Archaeometry at MLZ's PGAA-facility. Spectrometry and structure visualization of Gallo-Roman cultural heritage objects with PGAA and Neutron Tomography.

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Abstract

Thanks to the latest developments in neutron sources and advancements in digital signal processing, the capabilities of available gamma spectrometry and neutron imaging sights have significantly improved during the last decades. Instrumental neutron techniques such as Prompt Gamma-ray Neutron Activation Analysis (PGAA) and Neutron Tomography (NT) are effective methods to obtain chemical compositions with good detection limits or visualize internal structures within a sample. As non-destructive analysis methods, they are especially suitable for the investigation of cultural heritage objects and are therefore attractive for the field of archaeometry.

We report on the unveiling and analysis of the insides of various sealed amulet capsules and vessels of the Roman-Germanic Museum Cologne using these methods in combination at the PGAA facility of the Heinz Maier-Leibnitz Center (MLZ).

The PGAI-NT method

PGAI-NT is the combination of a position-sensitive three-dimensional extension of the *Prompt Gamma Neutron Activation Analysis* (PGNAA) of a sample and the sample's *Neutron Tomography* (NT) for the purpose of an easy assignment and clear representation of spectroscopy data [1-2]. The via position-sensitive PGNAA obtained distribution of the various elements within a sample is visualized by differently colored voxels, hence the term PGA-Imaging. The relative abundance of a specific element itself is visualized by different intensities of the color assigned. The resulting voxel-matrix is finally embedded into the tomography-volume of the bulk sample (Figure. 1).

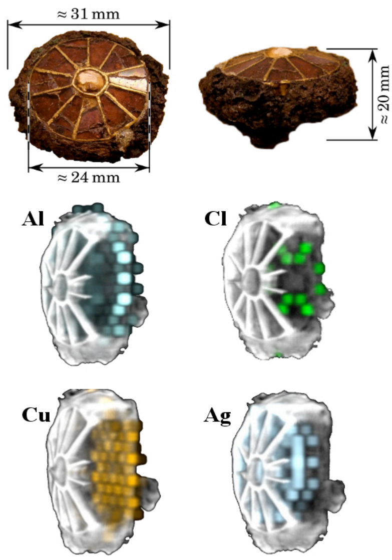

Figure 1: PGAI-NT recoding of a fibula from the 6. century showing the distribution and relative abundances of aluminum, chlorine, copper and silver via differently colored voxels embedded into the neutron tomography [2].

A PGAI sub-volume of a sample is established by the intersection of the collimated neutron beam and the collimated field of view (FOV) of one or more gamma detectors positioned in 90 degrees to the beam.

The Current Instrument

Because PGAI-NT is a method-combination with a strived application area, it should be as user friendly and cost effective as possible. For this reasons we opted for an all-in-one instrument approach by conducting the NT recoding at the same instrument site. To quicker parallelize the elliptically tapered beam of the facility for PGAI, a boron-lead collimator with a 2x2 cm^2 profile is used [3]. The pinhole-aperture used in combination with said collimator is a 3 mm thick boron-carbide (B_4C) plate with a 2 mm diameter. The resulting beam profile at sample position has a flux of 1.34×10^9 /cm^2s and a PGAI-resolution determining diameter of 3.2 mm. The previously used gamma collimator was replaced by two 50 mm longer heavy-lead collimators with a conical 2x8 mm^2 profile. In this way, the γ-energy dependent resolution in beam direction was improved by an average of 42%. The measuring time can be reduced significantly by using two collimated detectors simultaneously. The parallel-beam tomography flight-tube system was replaced by a cone-beam setup, realized by introducing a pinhole-aperture into the focal point of the even further elliptically tapered beam [4]. The boron-carbide pinhole-aperture for this usage is of 3 mm diameter and thickness, resulting in a 47% greater L/D ratio of 251(15). The current 5.5 megapixel camera in combination with a 100 µm ^{6}LiFZnS(Ag)P scintillator achieves a 130% improved object resolution of 175(4) µm. The reconstruction under cone-beam algorithms resolves now 140 µm details for negative and 40 µm details for positive contrast differences (ideal).

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