Toward 3D visualization of dislocation dynamics under deformation using transmission electron microscopy

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Observation of dislocation dynamics in three-dimensions (3D) using electron microscopy, which was firstly reported by Kacher and Robertson [1], is still challenging. After their report [1], the authors' group obtained a result of subsequently repeating *in-situ* specimen straining and electron tomography (ET) observation for a steel specimen in which a dislocation was interacting with a spheroidized cementite [2]. Although the observed magnitude of the dislocation movement was small, a few tens nm, the observation demonstrated the importance of 3D observation: the dislocation movement was recognized from some directions while not from the other directions. This different visibility of the dislocation movement is due to the geometrical relationship between the active slip plane and the viewing directions. In other words, a 3D imaging technique is indispensable for visualizing arbitral dislocation movements in such an *in-situ* straining and observation experiment. The importance of this point of view has been proven by Mussi *et al.* [3]: they recently reported a successful ET imaging of dislocation dynamics in MgO under heating and electron irradiation.

There are technical issues to be solved toward establishing a 3D dislocation dynamics imaging method under specimen deformation. For example, diffraction alignment is essential for visualizing dislocations in ET. If we can predict how dislocations move in a specimen, we could keep the diffraction condition during the dislocation movement by setting the crystallographic orientation regarding the loading direction. However, the aligned diffraction condition can change during the deformation of the specimen with applied stress. Therefore, the authors propose an alternative way to visualize 3D dislocation dynamics "without" keeping particular diffraction conditions during ET data acquisition [4], as Kacher and Robertson demonstrated earlier [1]. Another essential issue is to improve the time resolution of tilt-series data acquisition. As a related topic, five-second tilt-series acquisition in scanning transmission electron microscopy with deep-learning-based noise filtering [5] has been reported. This technique will be a promising imaging method for *in-situ* 3D imaging of dislocations and other material dynamics.

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