Mapping Grain Morphology and Grain Orientations by Laboratory Diffraction Contrast Tomography

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Summary: Recent developments in laboratory-based diffraction contrast tomography (LabDCT) has shown its capability to non-destructively map the 3D morphology and crystallographic orientation in the bulk of a polycrystalline sample. Here we introduce the methodology behind this novel imaging modality and provide examples of use cases taking advantages of the ability to characterise grain microstructures, non- destructively and in three-dimensions and thereby opening the path to 4D studies of materials evolution.

1. CONTEXT

Crystallographic imaging (i.e. imaging of crystallites/grains in polycrystalline materials) is primarily known from electron microscopy, and particularly the introduction of the electron back-scattering diffraction (EBSD) technique in the early 1990's, has made it a routine tool for research and/or development related to metallurgy, functional ceramics, semi-conductors, geology etc. The ability to image the grain structure in such materials is instrumental for understanding and optimization of material properties and processing. However, the destructive nature of 3D EBSD prevents the technique from directly evaluating the microstructure evolution when subject to either mechanical, thermal or other environmental conditions. Non-destructive x-ray-based crystallographic imaging methods allow for extended '4D' time dependent studies but have to date been primarily the domain of a limited number of synchrotron facilities [1, 2]. However, recently laboratory-based diffraction contrast tomography was introduced as an additional imaging modality on a commercially available X-ray microscope and thereby opened up a whole new range of possibilities for studies of the effect of 3D crystallography on materials performance.

2. EXPERIMENTAL METHOD

Laboratory diffraction contrast tomography (LabDCT) [3, 4] makes use of high-resolution diffraction images acquired on a ZEISS Xradia 520 Versa X-ray microscope. The diffraction signals are based on polychromatic X-rays and acquired in a special Laue-focusing geometry for improved signal to noise ratio and spot separation. The unique non-destructive 3D crystallographic imaging capabilities of LabDCT complement the structural data obtained by traditional absorption-based tomography and together they provide an unprecedented insight into the structure of materials.
Recent developments of the LabDCT technique have extended its capabilities to include full reconstruction of the 3D grain structure including both grain morphology and crystallographic orientation, thereby making the LabDCT more comparable to conventional 3D-EBSD data – while still supporting 4D time dependent studies.

3. RESULTS

We will present a selection of results of LabDCT with particularly emphasis on its non-destructive operation, demonstrated through 4D evolutionary studies obtained by repeating the imaging procedure numerous times on the same sample. We will discuss the boundary conditions of the current implementation, point to the future of the technique and discuss ways in which this can be correlatively coupled to related techniques for a better

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understanding of materials structure evolution in 3D.

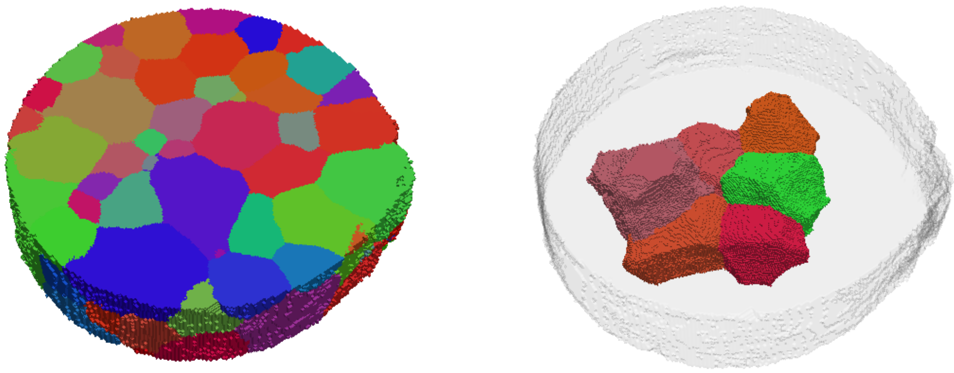
References

[1] H. F. Poulsen, D. J. Jensen, and G. B. M. Vaughan, "Three-Dimensional X-Ray Diffraction Microscopy Using High-Energy X-Rays," MRS Bull., vol. 29, no. 3, p. 166–169+155, 2004.

[2] W. Ludwig et al., "X-ray diffraction contrast tomography: a novel technique for three-dimensional grain mapping of polycrystals. II. The combined case," J. Appl. Crystallogr., vol. 41, no. 2, pp. 310–318, 2013.

[3] S.A. McDonald, P. Reischig, C. Holzner, E.M. Lauridsen, P.J. Withers, A.P. Merkle, M. Feser, Sci Reports 5 (2015) 14665.

[4] C. Holzner et al., "Diffraction Contrast Tomography in the Laboratory – Applications and Future Directions," Micros. Today, vol. 24, no. 4, pp. 34–43, 2016.



(a) (b)

Figure 1: (a) 3D reconstruction of an AlCu polycrystalline sample. Grains colors are function of their orientation (IPF coloring). (b) Visualization of a cluster of 6 grains embedded in the bulk of the sample (same color code)