Correlation of x-ray excited optical luminescence and x-ray topographic defect analysis for Silicon Carbide wafers

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Silicon Carbide (SiC) is a wide bandgap semiconductor. It can be used to fabricate devices which can operate at extremely high temperatures. In addition, its wide band gap and its large electrical breakdown field together with its radiation hard abilities allow its use in harsh environments. We report on a study involving the combined use of Synchrotron White Beam X-Ray Topography (SWBXRT) and X-Ray Excited Luminescence (XEOL) to examine a selection of 4H and 6H Silicon Carbide wafers.

SWBXRT is used to image crystal imperfections (e.g. dislocations, stacking faults) in single crystal semiconductors. XEOL is a photon in-photon out energy transfer process which excites all possible radiative and non-radiative de-excitation paths. The aim of this study is to correlate SiC wafer defect types and distributions with changes in XEOL behaviour as a means of benchmarking such processes in SiC.

Each wafer was characterized by scanning two pre-chosen areas on the wafer by SWBXRT and XEOL. Radiative transition due to impurities and impurity transition associated with N (n-type 4H/6H wafers), B and Al (4H-p-type) dopants were observed in the wafers examined. For example, quite complex XEOL induced transitions in 4H n-type SiC have been identified and include, amongst others, luminescence at 390nm (possibly due to a shallow Nitrogen donor), 521 nm (donor-acceptor pair Nitrogen to Boron) and 653 nm (possibly a or V(Si) or V(C)-C(Si) related defect or intrinsic to basal plane dislocations).

The resultant images from SWBXRT were analyzed for defect density and type. These defects were mainly basal plane dislocations (BPDs) and threading screw dislocations (TSDs). Each of these images was quantified by summing the defect densities and averaging over the area. The XEOL data from one region was referenced against the other area to give a ratio of peak intensities thus highlighting the area where the XEOL signal was strongest. This was then compared to the x-ray topographic defect analysis.

Comparing the TSD densities to the overall XEOL intensity signal it was found that in 60% of the 4H-n type wafers the area with the lower TSD density on that wafer corresponded to the stronger XEOL signal. It is also worth noting that 40% of the 4H n-type wafers have TSD defect values differing by less than 16% between the two areas on the same wafer.

On the 4H-p type wafer it is noted that the stronger XEOL signals corresponds to the greater TSD defect densities on the wafer.

A complete study of eight SiC wafer types (n- and p-type, (0001) surface oriented and a-plane) is currently being undertaken.
Figure 1. Large area back reflection topograph of a typical 4H-n-type SiC wafer. Closed core threading screw dislocations (CC-TSD) and basal plane dislocations (BPDs) are indicated.

Figure 2. Example of XEOL spectra from two regions of the same 4H-n-type SiC wafer. Plot (a) is from a region with a much lower overall TSD dislocation density, an average of 500 cm\(^{-2}\) compared to 830 cm\(^{-2}\) for region (b), which has a significantly lower XEOL intensity. Note the differing scales on the two XEOL spectra.