Quantitative, total metal imaging using 3D confocal x-ray fluorescence microscopy at the micron scale

Arthur R. Woll(1), David N. Agyeman-Budu(1), Ju-Chen Chia(2), Maryam R. Ishka(2), Yulin Jiang(2), Ryan Tappero(3), Yong Chu(3), Juergen Thieme(3), Olena Vatamaniuk(2)

(1) Cornell High Energy Synchrotron Source, Cornell University, Ithaca, NY 14853 USA
(2) College of Agriculture and Life Sciences, Cornell University, Ithaca, NY 14853 USA
(3) Brookhaven National Laboratory, Upton, NY 14853 USA

We present recent measurements of elemental distributions in a variety of plant samples on embedded unthinned samples, using synchrotron-based confocal x-ray fluorescence microscopy (CXRF). This approach overcomes important limitations of comparable techniques such as laser-ablation and secondary ion mass spectrometry, and especially XRF microtomography, while retaining part-per-million sensitivity and the ability to obtain quantitative element concentration distributions of many elements in parallel, e.g. K, Ca, Mn, Fe, and Zn. Our implementation employs custom-fabricated collimating channel array optics, developed at the Cornell High Energy Synchrotron Source, which permit CXRF to be performed with micron-scale, achromatic resolution. At this resolution, individual cells are distinguishable, permitting evaluation of elemental concentration differences among different tissue types. The technique constitutes a powerful tool for visualizing total elemental concentrations in biological samples, and specifically for the study micronutrient transport, signaling, and homeostasis in plants. Apart from new 2D and 3D imagery, we present novel characterization of CXRF performance, including quantitative evaluation of the elemental yield and solid angle of collection as a function of energy, as well as a method for direct measurement of the 3D probe volume.