Surface functionalization of p-(Al)GaN with MXenes – contact engineering for efficient deep UV emitters

Deep ultraviolet light emitting diodes (DUV LEDs) based on Al-rich AlGaN materials have many advantages over mercury lamps still widely used nowadays: low toxicity, small size, long working time, no heating time and low operating voltage. The only drawback of such devices is the low emission efficiency, which arises from such factors as high threading dislocations density in AlGaN layer or low hole concentration of p-AlGaN layer. Another challenge involves finding the right material for p-type contact layer, which would be transparent to UV light and exhibits low resistivity. Currently, p-GaN and p-AlGaN are the materials employed for the contact layer in DUV LEDs. Unfortunately, p-GaN is characterized by strong UV absorption. While the use of p-AlGaN enhances light extraction efficiency, it leads to poor contact parameters and shorter device lifetime. For p-AlGaN contact layer it is necessary to use a p-electrode material with high work function in order to obtain ohmic characteristics of the contact. Commonly used electrodes such as Ni\Au or Ni\Al have high forward voltages, which generate heat and consequently reducing the lifetime of the LED. Furthermore, the large lattice mismatch between GaN and most of metal electrodes leads to an appearance of the discontinuous metal/semiconductor interface with the lattice distortions and interfacial defects.

On the other hand, recently emerged the new type of 2D materials called MXenes, which have many unique properties, such as metallic conductivity, mechanical flexibility, good transmittance and chemical stability. These properties makes them suitable for use as electrodes in optoelectronic and electronic devices. The literature overview indicates that previous studies focused mostly on integration of $Ti_3C_2T_x$ MXene films with (n/p)-GaN. Hence, it is worth noting that no experimental works on the combination of other MXenes with p-AlGaN material have been published to date.

The integration of p-AlGaN with MXenes (exhibiting high work function) and its influence on the electrical properties such as hole concentration, sample resistivity and I-V characteristics will be the subject of this research. In the framework of this project it is hypothesized that surface functionalization of p-AlGaN semiconductor with proper MXene materials will improve the Ohmic characteristics of Mg-doped AlGaN with high Al content (~60%). In this research, III-N samples will be grown by molecular-beam epitaxy (MBE) as well as by metal-organic vapour phase epitaxy (MOVPE), while the facile drop casting method will be adopted to fabricate the MXene/p-(Al)GaN structures. Due to the influence of the different surface terminating functional groups of MXenes on their work function, the heat treatment of the 2D layers will be also investigated in this study.

The successful realization of the innovative approach presented in this project is expected to deepen the understanding of the physical phenomena at the MXenes/III-N interface and to overcome one of the factors decreasing the emission efficiency of semiconductor DUV emitters.