Tunnel junctions in nitride heterostructures for optoelectronic applications

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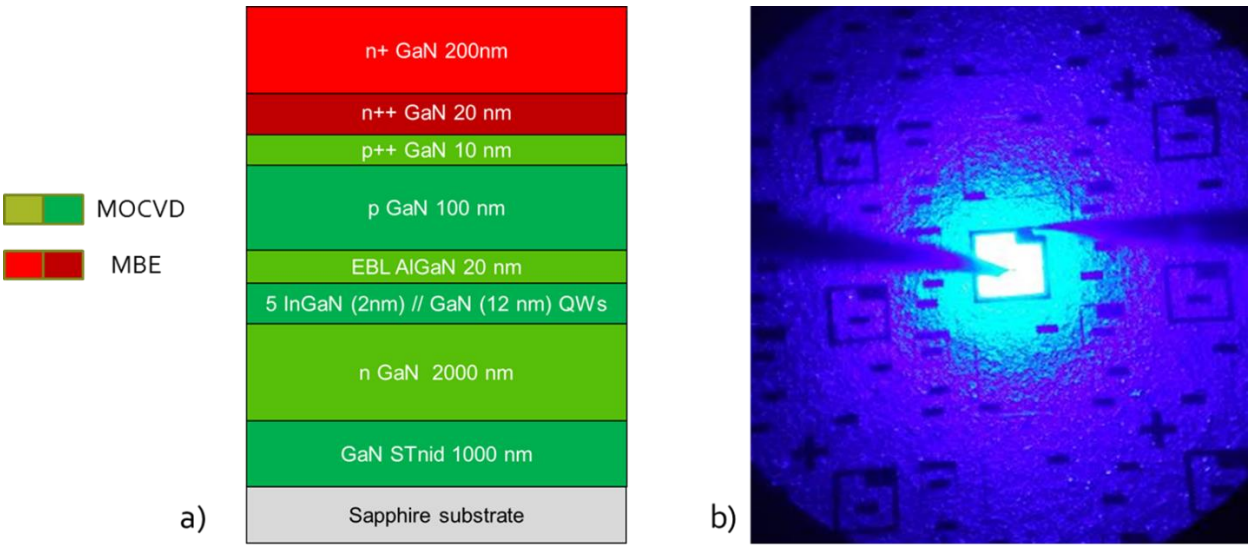
The efficiency of nitride-based UV LEDs suffers from an efficiency droop caused by the high acceptor activation energy in wide band gap semiconductors and poor light extraction efficiency. However, their efficiency can be improved by inserting a tunnel junction (TJ) on top of the structure, generating holes out of equilibrium and replacing the p-(Al)GaN contact layer by an n-contact layer, which is known to be less resistive. In the literature, the best GaN tunnel junctions are obtained using molecular beam epitaxy (MBE). However, all the LED industry is based on metal-organic chemical vapor deposition (MOCVD) and therefore understanding and improving the tunnel junctions grown by MOCVD would be of great interest. In this work we report the growth of different structures containing distinct GaN tunnel junctions – one grown by MBE, one by MOCVD and one hybrid combining MBE and MOCVD. The latter two TJs were grown on top of blue LED structures in order to evaluate their properties on visible LEDs before switching to UV-emitting devices. The samples were clean-room-processed using standard photolithography and reactive ion etching steps to fabricate LEDs. We measured the electrical and optical characteristics of these LEDs at room temperature under CW conditions. The MBE and the hybrid structures emitted light homogeneously throughout the surface – however, the emission in the all-MOCVD TJ LEDs was concentrated around the top n-contact. As expected, the hybrid TJ exhibited a lower voltage drop in comparison to the other structures. Inserting a 4-nm thick (Ga,In)N layer at the core of the tunnel junction grown by MOCVD will improve the LED electrical characteristics, reducing the gap between MBE and MOCVD tunnel junctions in the hybrid TJ. Ultimately, in order to reach UV-emissions, structures containing AlGaN TJs on top of AlGaN UV LEDs will be developed. This work is partially funded by GANEX (ANR-11-LABX-0014) and the CEA Grenoble.



a) Growth stack of the hybrid TJ LED

b) Hybrid TJ LED working under 20mA