Electronic phenomena at GaN-based interfaces studied by electromodulation spectroscopy

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Abstract

This doctoral dissertation is a series of four publications on the study of electronic phenomena on gallium nitride (GaN)/air, GaN/van der Waals crystal and GaN/perovskite interfaces via electromodulation spectroscopy methods, in particular contactless electroreflectance. The investigation of carriers behavior on GaN surface and its interface with emerging materials is a main problem tackled for in this work.

The first chapter states a compact introduction into the subject and investigated materials. After that, in the main part of the dissertation, four chapters corresponding to the following ones publications, are presented.

In the second chapter, being an introduction to the methodology, the influence of the photovoltaic effect on the electric field built-in at GaN surface is examined. The optimal measurement conditions for future experiments are determined and the architecture of structures with controlled distribution of the built-in electric field is explained, since they are a platform for research presented in further works.

The third chapter presents the investigation of h-BN/GaN interface. Through insightful analysis it is shown that h-BN induces an increase of the surface barrier height at GaN surface, what points to the shift of surface Fermi level deeper inside GaN bandgap. It is explained by the electron transfer from GaN surface states to the native acceptor states in h-BN. These findings are also reinforced by the demonstration of the h-BN/GaN Schottky diode.

The fourth chapter focuses on the examination of $MAPbI_3$/GaN interface, where MA = $CH_3NH_3^+$. The dependence of the direction of carrier flow across this interface on the surface Fermi level position in GaN is shown. What is more, the fast, simple, self-powered and broadband $MAPbI_3$/GaN-based photodetector is presented.

In the fifth chapter the robust high-temperature dependence of GaN surface densities of states is reported. A comprehensive case study including GaN, GaAs, graphene/GaN and h-BN/GaN hybrids points to the mechanism of temperature-induced carrier redistribution at GaN surface to be responsible for observed phenomenon.

As a result, in this dissertation, the hypothesis stating that methodology combining the utilization of GaN structures with controlled distribution of the built-in electric field and contactless electroreflectance spectroscopy is fully applicable to study the carriers behavior at GaN surface and interfaces with van der Waals crystals and perovskites, that hold great promise for the future of optoelectronics thus are in the center of interest of both scientific and commercial entities.