The rapid pace of technological advancement in recent years has ignited optimism and fueled bold visions of a future where humans can rely on increasingly intelligent systems. However, these ideas and concepts, often explored in science fiction or theoretical designs, would be meaningless without a solid foundation of experimental research and real materials that exhibit the desired properties. These materials are the building blocks of functional systems, from smartphones and computers to entire spacecraft. New materials are, therefore, the undeniable foundation of new technologies, and enabling research into them and developing large-scale production methods should be one of the primary goals of modern science. This is also our goal. Within this project, we will focus on researching and developing new methods to enhance the future material, two-dimensional boron nitride (BN).

At the Faculty of Physics, University of Warsaw, we have been conducting research on two-dimensional boron nitride for over a decade. This material, composed of hexagonal rings of alternating boron and nitrogen atoms, possesses extraordinary properties such as exceptional resistance to external conditions (chemical, temperature), a bandgap of around 6 eV, and flexibility. These attributes make it an ideal material for various applications, including ultraviolet light sources, insulating barriers, substrates for the growth of other 2D materials, neutron detectors, water filters, and more. New applications are continually being proposed, and their realization requires the development of efficient and reproducible methods for producing large quantities of this high-quality material.

The goal of this project is to conduct a series of homoepitaxial processes using Metalorganic Vapor Phase Epitaxy (MOVPE) on flakes exfoliated from bulk material and to thoroughly examine the resulting samples. This idea is innovative in itself, as apart from our group's work, there are no other reports of such processes being conducted in other laboratories. Homoepitaxy of gallium nitride yielded excellent results years ago. It improved the optical quality of the epitaxial material – exciton lines narrowed from meV to single μeV, and various epitaxial growth techniques are still used today in the production of ultraviolet lasers. Our primary objective is to achieve the same success for boron nitride. A key innovation in this research will be the use of flakes with isotopically pure boron ^{10}BN as substrates. Due to the differing characteristic vibration energy compared to natural BN, it will be much easier to distinguish the epitaxial material from the flake substrate in Raman measurements. This will allow us to unequivocally determine what we managed to grow during the process and how the flake itself behaved. Did it change under the influence of high temperature and reagents, did it start to etch or grow on sapphire beyond its boundaries, maintaining better quality? Another new idea is to structure these flakes to obtain different thicknesses, cutting angles, and shapes. This, in turn, will allow us to check whether an individual flake – its shape and thickness – can influence the properties of the boron nitride growing on it. Preliminary studies indicate that, among other things, it is possible to control the polytype in this way, and thus the ferroelectricity or piezoelectricity of such a structure.

Samples produced as a result of homoepitaxial processes will be thoroughly characterized using atomic force microscopy (AFM), X-ray diffraction (XRD), scanning electron microscopy (SEM), and Raman and ultraviolet photoluminescence spectroscopy. Through this research, we will determine: 1. Whether we can control growth through flake patterning to obtain specific BN properties? 2. Are flakes capable of nucleating growth also on sapphire and improving the quality of the epitaxial material on the entire substrate? 3. Does studying the simple case of BN/BN homoepitaxy allow us to understand the growth mechanisms and apply this knowledge in more complex heteroepitaxial processes, such as BN/Al_2O_3 growth? The answers to these questions, in addition to explaining the not fully understood epitaxy of layered materials, will bring us significantly closer to transferring BN growth technology from research laboratories to the "production line."