AN 463

Rapid Defect Typing in GaN Using a Dedicated Scanning Transmission Electron Microscope (STEM)

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Introduction

Rapid development of light emitting diodes (LEDs) for use in commercial lighting applications continuously pressures manufacturers to improve the performance of their devices. The National Renewable Energy Laboratory has set goals for increasing the internal quantum efficiency (IQE) of GaN based LEDs to 90% by 2015 [1]. Research has shown that the threading dislocation type (edge, screw, or mixed) has a strong influence on the IQE [2] of the device. As such, there is a growing need to efficiently and quickly determine threading dislocation type.

Discussion

Traditionally, defect or dislocation typing in various materials is carried out by extensive conventional transmission electron microscopy (TEM) analysis of cross-section samples. However, TEM images can be complicated by thickness fringes and bend contours as is shown in Figure #1. A corresponding image from a scanning transmission electron microscope (STEM) is shown in Figure #2. As compared to the TEM, the scanning convergent electron beam of the STEM provides images of dislocations with greatly simplified contrast, allowing rapid observation of all dislocation types simultaneously.

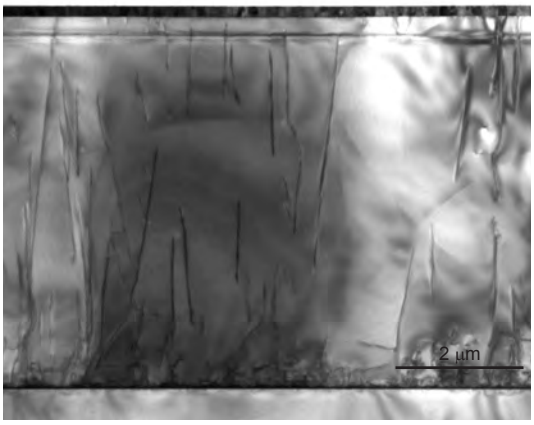

Figure 1: TEM bright field image showing contrast from dislocations as well as thickness fringes and bend contours.

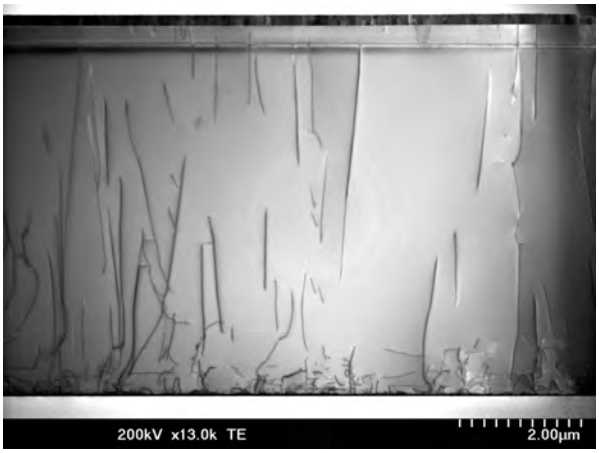

Figure 2: STEM bright field of the identical sample as in Figure 1 showing simplified and more uniform contrast.

By utilizing specific sample tilts in the STEM, threading dislocations in cross-sections can be further sorted into type: edge, screw, or mixed. Figure 3 shows an example of the sample oriented to highlight dislocations with edge type (e) while Figure 4 shows the same sample oriented to highlight dislocations with screw type (s). Dislocations highlighted at both tilts, in Figures 3 and 4, are considered to be of mixed type (m) with characteristics of both screw and edge.

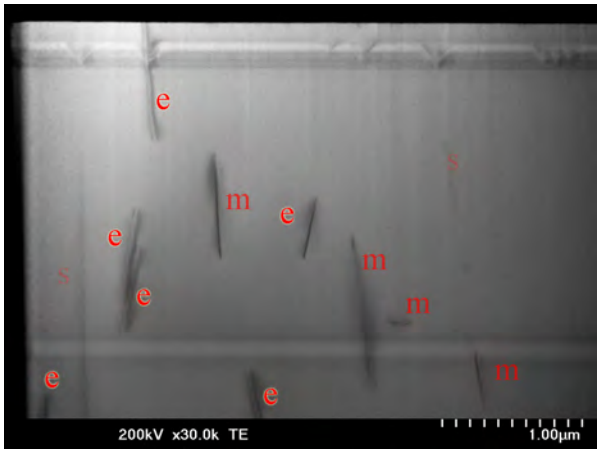

Figure 3: STEM bright field image with sample orientated to highlight edge dislocations (e-edge, m-mixed, s-screw).

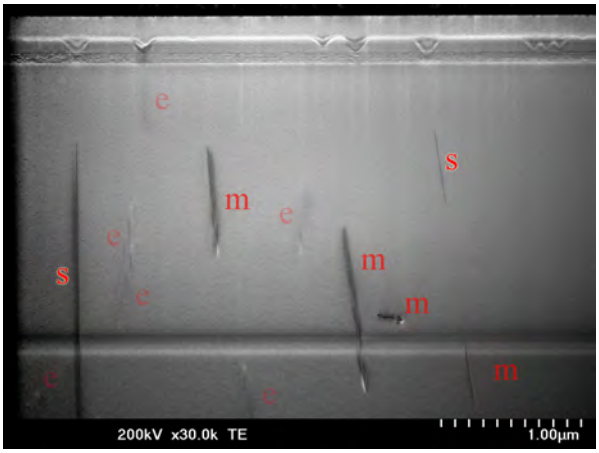

Figure 4: STEM bright field image with sample orientated to highlight screw dislocations (e-edge, m-mixed, s-screw).

1. RESEARCH CALL TO DOE/FEDERAL LABORATORIES SOLID-STATE LIGHTING CORE TECHNOLOGIES DE-PS26-09NT013775 2009, page 6

2. I. Arslan and N. D. Browning, PHYSICAL REVIEW LETTERS, VOLUME 91, NUMBER 16 2003