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The Use of Stereomicroscopy in Conjunction with *In Situ* Straining TEM for Studying Dislocation Behavior

Rodney J. McCabe*, Amit Misra*, Terence E. Mitchell*

*MS-G755, Los Alamos National Laboratory, Los Alamos, NM 87545

The ability to monitor dynamic motion and interactions of dislocations in three dimensions in the TEM would be beneficial for enhancing the understanding of dislocation behavior. Such capabilities would also be useful for direct input and validation of 3D discrete dislocation dynamics models. The present study employs the use of stereomicroscopy in combination with *in situ* straining TEM to study dislocation behavior. The experiments involve obtaining a 3D description of dislocation configurations including Burgers vectors using a modified stereo-TEM technique that is usable with a single tilt (*in situ*) TEM holder. Following the 3D analysis, the specimen is strained *in situ* in the microscope and the dislocation motion and interactions are recorded. Following deformation, a 3D description of the final dislocation microstructure is obtained. Although direct 3D observations of dislocation motion is not possible, knowledge of the 3D configuration preceding and following deformation along with the 2D record of the motion allows for a reasonable description of the 3D behavior.

Conventional stereomicroscopy of crystalline materials is almost never possible with a single tilt TEM holder making it unfeasible for most commercial *in situ* TEM holders. A modified stereo technique was developed in order to utilize stereo-TEM using single tilt holders. The technique is a weak beam technique demonstrated in Figure 1 involving changing the sign of **g** and/or s_g while tilting across a Kikuchi band that is at less than around 30° to the tilting direction. For dislocations, a change in either **g** or s_g results in a shift in the peak in image intensity with respect to the dislocation core position [1]. To avoid errors associated with this shift, the ideal stereo conditions for this technique are for both **g** and s_g to change signs between the two stereo images.

An example of the use of stereo-TEM in conjunction with *in situ* straining microscopy for an annealed copper sample is given in Figures 2 and 3. Figure 2 is a sequence showing dislocation motion recorded during *in situ* straining. Figure 3 is the 3D analysis of the before and after configurations of three of the dislocations. The before data comes directly from the micrographs in Figure 1. The stereo analysis was performed using Sterecon, a 3D reconstruction software developed at Wadsworth Laboratories, Albany, NY [2]. Using the 3D analysis, the *in situ* record, and knowledge of the active slip systems for the dislocations, it is possible to deduce that the dislocations numbered 1 and 2 do not intersect during the *in situ* portion of the experiment even though they appear to in the 2D projection [3].

References

[1] Cockayne DJH. *J. Microsc.* 98 (1973) 116-134
[2] Marko , M. and A. Leith. Sterecon -- Three-Dimensional Reconstruction from Stereoscopic Contouring. *J. Structural Biol*, 116: (1996) 93-98.
[2] This research is funded by the US Department of Energy, Office of Basic Energy Sciences.

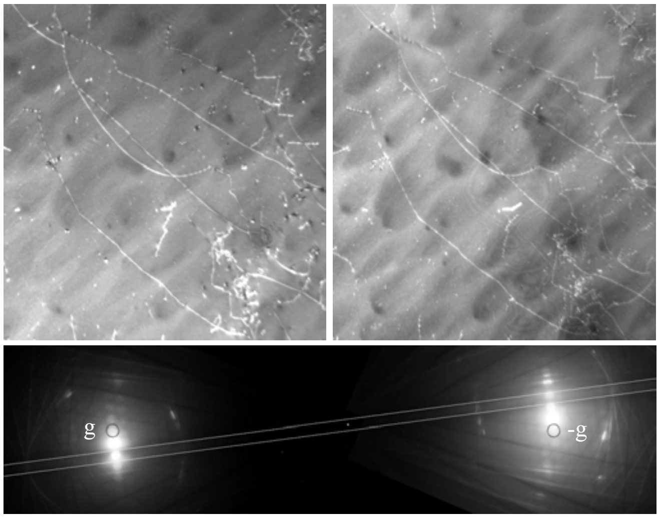

Figure 1. Stereo-pair obtained with the modified stereo technique. In the left image, **g** is used for imaging and –2**g** is near the Bragg condition. In the right image, **-g** is used for imaging and 3**g** is near the Bragg condition.

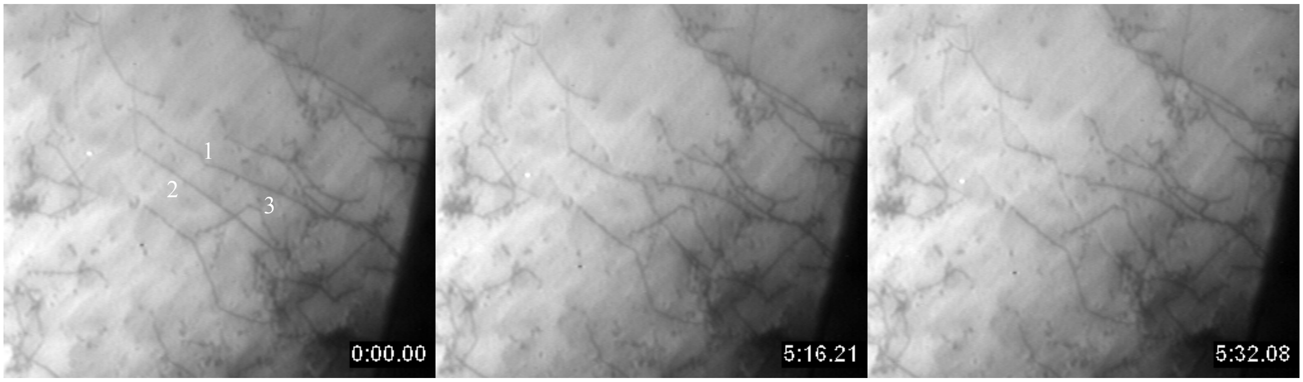

Figure 2. Progression of images during in situ loading. From these 2D projections, dislocations 1 and 2 appear to possibly intersect.

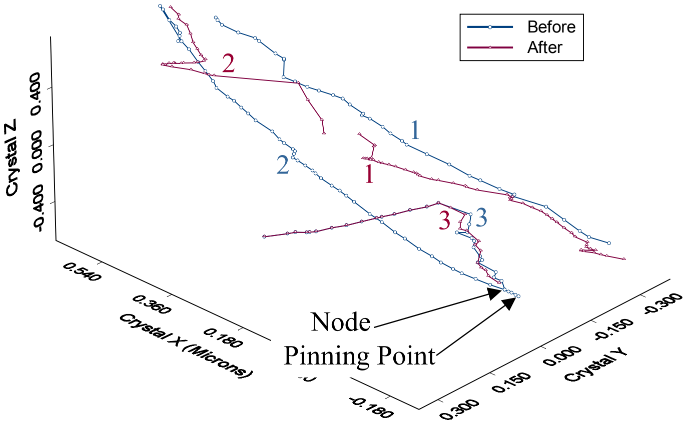

Figure 3. Before and after 3D representation of some notable dislocations.