Mechanism of damage buildup in ion bombarded compound single crystals

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Although ion bombardment of compound semiconductors has been studied extensively over the last three decades, a lack of understanding remains on the fundamental mechanism of damage buildup and amorphisation of these materials. For single element semiconductors a continuous growth of damage clusters up to amorphisation has been observed. In the majority of compound crystals structural transformations at specific fluences occur, what can be visualized as steps in a defect accumulation curve. Ion channeling is principally used in such studies. However, since this technique can hardly distinguish between different types of defects the oversimplified model of randomly displaced atoms (RDA) is usually applied and disorder accumulation model has been fitted to such data. Important step forward has been made by the recent development of the Monte Carlo McChasy simulation code, which makes it possible to distinguish between RDA and extended defects producing long range lattice distortions. It has been clearly shown that in compound crystals the growth of extended defects (dislocation, dislocation loops, etc.) upon ion bombardment and their role in defect transformations are by no means negligible. Moreover, the complementary techniques like high resolution X-ray diffraction (HRXRD) and high resolution TEM (HRTEM) have provided important data that are indispensable for elucidation of the mechanism of damage growth and defect transformations. HRXRD allows to follow the strain evolution in the bombarded materials whereas HRTEM reveals the structure of defects responsible for such an effect.

Recently detailed study on damage buildup has been performed for GaN. Three step damage accumulation process has been revealed. HRXRD analysis has indicated that ion bombardment to low fluences leads to strain buildup in the implanted region. Once the critical value of stress has been attained a plastic deformation due to the dislocation slip occurs and lead to the formation of dislocations tangle. The transition to the stage III – amorphisation – takes place at high impurity concentration and is apparently due to the defect-impurity interaction. Similar behavior has also been observed for ZnO crystals. Extended study on this process in a variety of oxide single crystals ($SrTiO_3$, ZrO_2, spinel, and powellite) by French-Polish group clearly indicated that also in these materials strain-mediated defect transformations occur.

The essential experimental data on a variety of compound crystals will be reviewed and the defect transformation models will be discussed. This allows the conclusion that microstructure transformations driven by the lattice strain leading to the multistep damage accumulation is a typical phenomenon in ion bombarded compound single crystals. Some consequences of this model for practical applications will also be presented.