Spatially-Resolved Ion Beam Induced Phase Transition and Defect Analysis in Gallium Oxide

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Gallium Oxide (Ga_2O_3) is a promising ultra-wide bandgap semiconductor material that has gathered significant attention due to its easy large-scale production via melt growth and its high breakdown voltage. Beta Ga_2O_3 is the most thermally and chemically stable polymorph among other polymorphs of Ga_2O_3. Unfortunately, controlling and manufacturing other phases is immature due to the metastable structure of those phases.

It has been shown that above a critical damage level (dpa), a polymorph conversion from the beta to gamma phase can be induced with the help of ion beams [1]. This conversion is independent of the used primary ion species. The formed polymorph is highly resistant against amorphization for very high damage levels up to 265 dpa. From the multi-species implantation experiments, we conclude that it is the induced strain by the defects and not the chemical nature of the implanted ions that drives the transition.

Here, we present a multi-method analysis approach to better understand and characterize the role of atomic defects before, during, and after the beta-to-gamma conversion. We use Helium Ion Microscopy (HIM) to locally irradiate Beta Ga_2O_3 substrate with Neon ions and create small structures to observe the resolution limit for phase conversion to gamma phase. Electron backscatter diffraction (EBSD) is used to confirm the successful conversions from beta to gamma Ga_2O_3. Transmission Electron Microscopy (TEM) is performed to observe the depth profile of the converted layer. We observed that with HIM controlling and inducing well-defined gamma structure is possible at the nanoscale. Furthermore, broad beam irradiated samples are prepared for Positron Annihilation Lifetime Spectroscopy (PALS) and Doppler Broadening Variable energy Positron Annihilation Spectroscopy (DB-VEPAS) to understand the defect structure during the phase transition. We see a reduction in defect concentration after the phase transition into the gamma phase, and also changes in defect size depend on implanted ion fluence. This work is supported by the state of Saxony.

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