Single-shot three-dimensional electron imaging for in-situ dynamics

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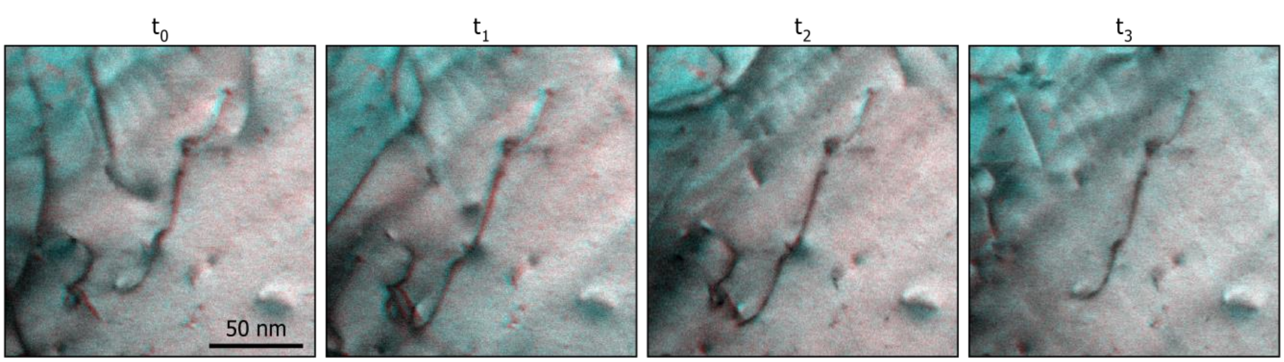
A significant challenge in physical and biological sciences is the characterization of complex three-dimensional (3-D) structures on small length scales. To this end, the field of tomographic reconstruction has blossomed during the last decade, for instance by using an angular or focal series of 2-D (scanning) transmission electron microscopy (TEM) images [1-3]. In these techniques, however, the prolonged exposure of the sample to the electron beam remains an inherent problem, in particular when the sample is sensitive to the electron beam.

Here, we introduce a novel methodology for 3-D imaging in TEM that promises to be more efficient in both acquisition time and electron dose [4]. This new methodology images the sample from different angles in a single scanned acquisition. The stereoscopic images correspond to different incident beam angles contained within the convergent electron probe used during scanning TEM (STEM), and are recorded simultaneously using new generation segmented STEM detectors. This method of acquisition also greatly eases the 3-D imaging of features such as crystalline defects under well-defined diffraction contrast conditions. In fact, for a crystal orientation where a systematic row of reflections is excited, choice of opposing incidence angles perpendicular to the direction of the diffracted beams corresponds to the same excitation condition. By selecting the intensities of two counterparts on opposing sides of the (0 0 0) direct beam disc (in the convergence electron beam pattern) for image formation, a pair of stereo bright-field STEM images are recorded with exactly the same deviation from the Bragg diffraction condition; an important criterion for imaging the 3-D network of one-dimensional crystalline defects known as dislocations. For the case of dislocations and other curvilinear structures, a dedicated stereovision reconstruction algorithm is applied to yield a reliable 3-D reconstruction of their structures [5].

This new imaging methodology will enable the 3-D imaging of dynamic processes evolving on a millisecond timescale, such as entanglement of dislocations under mechanical stress, or equally resolving beam sensitive biological structures in 3-D. Here, the success of this method is demonstrated by imaging the evolution of a 3-D network of dislocations under mechanical stress applied *in-situ*, as well as for resolving the 3-D distribution of nanoparticles in a nano-catalyst.



Series of superposed stereo STEM images (coloured anaglyphs) showing the evolution of a 3-D network of dislocations during *in-situ* mechanical deformation of a copper foil.

References

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