Ion beam modification of crystalline materials for optoelectronic application

A. Macková[1,2*], P. Malinský[1,2], A. Jagerová[1,2], Z. Sofer[3], P. Nekvindová[3], J. Cajzl[3], K. Klímová[3], J. Lorinčík[4], R. Böttger[5], S. Akhmadaliev[5]

[1]Nuclear Physics Institute of the Academy of Sciences of the Czech Republic, v. v. i., 250 68 Rez, Czech Republic
[2]Department of Physics, Faculty of Science, J.E. Purkinje University, Ceske Mladeze 8, 400 96 Usti nad Labem, Czech Republic
[3]Department of Inorganic Chemistry, Institute of Chemical Technology, 166 28 Prague, Czech Republic
[4]Research Centre Rez, Hlavní 130, 250 68 Husinec-Řež, Czech Republic
[5]Institute of Ion Beam Physics and Materials Research, Helmholtz Zentrum Dresden-Rossendorf, 01328 Dresden, German

Doping and dopant diffusion control in GaN is not only important for green to ultraviolet (UV) light-emitting diodes, lasers, and detecting devices but also for high-frequency, high-temperature, and high-power electronic devices. Ion beam implantation is very powerful, versatile and unique technique enabling creating of supersaturated layer and by changing the implantation parameters tuning the optical and electrical properties. It has been found that the ion-beam-induced processes in various crystallographic orientations influence the defect accumulation, which is closely connected to the optical and electric properties of the films. An attempt was be made in this study to coax the optical properties of various crystallographic orientations to enhance the understanding about the interaction of implanted specie with the crystalline substrate. The various crystallographic orientations in semiconductors as ZnO, GaN exhibit different resistivity under the ion beam irradiation/implantation and study of various crystalline orientations is mandatory for the nano-structured semiconductor systems, as they exhibit several facets which are modified during ion beam implantation. It has been shown that ZnO exhibit strong dynamic annealing i.e., migration and interaction of ion-beam-generated defects during ion irradiation and much lower surface damage accumulation comparing to GaN. Structure, morphology, and optical properties of Gd, Er, Au, implanted GaN and ZnO, layers and bulk crystals were studied in a-, c- and m-plane using the distinct ion energies from 200 keV to 5 MeV. Dopant depth profiling was accomplished by Rutherford Back-Scattering spectrometry (RBS). Structural and optical changes during subsequent annealing were characterized by RBS, Raman spectroscopy, and photoluminescence measurements. Surface morphology was investigated by AFM and Scanning Electron Microscopy. Post-implantation annealing induced a structural reorganization of crystal structure in the buried layer depending on the introduced disorder level, i.e. depending on the ion implantation fluence and on crystallographic orientation. The defect density depth distribution was evaluated by RBS. The surface morphology and optical properties depend on particular crystallographic orientation.

[*]Corresponding author, Email: mackova@ujf.cas.cz