Abstract

Tunnel junctions provide an alternative solution to issues that limit the efficiency of ultraviolet light emitting diodes, such as the high resistivity of p-doped AlGaN layers and the resulting poor hole injection. The objective fo this thesis is the optimization of GaN and AlGaN based tunnel junction LED structures and their structural and optoelectronic characterization. The growth of a JT LED entirely by MOCVD is industrially appealing, but the p-doped (Al)GaN layers developed by this technique suffer from the repassivation of the Mg acceptors by the hydrogen present in the growth chamber. We have tried and succeeded to minimize this problem by modifying the growth conditions of the tunnel junction. Positive results have been achieved on blue LEDs, in particular with GaN tunnel junctions including an InGaN interlayer that increases its tunnel transparency. However, this all MOCVD process seems difficult to optimize and its extension to AlGaN materials difficult. Thanks to a hybrid MOCVD+MBE growth approach, p-doped GaN and AlGaN layers can be obtained with active Mg acceptors while taking advantage of high quality active regions provided by MOCVD. With a GaN-based hybrid JT, we have been able to obtain, with both Si and Ge, higher levels of n++ doping than those of the MOCVD JTs, thus significantly reducing the operating voltage of the devices. The strong Ge doping of the GaN layers allowed us to obtain electron densities of the order of $5x10^{20}cm^{-3}$ with state-of-the-art mobilities and resistivities, without introducing a strong constraint in the network. In the second part of this work, we have developed AlGaN-based JTs doped with Ge on UV LEDs by gradually changing their Al concentration up to a value of 70%. In the UV range, the JTs become of paramount importance by increasing the injection efficiency without compromising light extraction. High levels of Ge doping have been obtained leading to thin junctions as shown by electronic holography. Even if the voltage drops introduced by the use of JTs remain significant (a few volts), the injection of out-of-equilibrium holes allows for a significant increase of the injection efficiency in the LED leading to a strong increase of the quantum efficiency of these devices.

Keywords: tunnel junctions, hybrid growth, germanium doping, polarization engineering, gallium nitride, aluminum gallium nitride.