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Contributions of Inelastically Scattered Electrons to Defect Images.

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We have made measurements of the contribution of inelastically scattered electrons to images of dislocations in Ni_3Ga and nanometer-sized defects in ion-irradiated Au under weak-beam dark-field diffraction conditions [1]. The purpose is to determine the conditions for data acquisition required to eventually make detailed and quantitative comparisons to simulations of images for various defect models, thus determining defect structure, composition, and local strain field. Such image simulations usually consider only elastically scattered electrons, and thus it is important to understand and possibly eliminate the contribution of inelastically scattered electrons to the experimental images for quantitative comparisons with image simulations.

Experimental data have been acquired with either JEOL 2010F or 3000F microscopes, both equipped with Gatan Imaging Filter electron spectrometers. Samples examined in the 2010F were Au, ion-irradiated to low dose (10^{11}Kr ions at 1 MeV energy) to form individual defects (1-10nm sized Frank dislocation loops and partial stacking fault tetrahedra). Samples examined in the 3000F were Ni_3Ga with long dislocation defects. Imaging conditions included weak-beam dark-field with deviation parameter generally > 0.2 nm^{-1}. Energy filter slit width was set to 10 eV and centered on the zero loss peak in both instruments to obtain images produced by elastically scattered electrons. In the Au experiment an energy window was also set to image the 10-40 eV loss range to investigate the contribution to the defect images of plasmon-loss electrons. Electron intensity in defect images and backgrounds was measured by summing pixel values in appropriately sized rectangles using Digital Micrograph (Gatan) software.

Examples of defect images in the exact same area in Au for three imaging conditions, unfiltered, zero-loss, and plasmon-loss, are illustrated in Fig. 1. Note the great similarity in image resolution and contrast for the first two, and some loss of resolution (at four times the exposure time of the first two) for the image formed by plasmon-loss electrons only. Integrated intensity measurements on four of the defects and neighboring backgrounds showed between 15 and 20% of the total contrast to come from inelastically scattered electrons, and about one third of that could be assigned to plasmon-loss electrons. Making the assumption that the electron thermal diffuse scattering does not contribute to image contrast [2], this means that about two thirds of the inelastic scattering that is image forming is due to single electron events [3]. A possible example of such scattering is found in weak defect images which are formed at 1.3 times the 200 Bragg angle, corresponding to M-shell ionization-loss electrons in Au (2.2 keV). These very weak images cannot be found in zero-loss electrons at this position in reciprocal space.

An example of a much stronger contribution to defect (dislocation) images in Ni_3Ga for inelastically scattered electrons is illustrated in Fig. 2. Here it was found that such electrons constitute 50-60% of the image in thin area, and as much as 90% in thicker area. In this lighter material advantages to energy filtering on zero loss electrons are indeed great, enhancing both image peak-to-background contrast and image resolution, especially in thicker area [4].

[1] Characterization of Radiation Damage by Transmission Electron Microscopy, M. L. Jenkins and M. A. Kirk, Inst. Phys. Publ., Bristol, UK, 2001, pp. 1-224.
[2] S. L. Cundy, A. Howie and U. Valdre', Phil. Mag. 20 (1969) 147.
[3] C. J. Humphreys and M. J. Whelan, Phil. Mag. 20 (1969) 165.
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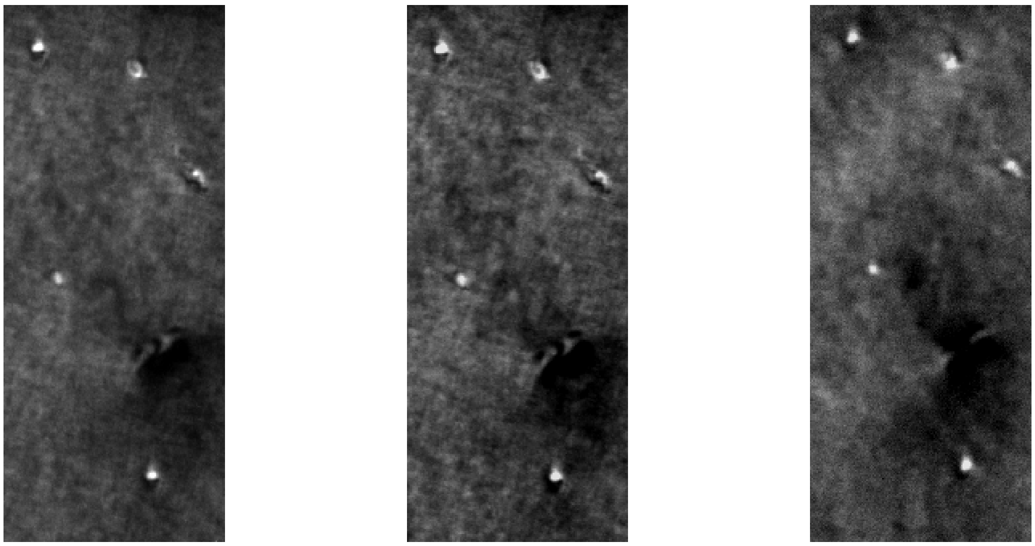

Fig. 1. Defect images in ion-irradiated Au. Left: unfiltered, middle: filtered on zero-loss peak with 10 eV slit width, right: filtered on plasmon-loss electrons with 10-40 eV window.

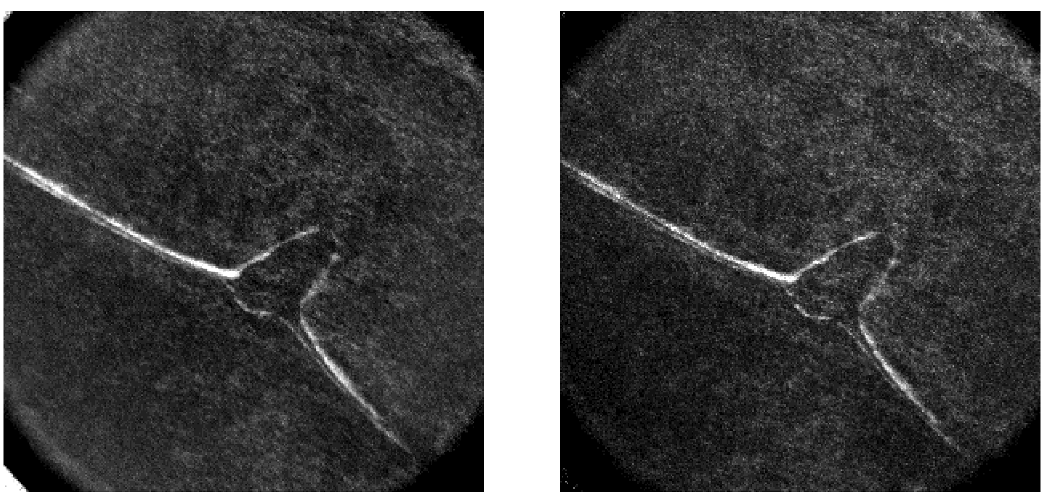

Fig. 2. Dislocation images in Ni_3Ga: left image unfiltered and right image filtered on zero-loss peak with 10 eV slit width.

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