3rd International Conference on Tomography of Materials and Structures
Lund, Sweden, 26-30 June 2017, ICTMS2017-211

COMBINED 3D CHEMICAL AND MORPHOLOGICAL CHARACTERIZATION USING AN INTEGRATED SYSTEM

Matthieu N. Boone*[1], Brecht Laforce[2], Bert Masschaele[1,3], David Schaubroeck[4], Manuel Dierick[1], Veerle Cnudde[5], Bart Vekemans[2], Luc Van Hoorebeke[1] & Laszlo Vincze[2]

[1]UGCT – Radiation Physics, Dept. Physics and Astronomy, Ghent University, Belgium
[2]X-Ray Microspectroscopy & imaging – Dept. Analytical Chemistry, Ghent University, Belgium
[3]XRE bvba; Technologiepark 5; 9052 Zwijnaarde
[4]Center for Microsystems Technology (CMST), imec and Ghent University, Technologiepark 15, 9052 Ghent, Belgium
[5]UGCT – PProGRess, Dept. Geology, Ghent University, Belgium

Keywords: X-ray tomography, X-ray fluorescence, multi-modality imaging, gold nanoparticles

Summary: A new scanner system is presented that combines high-resolution X-ray transmission tomography with high-resolution confocal XRF and XRF-CT modalities. The integrated system contains a high-precision positioning stage that allows for sample transfer between the three modalities at micrometer accuracy. The technical details of this system are presented, as well as some preliminary application results.

1. INTRODUCTION

High-resolution X-ray computed tomography (micro-CT) is nowadays an established technique for material characterization. However, the technique only yields morphological information, and the composition of the object can only be retrieved based on an educated guess. On the other hand, three-dimensional high-resolution X-ray fluorescence spectroscopy (µXRF) is an analytical technique that yields the chemical composition of a sample. In the past, several efforts have been made to combine both methods. Typically, they apply both techniques at different setups, and register the results [1,2]. One notable system combines micro-CT and full-field XRF in one apparatus [3].

At the Ghent University, the X-ray Microspectroscopy and Imaging (XMI) research group and the Radiation Physics research group (RP, part of the Centre of X-ray Tomography UGCT) have realized a laboratory scanner system called Herakles that combines three measurement stages: one high-resolution transmission tomography stage, one confocal µXRF stage and one µXRF-CT stage. This system allows for registration-free combination of morphological and chemical information at a high precision.

2. EXPERIMENTAL METHOD

The setup is built on a large granite table and contains a high-precision air-bearing system provided by LAB (Leuven, Belgium). This is required to move the sample between the different measurement stages, which corresponds to a maximum travel range of over 80 cm. To avoid post-processing registration, the positioning accuracy is below 1µm.

The µCT stage is positioned in the middle. It consists of an X-ray WorX transmission-type tube and two different detectors, one for low-attenuating samples and one for high-attenuating and larger samples. The highest achievable resolution on this setup is approximately 500nm.

The confocal XRF stage consists of a 50 W tube with Mo target equipped with polycapillary optics to generate a focused X-ray beam with a working distance of 3.6mm and a spot size of 10µm x 13µm, and two large area SDD

* e-mail: Matthieu.Boone@UGent.be

detectors, of which one is equipped with polycapillary optics. By aligning the focal points of both optics (i.e. tube and detector), a confocal measurement of a single microvoxel can be performed [4]. The size of this voxel is approximately 30µm x 30µm x 30µm.

The XRF-CT setup consists of a similar source with monocapillary optics, resulting in a pencil beam, and two large area SDD detectors, without optics, which are used to detect the spectrum from the illuminated line in the sample. By stepping the sample sideways and rotating, a first-generation tomography setup is realized [5].

3. RESULTS

We show results from both calibration phantoms and samples scanned in the framework of scientific collaborations. A notable application is the localization of gold nano-particles (AuNP) in both soft tissue and mineral building materials. These applications show clearly the advantage of both the possibility to measure point spectra at specific locations indicated on the µCT images as well as the possibility to measure chemical mappings for complete 2D slices which can be correlated with the high-resolution images of the transmission CT.

References

[1] B. De Samber, G. Silversmit, K. De Schamphelaere, R. Evens, T. Schoonjans, B. Vekemans, C. Janssen, B. Masschaele, L. Van Hoorebeke, I. Szaloki, F. Vanhaecke, K. Rickers, G. Falkenberg, and L. Vincze, Element-to-tissue correlation in biological samples determined by three-dimensional X-ray imaging methods. *J. Anal. At. Spectrom*. 25(4), 544-553, 2010

[2] N.L. Cordes, G.J. Havrilla, I.O. Usov, K.A. Obrey, and B.M. Patterson, Non-destructive elemental quantification of polymer-embedded thin films using laboratory based X-ray techniques. *Spectrochimica Acta Part B: Atomic Spectroscopy*, 101, 320-329, 2014

[3] P. Bruyndonckx, A. Sasov, and X. Liu, Laboratory 3D Micro-XRF/Micro-CT Imaging System, *in 10th International Conference on X-ray Microscopy*, 61-64. 2011

[4] L. Vincze, B. Vekemans, F.E. Brenker, G. Falkenberg, K. Rickers, A. Somogyi, M. Kersten, and F. Adams, Three-Dimensional Trace Element Analysis by Confocal X-ray Microfluorescence Imaging. *Anal. Chem.*, 76(22), 6786-6791, 2004

[5] C.G. Schroer, Reconstructing x-ray fluorescence microtomograms. *Appl. Phys. Lett*., 79(12), 1912-1914, 2001

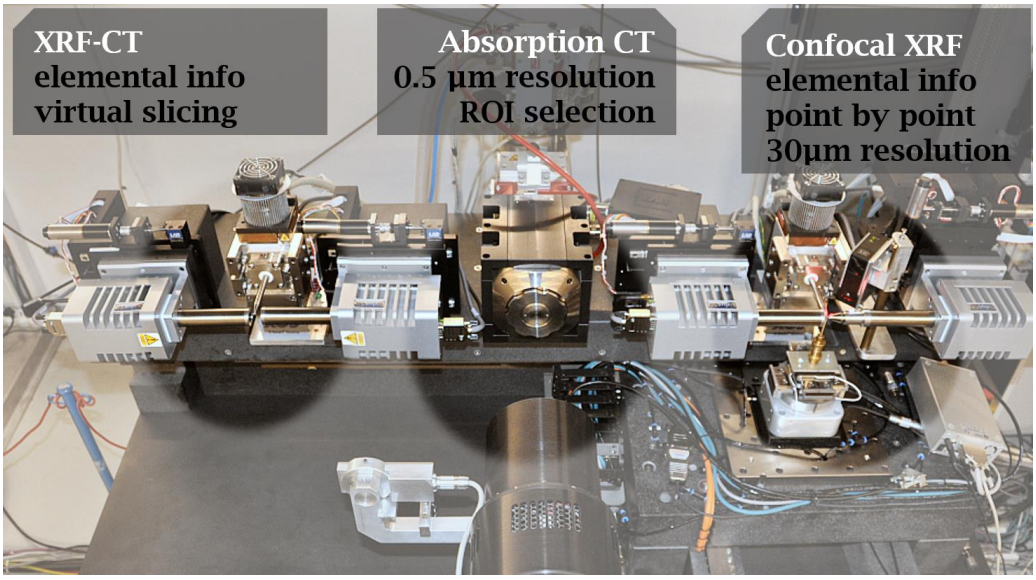

Figure 1: A picture of the setup with the three measurement stages indicated.