

Electron Channelling Contrast Imaging in a Low Voltage Scanning Electron Microscope

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Understanding of defects and their role in plastic deformation, as well as in device reliability, helps in the development a wide range of novel materials for the next generation of electronic and optoelectronic devices. Electron channelling contrast imaging (ECCI) performed in a scanning electron microscope (SEM) is a rapid and non-destructive structural characterisation technique for imaging defects such as dislocations in crystalline materials [1, 2]. Changes in crystallographic orientation or local strain produce contrast in an image constructed by monitoring the intensity of backscattered electrons (BSEs) as an electron beam is scanned over a suitably orientated sample. Defects are imaged due to their resultant lattice plane distortions and local strain. Although ECCI provides the structural characterisation capability for various materials ranging from metals to ceramics, there are challenges in analysing low atomic weight, beam sensitive materials. One potential method is to minimise the interaction volume and thereby improve the spatial resolution of BSE images by employing low voltage SEM – the subject of our work.

In the present work, we demonstrate the prospect of performing low energy ECCI using conventional detectors in a Zeiss Auriga focused ion beam field emission SEM. We show that all the scattered electrons, including the secondary electrons (SEs) can provide diffraction contrast as long as the sample is positioned appropriately for the incident electron beam to diffract. Figure 1 show ECCI micrographs acquired from a GaN thin-film at 20 keV using a BSE detector, Everhart-Thorley detector (E-T) and the in-lens secondary electron detector. Surface penetrating dislocations appear as spots with black white contrast which carry information on dislocation types [2]. The image acquired with the BSE detector and the E-T detector look similar since the former collects only BSE and the latter collects predominantly the SE2s (created by the backscattered electrons on their way out from the sample) and BSEs, hence they look similar. However the in-lens detector image looks different since it collects predominantly the SE1s. This is due to the electrostatic field of the immersion lens which acts as a low-pass filter for secondary electrons for the in-lens detector and as a high-pass filter for the E-T detector [3]. We then repeated the experiment at 2 keV (an order of magnitude lower in energy); this is shown in Fig. 2. We have used the EsB detector (in-lens BSE detector) for acquiring the BSE image and a grid voltage is set to prevent SEs reaching the EsB detector. The magnitude of the strain field of the dislocation contrast looks similar for all the three images at low energy, but was different at high energy (see Fig. 1b&c). It is worth to note that the magnitude of the strain profile of dislocations is similar for ECCI micrographs acquired using in-lens detector at 2 keV and 20 keV.

Extracting diffraction information through secondary electrons opens up the vision of performing low energy electron channelling methods for characterising low atomic weight and ultra-thin film materials. As long as the sample is positioned appropriately for the incident electron beam to diffract, ECCI micrographs can be obtained using any electron sensitive devices. Although we have shown example from a semiconductor material, our methodology can be adopted as a large area, nanoscale structural characterisation method for any crystalline material.

References:

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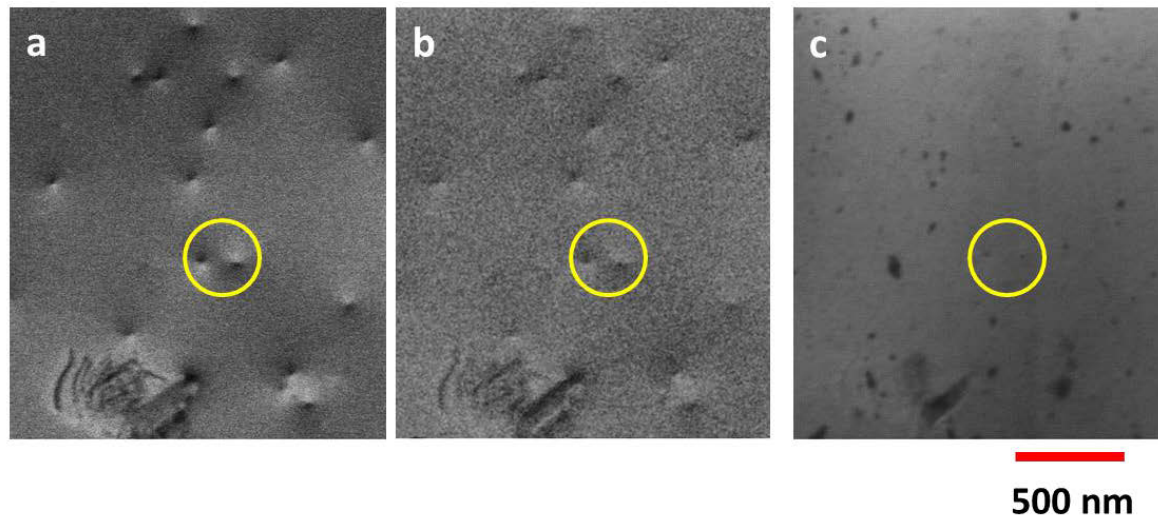


Figure 1. ECCI micrograph from a Si-doped GaN acquired at 20 keV using an (a) quadrant BSE detector, (b) Everhart-Thorley detector and (c) in-lens secondary electron detector.

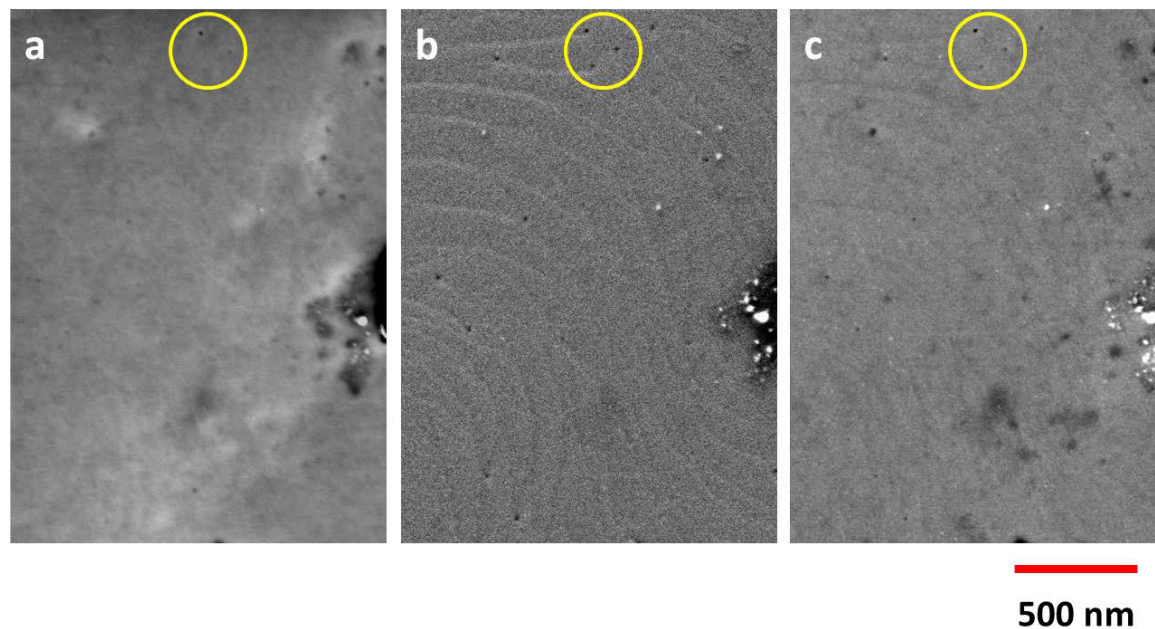


Figure 2. ECCI micrograph from a Si-doped GaN acquired at 2 keV using an (a) EsB detector (in-lens BSE detector), (b) Everhart-Thorley detector and (c) in-lens secondary electron detector. The yellow circles highlight the surface penetrating dislocations.