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Spectral micro-CT imaging of soil: retrieving atomic information and density maps

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Introduction

Micro-CT is a unique technology to non-destructively investigate the internal structure of samples, spanning a range from centimeter to micrometer scale. However, when it comes to material identification, the technology has some inherent limitations. The contrast observed within a micro-CT scan arises from a multitude of factors. The attenuation coefficient of a material is influenced not only by its atomic number and density but also by additional variables such as X-ray energy, the X-ray spectrum, and the characteristics of the employed detector. These diverse factors collectively contribute to the observed contrast, making the process of material identification in micro-CT scans a nuanced and multifaceted endeavor.
By using a spectral detector, not only the attenuated intensity of the X-ray beam can be measured, but the energy spectrum of the X-ray beam is captured when it passes through a sample. This capability facilitates the segregation of information relating to both the atomic number and density within the spectral scan.

Materials and Methods

A contaminated soil sample was into a 7 cm diameter container and scanned on a TESCAN UniTOM XL SPECTRAL using both traditional attenuation-based tomography and spectral tomography which allows to measure the entire energy spectrum between 20 and 160 keV of the X-ray beam. The spectral data was reconstructed and analyzed using the TESCAN Spectral suite, which enabled to extract spectra and analyze K-edge information from dense mineral phases in the sample and generate maps of the atomic information (Zeff) and the density in the soil.

Results and Conclusion

In this work we show how spectral micro-CT can improve material identification for porous geological material like soil. The soil was contaminated with heavy metals and the spectral K-edge imaging was used to analyze the distribution lead in the soil. This is illustrated in figure 1, where the spectral signature of 2 dense grains is shown. The presence of the K-edge of Pb in one of the spectra is clearly present, positively identifying lead bearing particles in the soil.
The attenuation coefficient in a micro-CT image depends on the X-ray energy, the atomic number and the density. Because we have information of all the X-ray energies between 20 and 160 keV in the spectral CT a better distinction between the atomic information (Zeff) and density can be made.
In the soil we have larger granules in a finer grained matrix. In figure 2 we can see that in the Zeff map there is no difference between the granules and the matrix. While in the density map the matrix and granules can clearly be discriminated. This shows that the granules in the soil have the same chemical composition as the matrix (same Zeff) but have a clear difference in density, where the granules are far denser compared to the matrix.
All results show the large potential of spectral CT in enhancing attenuation-based micro-CT and providing new and unique insights in all types of materials.

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Primary author: BOONE, Marijn (TESCAN XRE)

Co-authors: Dr MASSCHAELE, Bert (TESCAN XRE); VAN LOO, Denis (TESCAN XRE); DEWANCKELE, Jan (TESCAN XRE); DE BOEVER, Wesley (TESCAN XRE)

Presenter: BOONE, Marijn (TESCAN XRE)

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