Renata Ratajczak
Reg. No: 2022/45/B/ST5/02810; Principal Investigator: dr Renata Katarzyna Ratajczak

"Comprehensive approach to the studies of gallium oxide implanted with rare-earth ions for future optoelectronic device applications"

Nowadays, material research is driven by new technologies that aim to improve existing materials and replace them with cheaper and more efficient equivalents. Since several decades, the semiconductor compounds technology fits in perfectly with this trend. Such technology is irreplaceable for optoelectronic applications such as lasers, displays, or white LEDs, where silicon cannot be used due to its indirect and not very wide-bandgap.

Gallium sesquioxide (in its thermodynamically stable β-Ga_2O_3 phase) is a transparent conductive material with a wide bandgap of about ~4.9 eV, considerably larger than other transparent conducting oxides. Recent works have demonstrated a significant potential of this semiconductor for optoelectronic and electronic applications, mainly for high power devices, light-emitting diodes (LED), lasers, transparent 'intelligent' windows, and solar cells. Moreover, the wider bandgap is the reason for the increased both thermally and chemically robustness, which makes such material less prone to aging and ideal for radiation-intense space applications or military systems. Furthermore, with the development of the production the large single crystals β-Ga_2O_3 as well as the possibility of growing thin β-Ga_2O_3 films, this material became a perspective for low-cost fabrication possibility with the industrial-scale applications.

The basic light emission from β-Ga_2O_3 is located in the ultraviolet spectral range, but it can be tuned into the visible region by the rare-earth (RE) ions doping. β- Ga_2O_3 is an excellent host material for rare earth (RE) ions as it allows the most efficient and intense luminescence from the dopant due to its widest bandgap. Doping Ga_2O_3 with RE during the growth process is challenging due to the low solubility limits in the beta phase, which often leads to segregation and secondary phases. An alternative method of doping is ion implantation. Despite the many advantages, an important limitation of this technique is the buildup of lattice disorder due to the ballistic nature of the process. Structural defects quench the luminescence and adversely affect the lifetime of devices based on such material. Thus, thermal annealing aimed at the recovery of implanted materials is required. This, in turn, can lead to defect interactions, clustering, and other phenomena. **Therefore the knowledge of the fundamental properties of different RE ions in the β-Ga_2O_3, the nature of defects formation, and the mechanism of their transformations are crucial for further possible applications as efficient monochromatic light source emitters that would have been operated even under hard conditions.**