Dislocations in ceramics: Opportunities and challenges in quantitative 3D imaging

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While dislocations are very well understood in metals, dislocations are often not associated with ceramics. Their potential for tuning the functional properties of ceramics[1] as well as shaping or toughening is not commonly understood or appreciated. The charged dislocation core, which does not occur in metals, leads to space charge zones and other effects. In consequence, dislocations can be used to tune a range of functional properties such as electric, ionic or thermal conductivity as well as ferroelectric properties and others.
Surprisingly, despite ionic bonds, many ceramics can be easily deformed by dislocations - some even at room temperature and below (as single crystals). Furthermore, plastic deformation of polycrystals beyond 20% strain is feasible at elevated temperatures[2]. Much of the knowledge on dislocation-related mechanical behavior of ceramics stems from the 1960s[3]. The availability of modern techniques, such as atomic resolution TEM, molecular dynamics and dark-field x-ray microscopy invites to revisit some of the very fundamental understanding of dislocation mechanics in ceramics.
In this talk, I will give an overview of the research field of dislocations in ceramics and highlight the potential role of dark-field x-ray microscopy to understand the multiscale behavior.
Because dislocation density in ceramics tends to be lower than in metals individual dislocations are more easily visualized with dark-field x-ray microscopy, see Figure 1. This allows to depict and quantify multiscale processes such as dislocation multiplication or percolation of 3D networks. Simultaneously, dislocation motion in ceramics can be slow and, hence, easy to capture. 3D reconstruction of individual dislocations inside deformed ceramics including quantitative mosaicity and strain data appears to be achievable according to data recoded on a deformed $SrTiO_3$ single crystal[4]. For verification, analysis is compared to ultra-high voltage TEM images. This could make dark-field x-ray microscopy a central tool in understanding dislocation mechanics in ceramics.

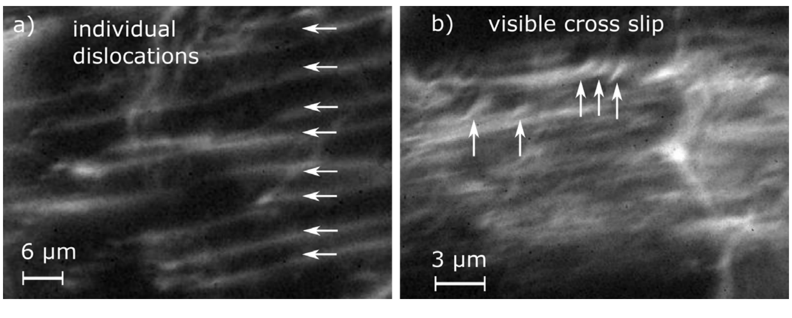

Figure 1: DFXM can reveal individual dislocations (a) and visualize features such as cross slip (b)

References
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