3D movies of self-organisation of individual dislocations during plastic deformation

Borgi¹, G. Winther², H. F. Poulsen¹

B Technical University of Denmark, Department of Physics, Denmark,
Technical University of Denmark, Department of Civil and Mechanical Engineering, Denmark

Email of communicating: borgi@dtu.dk

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The mechanical and many physical properties of metals are governed by defects, known as dislocations. TEM can display these line defects in thin films but cannot probe the structural dynamics and the local stress field in a representative way, as this requires studies of bulk specimens. As a result, it has until recently been impossible to visualize the self-organisation of dislocations taking place during plastic deformation.

In this talk I present the first in situ 3D experimental movies of the initial patterning of dislocations in a pristine sample during deformation using Dark-Field X-ray Microscopy, DFXM [1]. The angular sensitivity of DFXM is 10⁻³ degrees, allowing the dislocations to be in Bragg condition, while the rest of the crystal lattice is not, giving rise to contrast. Using a tensile rig, individual defects are identified deep within a mm-sized single crystal of aluminium and tracked as function of external load at beamline ID06 at ESRF. As an example, Figure 1a is a snapshot of an ensemble of dislocations within a 2D slice of the sample.

Next, I present forward simulations of DFXM images based on either geometrical optics or wavefront propagation. As an example, Figure 1b displays a DFXM image of a 2D slice of an aluminium single crystal, with a large domain exhibiting a few randomly dispersed dislocations. Comparing experimental data and simulations is used to guide the modelling, e.g. to identify dislocation types. The forward simulations tools also allow to interface data directly to discrete dislocation dynamics (DDD) [2]. Depending on progress with analysis I will report on the physical mechanisms underlying the self-organization observed and discuss current limitations.

Figure 1. 2D images of a layer in a single crystal aluminium (111 reflection). (a) Experimental DFXM image of domain with clear individual dislocations, in a weak beam configuration. (b) Simulated DFXM image, displaying the contrast of 5 random edge dislocations within a domain.
