The project objectives: The goal of the project is to study the mechanisms of defects creation in gallium nitride (GaN) layers. Three types of GaN materials will be analyzed in the project: (1) as-grown, (2) carbon doped and (3) irradiated with electrons. At the same time, we believe to assess the impact of defects on the physical properties of these structures such as: structural, electrical and optical. Our work will be mostly focused on defects related to carbon, gallium and nitrogen vacancies and their combination. Nitride semiconductors family is now considered as a second, just after silicon, type of semiconductor in terms of investment in research and applications. In contrast, nitrides still suffer from the lack of a complex understanding of the mechanisms of defects creation and their impact on the material properties.

Motivation: Fig. 1 shows a piece of the mature corn cob (left hand side) and a piece of the cactus tree (right hand side). In the case of corn cob, one can observe two types of stacking faults: 1) excess corn causing "compression" of the other grains in the closest vicinity, and 2) the lack of corn grain leading to forming a gap called vacancy. In the latter case, one can observe some changes in the shape of longitudinally extending cactus ribs. Stacking faults seen in a case of corn are typical point defects while those observed in the cactus are examples of so-called extended defects. All crystals existing in nature can be somehow compared to described above corn cob wherein instead of uniformly distributed grains, specific atoms are placed. Gallium nitride is a binary material and it consists of nitrogen and gallium atoms, mixed in a specific pattern called wurtzite structure. Other nitride semiconductors are formed in a similar manner where gallium is replaced fully or partially by indium or aluminum. In general, defects in semiconductors are undesirable objects because they affect on their electrical and optical properties. The most common forms of defects in crystals are point defects such as: lack of atom in the network node, interstitial atom or the presence of foreign atoms in the structure (i.e, carbon). Besides point defects, there exists also so-called extended defects. The most common form of extended defects are dislocations, which are the result of stress relaxation occurring in the crystal. There are many reasons why defects occur in nitrides. One of the major reason is the growth of crystals and epitaxial structures far away from the thermodynamic equilibrium, ie. commonly, nitrides crystallize at extremely low temperature. The second reason is the difficult access to high-quality lattice-matched substrates (native GaN substrates), which forces the growth of structures on substrates with high lattice mismatch: mainly on sapphire and silicon. This fact causes very high stresses presence in overgrown layers and consequently a large number of defects and dislocations. Institute of High Pressure Physics Polish Academy of Sciences (IH PAS) dispose an innovative technology for high-quality GaN substrates fabrication using a hydride technique commonly known as HVPE as well as ammonothermal growth of highly conductive GaN substrates. The crystals obtained with these technique are one of the best substrates available in the world today. Mostly, due to the ultra-high purity and a world class record in terms of low dislocation density. For the reasons mentioned above, it is very important that grown structures should be free of point defects and dislocations. To control the formation of defects in nitrides one need to understand what mechanisms determine their creation what is the main goal of the project. Especially, vacancy and carbon-related defects are of high importance since can effectively compensate the conductivity of GaN making the material less conductive.

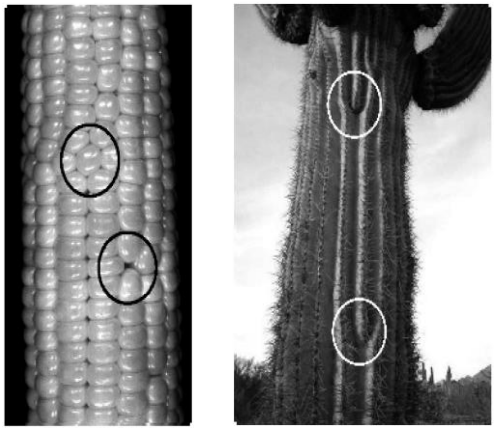

Fig.1. *The examples of natural imperfections observed in nature presenting idea of defects in solid crystals. Source: Semiconductor Material and Device Characterization, D.K.Schroeder, 2006*

Description of fundamental research to be realized in the project: Implementation of the project posed to be proceeded by creating a specially designed epitaxial structures (in different growth conditions) and to perform a variety spectrum of basic research. The most important will be the study of phenomena of charge carrier (electrons or holes) emission and capture from defect state which is introduced to the forbidden bandgap by defects. On the basis of such research, one can obtain a variety of defect parameters such as i.e.. their number per volume unit, ease of trapping and the energy level position.

The samples analyzed in these studies will form the series differs from each other by the GaN-substrates used for growth, deposited layers and the conditions under which structures were grown. The key growth parameters (fingerprints) include: temperature, pressure and the amount of chemicals which follows further growth. Last but not least, the impact of carbon doping, thermal annealing as well as electron irradiation impact on defects formation will be analyzed and verified. All these factors will cause the formation of various types of defects which parameters can be correlated to the conditions in the growth chamber. The informations obtained in these studies will significantly broaden the current state of the knowledge about the defects and the mechanisms of their formation in nitride structures.