High Spatial Resolution Detectors for 3D Studies using 30-100 keV X-rays

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The use of synchrotrons for 3D characterization in materials science is rapidly growing. With hard x-rays millimetre - centimetre thick specimens can be investigated, and with novel reconstruction methods 3D movies of the dynamics of the microstructure can be acquired (see Fig 1). Hence, for the first time it is possible to observe directly how structural elements nucleate, grow, deform, transform or crack and in general how they interact with their local neighbourhood.

One emerging methodology is 3D X-Ray Diffraction (3DXRD) microscopy [1,2]. Based on ray tracing with several detectors, the position, volume, orientation, elastic and plastic strain can be derived for hundreds of grains simultaneously. Furthermore for coarse-grained materials grain boundary maps can be generated. With the present set-up at Beamline ID11 at the ESRF, the spatial resolution is ~5 μm. Another methodology in rapid development is (absorption and phase contrast) tomography. As one example: at 100 keV tomograms have been made within 2 seconds and with a spatial resolution of 2.8 μm [3].

At the moment the main limitation for these techniques is the area detectors used. Based on optical coupling of a fluorescence screen to a CCD, these are intriniscally limited to a resolution around 1 μm. Furthermore, to obtain the maximum resolution, the screen needs to be very thin, such that the efficiency of the detector is ~1%.

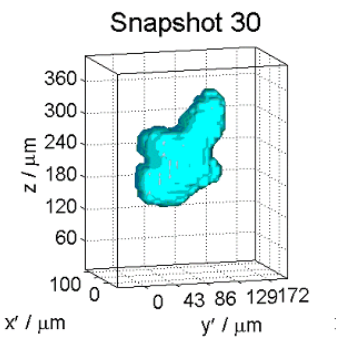

Fig.1: Snapshot from a 3D movie of the growth of a recrystallising grain obtained by 3DXRD [1]. The space and time resolutions were 5 μm and 10 min, respectively.

The case for a new generation of hard x-ray area detectors will be made. These should combine high spatial resolution (ideally 100 nm) with high efficiency, high stability and minimum 12 bit dynamics range. Two untested ideas for the concept of such detectors will be forwarded.

References

[1] - Poulsen, H.F. *Three Dimensional X-Ray Diffraction Microscopy: Mapping Polycrystals and Their Dynamics* (Springer Verlag, Berlin, 2004).

[2] - S. Schmidt, S.F. Nielsen, C. Gundlach, L. Margulies, X. Huang, and D. Juul Jensen, Science **305**, 229-232 (2004).

[3] - O. Lame, D. Bellet, M. Di Michiel, and D. Bouvard. Acta Mater. **52**, 977 (2004).