Geophysical Research Abstracts,
Vol. 11, EGU2009-1240, 2009
EGU General Assembly 2009

X-ray spectromicroscopy in soil and geosciences

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X-ray microscopy achieves a much higher resolution than light microscopy due to their much shorter wavelength compared to visible light. The smallest structures that can be seen in an X-ray microscope at present are reaching the 10 nm size range. The technique is capable of imaging specimens directly in aqueous media. By choosing the used X-ray energy appropriately, it is possible to perform spectromicroscopy studies. Comprising, it is a powerful tool for addressing key questions in many scientific areas, e.g. to study structures in the environment showing dimensions on the nanoscale. As a result of the refractive index of matter being close to unity scattered X-ray light will not be reflected from inner surfaces in inhomogeneous media. Clear images without scattering background are obtained even when studying thick and inhomogeneous samples. Therefore, X-ray microscopy images can be used for tomographic reconstructions of thick samples. Electron storage rings, being X-ray light sources of extreme brightness, are normally the site of installation for X-ray microscopes, however, small scale laboratory X-ray sources have already proven their value for imaging and spectroscopy.

Applications from soil science, geomicrobiology and water chemistry show the significance of X-ray spectromicroscopy as a tool to study the submicron world. Samples from soils and groundwater aquifers have been imaged to visualize the appearance of structures on the nano- and microscale. The effect of changing chemical conditions in an aqueous environment on the appearance of these structures has been imaged and evaluated. Using the spectromicroscopy potential, the distribution of organic and inorganic components has been studied; spectra have been analyzed for major chemical constituents. For example, anthropogenically produced nanoparticles and their effects in the environment have been studied. Spectromicroscopy has been used as well to assess different sulfur and iron species in an entire soil profile. Clay dispersions, microhabitats, and morphological effects of biologically induced redox changes of humic substances have been imaged tomographically conveying a detailed three-dimensional presentation of the specimen structure.