SUMMARY

„Piezotronics effects in AIIIN devices"

Nitrides of the third group of the periodic table are one of the most important materials in modern electronics. For more than 20 years, they have been intensively researched in order to improve the parameters of devices fabricated in them and to find new areas of application. Nitride heterostructures are used both to manufacture electronic devices, such as microwave transistors and high-power transistors, as well as optoelectronic devices (diodes and UV/DUV lasers). AIIIN materials are also, due to their crystallographic structure, piezoelectric. The piezoelectric effect can be used to produce passive acoustic elements and to construct sensor elements. Traditionally, the design of each type of devices, such as diodes and transistors or elements using the piezoelectric effect (e.g. piezogenerators, SAW transducers) is carried out using different, specialized research and simulation methods dedicated to a given type. Piezotronics seeks to unify these areas, both to optimize the performance of already existing devices and to develop completely new designs that simultaneously exploit the semiconductor and piezoelectric properties of AIIIN materials.

The aim of the dissertation was to investigate the relationship between static and dynamic stress fields in AIIIN structures and the operation of electronic devices fabricated in them. Nitride heterostructures deposited by Metalorganic Vapour Phase Epitaxy (MOVPE) on sapphire substrates were studied. In the process of fabrication of the experimental structures, classical device processes compatible with the AlGaN/GaN High Electron Mobility Transistor (HEMT) fabrication technology were applied. Specialized device structures such as: AlGaN/GaN heterostructures with van der Pauw structures for Hall measurements, AlGaN/GaN Schottky diodes and various variants of interdigital transducers, as well as systems simulating the gate operation of HEMT transistors made in AIIIN layers and heterostructures were fabricated and examined. Luminescence measurements, DC characteristics measurements and microwave transmission and reflectance measurements were carried out on them. The results of measurements were compared with the results of simulations performed in COMSOL Multiphysics and APSYS environments using the finite element method. Both electrical and quantum effects as well as mechanical stress distribution and acoustic wave propagation were simulated. An in-house implementation of the matrix methods was created to accurately analyze thin-film systems. The results of the analysis were related to existing literature on the subject.

The results obtained have shown that when designing nitride semiconductor devices, it is necessary to consider the occurrence of static and dynamic stress states, which significantly affect the performance of the devices manufactured in them. Additionally, the current state of knowledge on the generation and propagation of bulk and surface waves in AIIIN multilayers deposited on sapphire is comprehensively reviewed. A novel application of surface waves for non-destructive diagnostics of epitaxial nitride layers is proposed.

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