distribution of the elements must be interpreted as follows:

- The inlaid work (measurement point MP2) is made of brass (Cu and Zn). The single element distribution suggested that the inlaid work contains Ni. However, the red spectrum of Figure 7 shows that there is no Ni, but the spectral background is high due to the shelf of the high Cu and Zn peaks. This has been considered for the quantification.
- The sword's blade is made of steel (measurement point MP3, green spectrum of Figure 7). The steel contains Fe and traces of Mn and Ni. The other elements in this spectrum (Cu, Zn and Ca) result from contamination from the inlaid work and also from the environment, since the object lay on the ground for a long period of time.
- The results for the measurement point MP1 show a high content of Ca but reduced concentrations of Fe, Mn and Ni, as displayed in the blue spectrum of Figure 7. The intensity of Cu and Zn is also higher than in MP3. This is probably due to a slightly different composition of the corrosion layer covering the metal.

The quantification results obtained after evaluating the spectra are shown in the table below.

Quantification results

Element	Mn	Fe	Ni	Cu	Zn
Brass MP2	–	2.2	–	75	22.5
Steel MP3	0.5	98.2	0.1	0.5	–

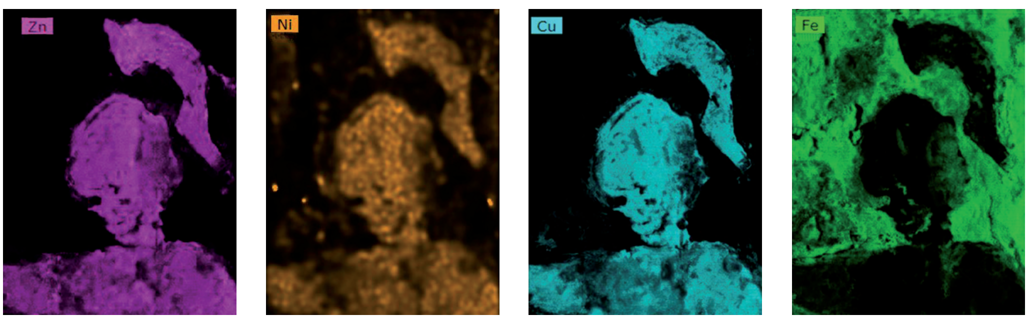

Figure 4
Elemental distribution of the upper part of the inlaid work

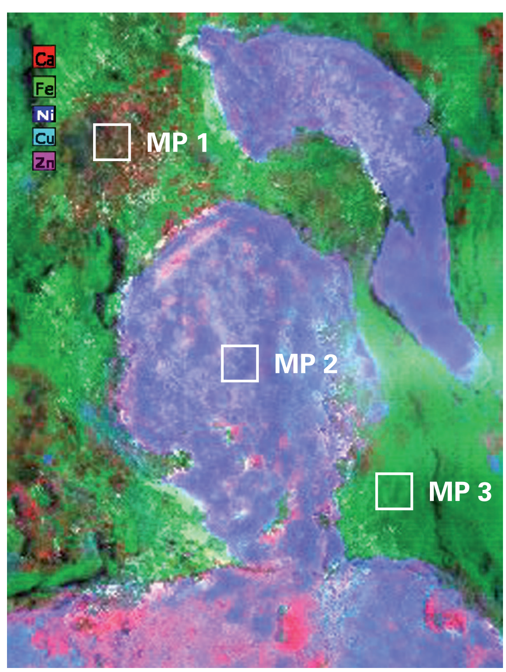

Figure 5 (left)
Picture showing the inlaid work on the blade of the sword

Figure 6 (right)
Multi-element image showing the distribution of Ca, Fe, Ni, Cu, and Zn in the upper area of the head of Victoria with the measurement points (MP) 1, 2 and 3 indicating the measurement locations.

Conclusions

Sensitive and valuable archaeological objects can be easily and reliably analyzed with micro-XRF. This technique permits a fast non-destructive analysis of collection objects, especially on small sample areas.

The analyzed Roman sword is made of low alloyed steel. It has inlaid work showing the goddess of victory. The spectral analysis gives an estimation of the elemental composition of both the steel of the sword and the inlaid work. It also indicates that a careful spectral analysis is necessary for the correct interpretation of the elemental distribution. This is the only way to identify overlaps or background effects correctly. The shape of the inlaid work can be recognized with very high detail on the element mapping image, allowing the reconstruction of the object shape without further preparation. The calculated composition values are crucial for the correct restoration of the object, since the technology chosen for the restoration works is highly dependent on the composition of the sample.

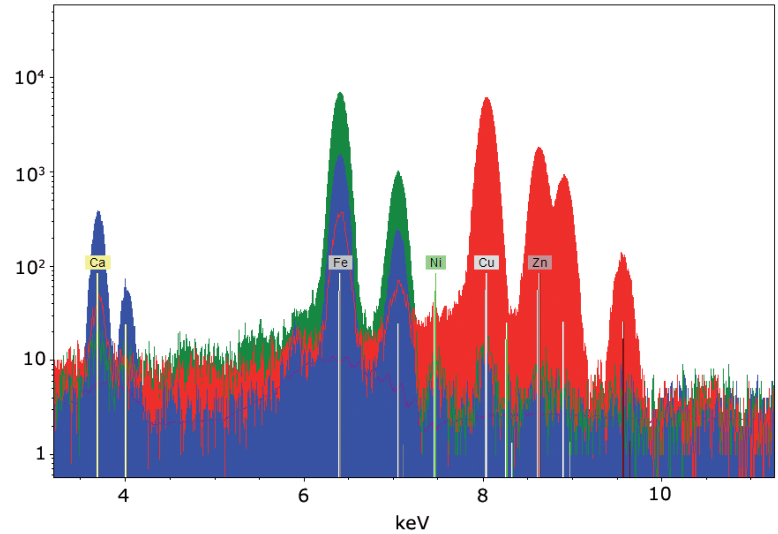

Figure 7
Spectra of the measurement points (MP1: blue, MP2: red, MP3: green)

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