Micro-CT/micro-XRF for 3D analysis of chemical composition

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X-ray fluorescence (XRF) tomography allows the 3D analysis of the interior chemical structure in a non-destructive way. To aid the interpretation of XRF studies, we designed a micro-XRF scanner with an integrated micro-CT that can augment the XRF images with morphological information.

In our system the sample is mounted on a rotation stage that can travel between the micro-CT part and the micro-XRF part of the system. The micro-CT part consists of a microfocus X-ray source and a cooled 1.3 Mega pixel camera. To generate the fluorescence X-rays for XRF imaging, two powerful X-ray sources (2x200 W) were used. An hourglass shaped pinhole in front of a 2D (512x512 pixels) energy sensitive XRF detector creates fluorescence projection images (camera obscura principle) in the range of 3 to 20 keV by operating the camera in a photon counting mode.

The operator can set up to 8 energy windows. During acquisition these energy windows are filled concurrently for simultaneous imaging of the different materials present in the sample. By rotating the object the scanner acquires all necessary angular two-dimensional views in either transmission or fluorescence mode for subsequent 3D reconstruction. To make the co-registration of the micro-CT images and micro-XRF images more reliable, the scanner acquires the projection in either modality such that they match each other exactly in position, magnification and spatial orientation. Micro-CT data is reconstructed with a modified Feldkamp algorithm (filtered back-projection) [3] while micro-XRF datasets are reconstructed by a maximum likelihood iterative algorithm [4]. The latter has to take the strong re-absorption of the low energy fluorescence x-rays in the sample into account. This is accomplished by using morphological information provided by the micro-CT images.

Figure 1 shows three virtual orthogonal micro-CT slices through a sandstone sample with iron containing parts (micro-XRF) highlighted in green. Figure 2 shows an example of the 3D distribution of the chemical composition in a geological sphalerite sample, a mineral that is a chief ore of zinc. The color-coded chemical composition is overlaid on the morphological structure from the micro-CT image shown in gray scale. Internally local channels of iron (red) and pockets of copper (blue) can be easily visualized.

These images show that our micro-CT/XRF system makes it possible to perform non-destructive 3D imaging and mapping of the internal chemical composition on samples from various origins.

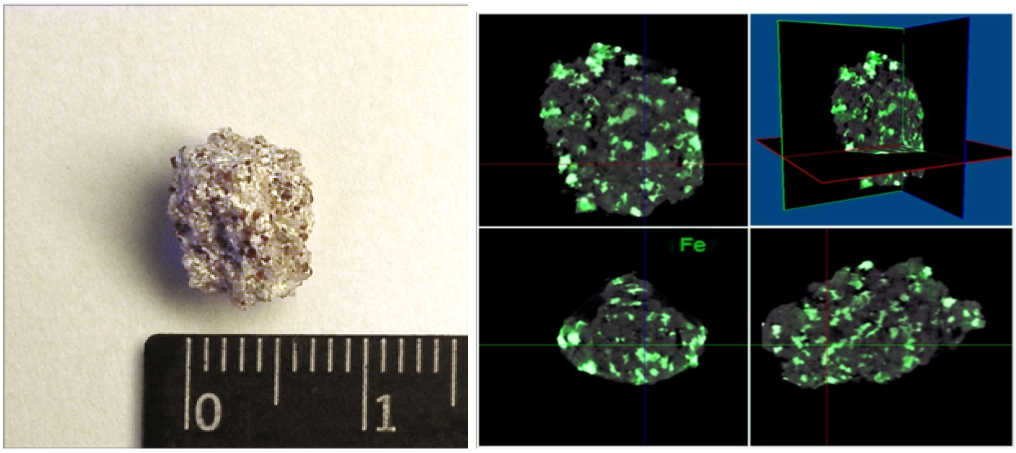

Figure 1. *(left) Visual image of a sandstone sample, (right) three virtual orthogonal micro-CT slices through the sample showing iron containing parts (superimposed micro-XRF image) highlighted in green*

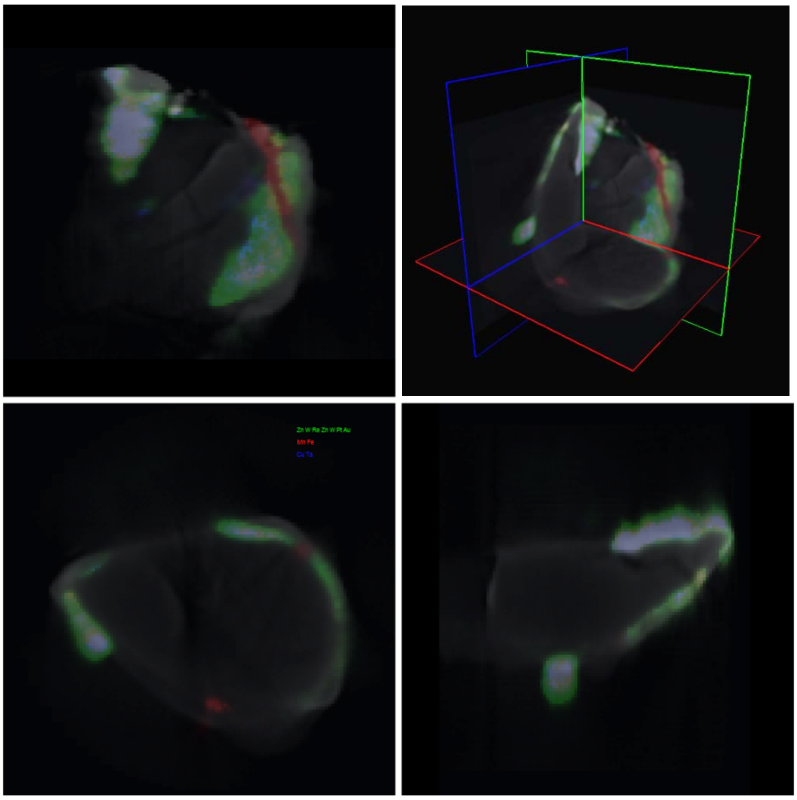

Figure 2. *Three orthogonal color-coded XRF sections overlaid on a gray scaled CT image. Locally some channels of iron (red) run through the sample. The blue spot indicate some pockets of cupper. The reconstructed volume was 17x17x17mm.*