Present situation in semiconductor industry is often described half-jokingly as „GaNification" because the compounds of GaN-InN-AlN are revolutionizing many applications. White LEDs are being manufactured in hundreds of millions pieces creating a market worth of about Eur 20 billion, blue and green laser diodes are being introduced in new generation projectors of unprecedented colour and resolution quality. Moreover, nitride emitters are used in many niche markets- in quantum tech (atomic clocks, gravity sensors, cryptography), for copper and gold welding, and many others. Because of COVID-19 pandemia, AlGaN-based LEDs UVC attract a lot of interest. These ultraviolet emitters eliminate not only viruses, but also bacteria and fungi. Nitrides are not only optoelectronic materials- they are also used for constructing transistors of high frequency and high power applied in new generations of radars, electric vehicles and photovoltaic cells.

In contrast to other semiconductors as Si, Ge, GaAs or InP, nitrides are very difficult to be grown and to be processed. The main reason of that situation is a necessity of growing nitride crystals and layers at temperatures much lower than their melting points. At low growth temperature, a large amount of defects are created, in particular, these are metal (Ga, In or Al) vacancies which are the subject of this Project.

Vacancies in nitride semiconductors influence significantly many parameters important for functioning of LEDs, laser diodes and transistors. Vacancies and their complexes with impurity atoms lower the effectiveness of current/light transformation and make diffusion of atoms during device operation much easier. The latter lowers the life time of these devices.

Examinations of vacancies are very difficult because they are not visible in standard analytic methods used for semiconductor characterization: electron microscopy, X-ray Diffraction or Atomic Force Microscopy. In luminescence measurements, so called "yellow luminescence" in GaN is attributed to gallium vacancies, however, it is also related to the presence of carbon impurities. Moreover, luminescence does not provide a quantitative information. The only reliable method of detecting and quantification of metal vacancies in nitrides is Positron Annihilation Spectroscopy (PAS).

This method is used in only few laboratories worldwide and in this Project is planned to be a main one. The PAS examinations will be done in Charles University (Prague, the Czech Republic) by the group of prof. Cizek. Samples will be grown using Metalorganic Chemical Vapour Phase Epitaxy (MOVPE) in the Institute of Physics Prague and in the Institute of High Pressure Polish Academy of Sciences (IWC PAN). MOVPE method has several growth parameters which are not independent to each other- therefore, there is no chance to test all possible parameter combinations. Layers of GaN, AlGaN, InGaN, AlGaInN will be differently doped, will have different concentrations of extended defects (dislocations) and will be grown at different temperature, pressure and in different flows of reactants. The samples will be characterized using different methods with respect to their optical, electrical and structural properties. The results of these examinations will be confronted with the PAS results, what will enable us to understand how metal vacancies are created and how they influence the parameters of the nitride-based devices.

Institute of Physics in Prague is mainly devoted to the research related to nitride-based ionizing radiation detectors. The research of IWC PAN has been so far focused on blue and green laser diodes, but next steps planned are technologies of LEDs UVC and cells for hydrogen generation by light-induced water splitting. The common Project should lead to much faster development of these technologies.