Janson, M.S., Hydrogen diffusion and ion implantation in silicon carbide
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Abstract

Secondary ion mass spectrometry (SIMS) has been employed to study the spatial distributions resulting from mass transport by diffusion and ion implantation in single crystal silicon carbide (SiC). By a systematic analysis of this data, fundamental processes that govern these phenomena have been derived.

The acceptor atoms Al and B are known to be electrically passivated by H in SiC. By studying the thermally stimulated redistribution of implanted deuterium (^{2}H) in various acceptor doped structures, it is found that hydrogen forms complexes with the doping atoms, and also interacts strongly with implantation induced defects. A comprehensive understanding of the formation and dissociation kinetics of these complexes has been obtained. The extracted effective capture radius for the formation of ^{2}H-B complexes is in good agreement with that expected for a coulomb force assisted trapping mechanism. The large difference of 0.9 eV in the extracted dissociation energies for the ^{2}H-Al and ^{2}H-B complexes suggests that the atomic configurations of the two complexes are significantly different. Furthermore, by studying the migration behavior of H in the presence of built-in electric fields, it is concluded that all of the mobile H is in the positive charge state in p-type SiC.

A large number of implantations have been performed with respect to ion mass, energy, fluence, and crystal orientation. The electronic stopping cross sections in the low velocity regime for ions with atomic numbers $1 \leq Z_1 \leq 15$ have been extracted from the ion range distributions. They display both Z_1-oscillations and a smaller than velocity proportional stopping for ions with $Z_1 \leq 8$, in agreement with previous reports for other materials. Furthermore, the degree of ion channeling in various major axial and planar channels of the 6*H* and 4*H*-SiC crystal has been explored. Two types of ion implantation simulators have been developed. One based on a statistical, data-base approach, and one atomistic simulator, based on the binary collision approximation (BCA). By fitting BCA simulated profiles to the experimental profiles, detailed information about the electronic stopping and implantation induced damage is extracted. In addition, the vacancy-related damage caused by the implantations has been investigated by positron annihilation spectroscopy (PAS). Two types of implantation induced positron traps have been isolated and are tentatively identified as a Si vacancy (V_{Si}) and a Si-C divacancy ($V_{Si}V_C$). The extension of detected V_{Si} is in good agreement with that predicted by BCA simulations, and for implantations with heavier ions V_{Si} are revealed at far greater depths than the mean projected ion range due to deeply penetrating channeled ions.