Obtaining and characterisation of novel gallium-containing wide-band-gap oxides for optoelectronics

The primary objective of the project is to explore pseudoternary oxides formed in the Ga_2O_3-Al_2O_3-In_2O_3 and Li_2O-Ga_2O_3-In_2O_3 systems with the focus on the monoclinic $(Ga\text{-}Al\text{-}In)_2O_3$ and spinel-type $Li_{1\pm\delta}(Ga\text{-}In)_5O_8$ compounds occurring within these systems.

The choice of the objects for research is driven by recent advancements in understanding the relationship between composition, structure and physical properties of gallium oxide-based alloys. These insights enable customising these compounds for optical and electronic applications. In this regard of particular interest is the simultaneous alloying of the monoclinic gallium oxide (β-Ga_2O_3) with aluminium and indium oxides, resulting in the formation of pseudoternary $(Al_xIn_yGa_{1-x-y})_2O_3$ compounds. This potentially opens up even greater pathways for tailoring the properties of β-Ga_2O_3.

The interest in the ternary system Li_2O-Ga_2O_3-In_2O_3 is inspired by recent findings indicating that the ultra-wide bandgap Ga-containing oxide, namely $LiGa_5O_8$ spinel, exhibits *p*-type conductivity at room temperature. This remarkable property positions it as the widest bandgap *p*-type oxide semiconductor known to date, sparking significant interest. The project aims to explore the possibility of tuning the electrical and optical properties of this material by changing Li stoichiometry as well as by alloying with indium oxide.

The project incorporates several innovative approaches including: (i) tuning the physical properties of the materials by deviating their chemical composition from stoichiometry and alloying with related chemical elements, (ii) investigating the alloyed compounds that appear highly promising yet remain unexplored, (iii) utilization of advanced techniques, such as the spark plasma sintering (SPS) and the high-pressure high-temperature (HPHT) pressing, to produce transparent (translucent) bulk materials which are highly sought for optoelectronic applications.

The proposed project combines forces of physicists and material scientists from the Institute of Physics of the Polish Academy of Sciences (IPPAS) and technologists and material scientists from the Łukasiewicz Research Network – Krakow Institute of Technology (Łukasiewicz KIT) on the way to creating new promising materials with enhanced properties. The wide range of practical applications of such materials for optoelectronics, especially for high-power electronics and solar-blind UV detection, underlines the significance of such research.

The main impact of the proposed project consists of: (i) a better understanding of the fundamentals of optical and electronic properties of the Ga-containing wide-band-gap oxides, (ii) an exploration of the possibilities to tune physical properties of the materials by deviation of their chemical composition and alloying with related chemical elements, (iii) obtaining and characterization of novel Ga-containing oxides of extended properties, and (iv) evaluation of the feasibility of their application for high-power electronics, solar-blind UV detectors or long persistent luminophores. Most important is that, if the *p*-type conductivity of $Li_{1\pm\delta}(Ga\text{-}In)_5O_8$ bulk compounds is confirmed, it will open up completely new opportunities for creating polar semiconductor devices for high-power electronics. In any case, the implementation of the project proposed will provide a solid basis showing the possibility of improving the functional properties of the Ga-containing wide-band-gap semiconductors under study. This, in turn, will give a strong impetus to the further development of these materials and their practical use to create new optical and electronic devices with enhanced properties.