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P-type 4H-SiC by Al Implantation and subsequent Annealing - Simulation, characterization and device design development

P-type doped 4H-SiC with very low resistivity is still one challenging technology in semiconducting fields. It is well accepted that p-type doping of 4H silicon carbide (SiC) by Al implantation and subsequent annealing results in free charge carrier concentrations which are significantly below what would be expected from activated and ionized Al concentrations. This is commonly explained by so-called compensating defects induced during the implantation process and which remain after annealing. Here, the experimentally determined compensation ratio (i.e., the ratio of defect concentration to activated Al concentration) is increasing with decreasing Al concentration. Obviously, this compensation significantly hinders the fabrication of todays and future SiC electron devices where both, fabrication of regions with moderate p-doping concentrations (such as p-well regions or junction determination structures) where accurate concentrations are required as well as regions where very high doping concentrations (e.g., ohmic contacts) are required.

In this talk, Molecular Dynamics (MD) simulations, Raman spectroscopy and sheet resistance measurements were used to study the preparation processes of low-resistance p-type 4H-SiC by Al ion implantation with ion doses of 2.45×10^{12} - 9.0×10^{14} cm^{-2} and annealing treatment with temperatures of 1700 - 1900 °C. Greatly different from the LOPC (longitudinal optical phonon-plasmon coupled) Raman mode found from the sample of doping 4H-SiC during epitaxial growth, no significant influence on the surface concentration could be found for the longitudinal optical (LO) mode of Al-implanted 4H-SiC samples. When the Al surface concentration is larger than around 1018 cm^{-3}, it was found that the intensity of the LO+ Raman peak (~ 980 - 1000 cm_{-1}) increases and its full width at half maximum (FWHM) drops with the increase of surface concentration after annealing treatment. Moreover, for surface concentrations above 10^{18} cm^{-3}, the LO+ Raman peak showed a left shift towards the LO peak, which could be related to the increase of free carrier concentration in the Al-implanted 4H-SiC samples. After higher annealing temperatures of 1800 °C and 1900 °C, the crystallinity of Al-implanted 4H-SiC was found to be improved compared to annealing at 1700 °C for surface concentrations larger than 10^{18} cm^{-3}, which is consistent with the results of sheet resistance measurements.

Speaker Biography

Zongwei Xu, Dr. Engineering, has his expertise in Micro/nano Manufacturing and Metrology. He was one of the pioneers of Micro/nano Functional Structures Fabricated using Ion Beam Machining. He has illustrated the Multi-parameters' Coupling Mechanism involved in nanoscale effects and developed several methodologies using Ion Beam Nanofabrication. Several functional structures, including Siemens Star Metrology template and Photomask Template in nanolithography, have been developed and applied in Erlangen-Nuremberg University, Germany, Mitutoyo Research Center Europe and Chinese Academy of Sciences. More recently, he has conducted Activation of 4H-SiC p-type Doping by Al Implantation and Subsequent Annealing - Simulation, Characterization and Device Design Development. He is author of over 60 papers, 6 book chapters on Micro/nano Manufacturing and owner of 12 patents. He was the recipient of several Awards, including "Newton Fund" granted by the Royal Society, "Young Researchers" Awards (the 14th China-Japan International Conference on Ultra-Precision Machining Process (CJUMP2018), and the 3rd Asian Precision Engineering and Nanotechnology International Conference (ASPEN2009)). He was the Associate Editor of Journal of Mechanical Engineering Science, Guest Editor of Current Nanoscience, and the Editorial Board Member of three International Journals.

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