Collimating Channel Arrays For 3D Micro Confocal X-Ray Fluorescence

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Confocal X-ray Fluorescence Microscopy (CXRF) employs overlapping focal regions of two x-ray optics—a condenser and collector—to directly probe a 3D volume in space. In general, polycapillaries are used as the collector owing to their large solid angle of collection. Here, we report the practical demonstration of spoked channel arrays (CCAs), a novel x-ray collection optic for confocal x-ray fluorescence microscopy (CXRF). The optic consists of micron-scale, lithographically-fabricated arrays of collimating channels (Fig. 1), all directed towards a single source position. In contrast to polycapillaries, the spatial resolution of these optics is nearly energy-independent. Most recently, we have fabricated a set of optics made from germanium substrates, rather than silicon, in order to extend their working energy range. In this way, we have successfully demonstrated CXRF at 2-µm depth resolution from 2-20 keV, and anticipate operation up to 30 keV with the same optics. Among other benefits, CCAs allows direct, 3D mapping in unthinned samples of both low and high Z elements at the micron scale (Fig 2). The feasibility of these optics for confocal XRF and XAFS on a variety of different sample types were demonstrated at APS beamline 20-ID-B, where they are now available to general users. The optic mounts in a custom-built holder, designed to mate easily to a single-element Vortex EX detector. Opportunities for future development will be discussed, including operation in conjunction with pixel-array-based energy dispersive detectors, such as the Maia. The later combination would allow fast, 3D mapping of samples not suitable for computed tomography, and suggests the possibility of simultaneous, parallel detection of emission from different depths in a sample, e.g. for fast 3D mapping of major elemental constituents, or time- and depth-resolved, in-operando studies of chemical reactions in layered systems.

Figure 1: Scanning electron micrograph of a lithographically-patterned channel array.

Figure 2: 2D map of Pb L\textalpha fluorescence in an un-thinned bone sample, obtained using confocal XRF with a spoked channel array as the collection optic. Scale bar is 100 µm.