Depth Dependence of Electron Channeling Contrast Imaging in Gallium Nitride

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Background incl. aims

Interest for Gallium Nitride (GaN) and wide band-gap semiconductors has been growing the last few decades as a green-energy solution for electronic power devices and digital transition. Their enhanced electrical properties such as reduction of power losses or lower energy consumption tends to make them more suitable for power electronics applications over silicon. However, it is unclear whether leakage currents or device failures are related to crystalline defects, such as Threading Dislocations (TD), for which defect densities in GaN are orders of magnitude higher than in silicon. Detailed characterization of the defect nature and estimation of their density is, therefore, relevant to understand and improve GaN power devices. In this context, Electron Channeling Contrast Imaging (ECCI) can provide valuable insights. ECCI is a non-destructive method that offers the capability to provide Transmission Electron Microscopy (TEM)-like diffraction contrast imaging inside a Scanning Electron Microscope (SEM) on bulk samples. ECC is generated from electrons that channel down the crystal planes. Strain and defects cause distortion of the crystal lattice, resulting in changes in Backscattered Electron (BSE) intensity, thereby producing contrast in the image.

Diffraction contrast in bulk material is widely assumed to be generated from the near-surface layers (from tens to hundreds of nanometers) by electron channeling but there is currently no consensus about the depth from which the collected information originates. Therefore, it is critical to understand the depth dependence of the method to ensure measurements are made in the layer of interest.

The present study provides an experimental measurement of the signal from which the information in ECCI arises. This estimation aims to sharpen the statistical dislocation density estimation through series of measurements at different accelerating voltage and to establish a model for information emission while imaging GaN by ECCI.

Methods

The layer of interest, the GaN layer, lies between an AlxGa1-xN barrier layer and a series of strain-relief layers called the superlattice, for which the composition differs from the first one. As such, misfit dislocations, due to lattice mismatch, stand at the interface between the GaN and the superlattice. A Focused Ion Beam (FIB) was used to create wedges of different angles across these layers to vary the GaN layer thickness. The incident electron beam energy of the SEM was varied and the final depth the misfit dislocations were visible was recorded. Comparisons between multi-beam and 2-beam diffraction conditions was also performed.

Results

First results show ECCI probing depth can be tuned as a function of incident electron beam energy and that there are discrepancies between multi-beam and 2-beam diffraction conditions as well as the theorized channeling extinction distance and the experimentally measured probing range.

Conclusion

The key expected outcomes are an increase in estimated dislocation density accuracy in GaN and a better understanding of ECCI micrographs. The dataset is expected useful for complementary dislocation related fields of study such as layer growth or electrical characterization.

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Keywords:

ECCI, GaN, SEM, Crystallography