Inspecting sub-grain level deformation in poly-crystals

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The ability to retrieve volumetric information about the crystallographic grain microstructure is necessary for understanding the initiation of damage and for establishing safety margins in critical applications. An interesting example is presented in [1], where the authors study the propagation path of corrosion cracks through polycrystalline steel samples (i.e., the materials used for the vessels of nuclear reactors), using a non-destructive three-dimensional orientation imaging technique, called Diffraction Contrast Tomography (DCT), in conjunction with traditional X-ray absorption Computed tomography.

DCT is based on a traditional X-ray absorption tomography setup, where the diffracted intensities and shapes of the illuminated grains are recorded together with the transmitted direct beam. It has traditionally been able to provide average grain positions and orientations, and even grain shapes in the case of undeformed granular materials.

In this talk we will first present a 6-dimensional extension of DCT, able to model and reconstruct local plastic deformations inside polycrystalline materials. The proposed framework also allows for mathematical extensions, like the introduction for prior knowledge about the materials, and the ability to include large portions of the samples in one single reconstruction. An interesting outcome of this flexibility is the ability to correctly reconstruct textured regions of samples, where traditional indexing techniques start to fail with increasing levels of deformation. In fact, when neighboring grains have similar orientations, they are more likely to generate overlaps in the diffraction data, which is in contrast with the assumptions of traditional indexing algorithms [2].

In addition to these results, we will also present recent developments, which aim at improving the quality and resolution of the 6D reconstructions, with the final goal of being able to address increasing levels of crystal deformations and sample sizes, which is necessary for the study of industrially manufactured materials.

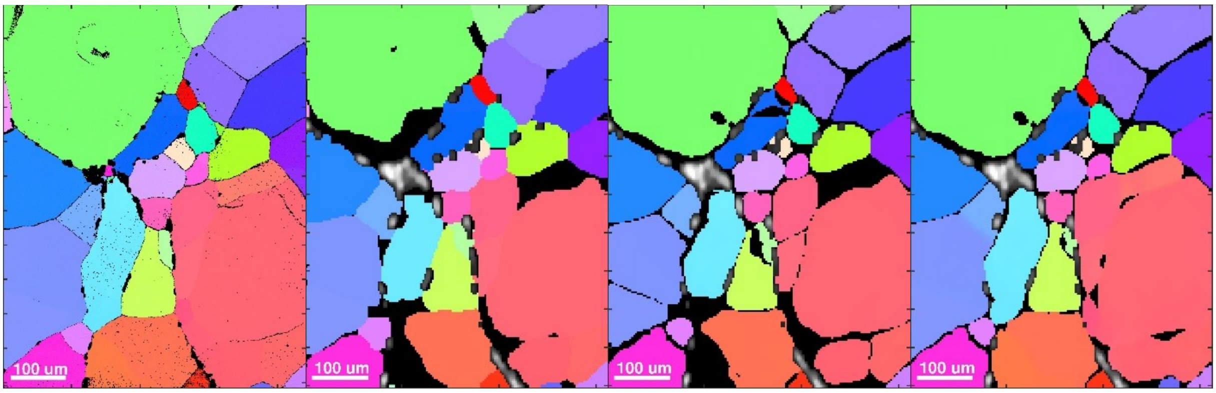

Figure 1: Orientation map of the surface of a rock-salt sample, by means of EBSD (a), 3D-DCT followed by grain dilation (b), single-grain 6D-DCT (c), and multi-grain 6D-DCT where new grains were identified by the reconstruction (d).

[1] A. King, G. Johnson, D. Engelberg, et al., Science, 2008, vol. 321, 382–385.
[2] N. Viganò, A. Tanguy, S. Hallais, et al., Sci. Rep., 2016, vol 6.