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Are Dislocations Present in Nanoparticles?: Fourier Filtering of Images obtained from In-Situ TEM Nanoindentation

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The deformation behavior of nanostructured metals continues to be an exciting area for materials research. While the mechanical response of nanopillars under compression has been very well characterized [1-3], the mechanisms driving the mechanical behavior remain elusive. Several models have been suggested to explain the novel mechanical behavior of nanopillars [4-6], but efforts to experimentally validate the proposed models have faced several challenges. Many of the experiments have been conducted in-situ in a SEM, but under these conditions it is very difficult to understand the dislocation mechanisms governing deformation.

To address this issue, phase-contrast in-situ transmission electron microscopy (TEM) nanocompression experiments have been conducted on a 7 nm silver nanoparticle to observe dislocations during the deformation process. The pre-indentation nanoparticle and its FFT are shown in figures 1a and b. Strain was increased incrementally and then held constant so that high resolution images could be captured using a CCD camera. The small particle size and discontinuous strain rates allowed stationary dislocations to be imaged. The dislocations appear in the images as additional lattice fringes that terminate within the nanoparticle. However, the possibility that the terminating lattice fringes are due to the presence of the tungsten indenter, random phase noise or perhaps another type of defect must be addressed.

To address this problem, once the phase contrast images of dislocations are captured, Fourier Filtering is used to confirm the presence of dislocations. Fourier filtering is done by first taking an image and performing a fast Fourier transform (FFT). Subsequently portions of the FFT are selected and an inverse FFT is performed using only the selected sections. This process is shown for figures 2a-d. The resulting image contains only image data corresponding to the periodic data that was selected in the FFT. By choosing areas of the FFT with crystallographic significance, we can create an image that allows for direct visualization of selected lattice fringes, combined with the elimination of most other noise. This method is used to confirm the presence of dislocations during indentation. Additionally, figure 3a shows that the dislocation disappears after the strain is removed.

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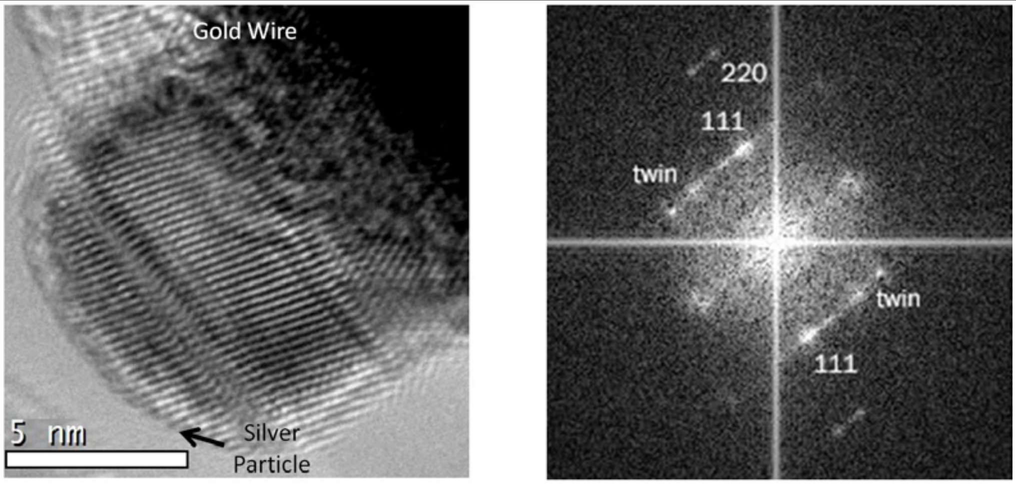
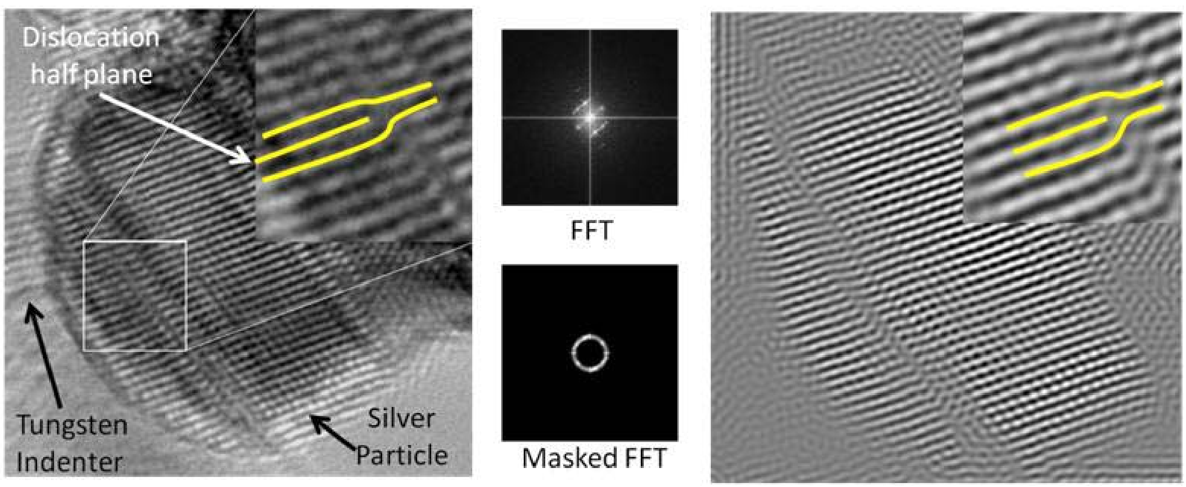
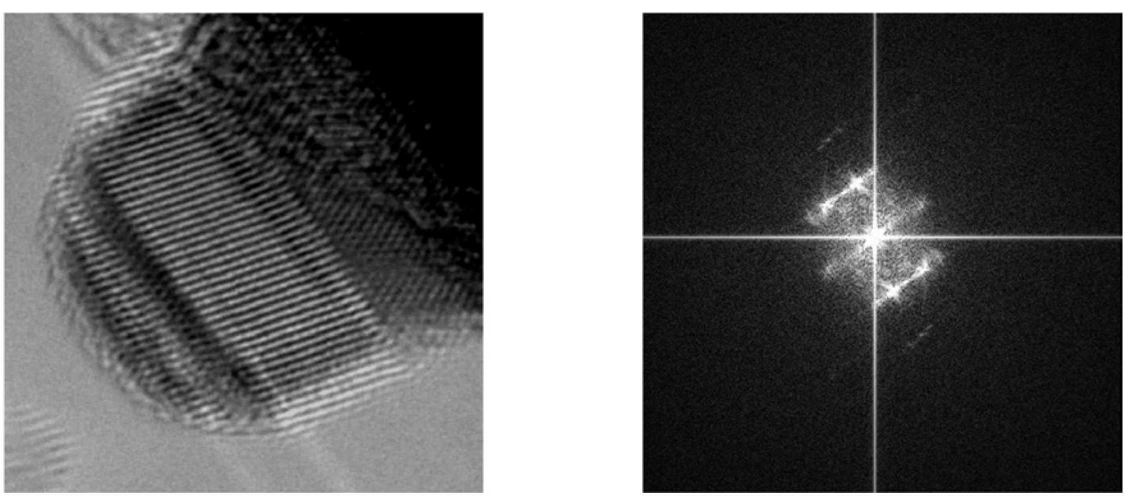


Figures 1a and 1b: a) High-resolution TEM image of the particle before indentation and b) FFT of a)



Figures 2a-d: a) The particle during deformations, b) it's FFT, c) the masked FFT that was used for Fourier Filtering and d) the Fourier filtered image. Not the dislocation that can be clearly seen in a) and d)



Figures 3a and 3b: a) The particle after indentation and its FFT.

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