The goal of the following proposal is to prepare a thick highly conductive (n-type) gallium nitride (GaN) single crystal using germanium (Ge) as a donor dopant in halide vapor phase epitaxy (HVPE). N-type GaN substrates are used for the production of electronic or optoelectronic devices such as high-power transistors and laser diodes. In the case of vertically operating devices (GaN-on-GaN technology) it is crucial that the wafers are of high electrical conductivity and high structural quality.

In order to crystallize HVPE-GaN of high structural quality, native seeds prepared by ammonothermal method are used. To increase the free carrier concentration in HVPE-GaN, the most commonly applied donor is silicon (Si). However, the usage of Si comes with a series of problems and disadvantages. In this project Ge, the other popular donor dopant for GaN, is proposed as an alternative for Si. Currently the most important difficulty in growth of HVPE-GaN doped with Ge is the stress appearing on the interface between the grown layer and the used ammonothermal seed crystal. The reason for this is the difference in the lattice constants of the seed and the HVPE-GaN. As a result, cracks start to appear in the seed when the thickness of the grown layer reaches around 500 µm. The work proposed in this project should overcome this obstacle and result in thick and uniform HVPE-GaN of high structural quality doped with Ge.

To enable growth of a layer with the desired thickness (~1 mm) it is crucial to reduce the stress on the layer/seed interface. Multiple HVPE growth procedures will be employed on the selected seeds according to the following scheme: the Ge precursor flow (germanium tetrachloride; $GeCl_4$) in each growth run will be increased gradually and the seed crystal will be partially removed by polishing after each process until being removed completely. The HVPE process will be repeated with an increased Ge precursor flow until the desired Ge concentration is reached on the (0001) plane of the grown crystal. As a last step, this crystal will be used as a seed for crystallization of a thick and uniform, in terms of Ge and free carrier concentrations, HVPE-GaN:Ge layer. The seed will be removed and a free-standing and thick HVPE-GaN:Ge crystal will be demonstrated. An example of an HVPE-GaN:Ge crystal is presented in Fig. 1.

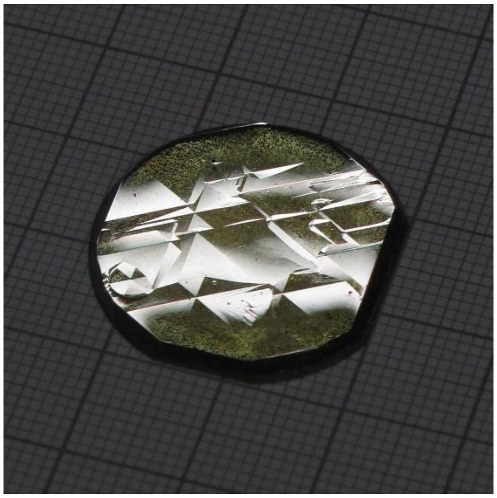

Fig. 1 Image of as-grown 500-µm-thick HVPE-GaN:Ge layer crystalized on a native ammonothermal seed.