Nitride semiconductors, i.e. gallium nitride (GaN), indium nitride (InN), aluminum nitride (AlN), and their AlInGaN alloys, are a group of materials well-known for their applications in electronic and optoelectronic devices. These devices are widely used in many fields from medicine through ecology up to defense. They are needed to master not only the technical but also social challenges of the 21st century. They can be used to meet the increasing global demand for modern mobility and information technology in a more energy-efficient way.

Most of the nitride-based structures are built on foreign substrates (sapphire, silicon, silicon carbide) covered with a thin (few hundred nanometers to a few micrometers) layer of nitride. Such substrates are called templates. Currently, there is a focus on replacing the foreign substrates with GaN and AlN ones. To operate at their full potential, these devices require epitaxial layers with a low dislocation density and smooth interfaces. This is especially mentioned in terms of high-power transistors, UV light emitting diodes or laser diodes. Due to their design, they should be built on a native nitride foundation of very high structural quality. In order to realize devices based on AlGaN, high quality native AlN and AlGaN substrates are needed. AlN wafers of high quality are already commercially available. Bulk crystals are grown at extremely high temperature (~2400°C) by physical vapor transport (PVT) method. In turn, bulk GaN crystallization is realized mainly by growth from the vapor phase (HVPE method) at much lower temperature (~1000°C). Thermodynamic stability of GaN is lost at 800°C in atmospheric pressure. However, in HVPE technology (at atmospheric pressure) NH_3 ensures the thermodynamic stability of GaN at around 1000°C. This temperature is too low for an effective AlN crystallization process but it is sufficient for the crystallization of AlGaN. **Nevertheless, crystal growth process of bulk AlGaN has never been demonstrated. It is still a big challenge for basic research as well as for technology.**

The main goal of this project is to investigate the crystallization process of thick layers of aluminum gallium nitride (AlGaN) by HVPE method and demonstrating, first time in the world, a free-standing AlGaN crystal of very high structural quality. Gallium nitride (GaN) seeds of the highest structural quality will be used in the crystal growth processes. The deposited AlGaN layers, up to 300-µm-thick, should be crack-free with a uniform Al composition reaching 30%. They are necessary for fabricating 300 nm UV emitters.

Growth of HVPE-AlGaN will be performed at temperature of the order of 1100°C. Before the crystallization processes a computational optimization of the HVPE reactor growth zone as well as growth parameters will be carried out. Fluid dynamics will be applied for this purpose. The goal is to define an optimal configuration of the growth zone in order to obtain a uniform concentration of reactants ($AlCl_3$, GaCl and NH_3) as well as appropriate supersaturation on the crystal's surface. This will ensure the growth of homogeneous (in terms of composition) AlGaN layers. Influence of temperature, pressure, ratio of used precursors ($Ga/Al/NH_3$), and reagents flows on composition, morphology, structural quality, and growth rate of AlGaN will be examined. GaN seeds with different polarity will be applied. In order to avoid stress between the crystallized layers and the seeds, the letters ones with proper lattice parameters (close to those of AlGaN) will be selected. In particular, crystallization processes with gradually increasing content of Al in the AlGaN layers are planned. An innovative multi-step growth procedure will be explored in order to minimize the impact of the lattice mismatch between GaN and AlGaN. After an HVPE process, the sample will be analyzed (the Al content will be determined) and its surface will be prepared for the next crystallization run. Additionally, the GaN seed will be partially removed mechanically after each AlGaN growth process. **This procedure is absolutely innovative and will allow to obtain an AlGaN crystal without any cracks.**