Tunnel junction as a way to invert built-in polarization in nitrides

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The internal polarization-induced electric fields in violet to green nitride light emitting diode (LED) and laser diode (LD) structures point in a direction opposite to what is desired for efficient flow of electrons and holes. This state of affairs has persisted because of the need to have p-type layers on top of the structure to activate it and the lack of efficient structures grown along [000-1] direction.

In this work, we develop a new approach towards nitride vertical devices by introducing tunnel junction (TJ) placed below the actual device [1,2]. The bottom-tunnel junction design aligns the polarization fields in a desired direction in the quantum well of LEDs, while simultaneously eliminating the need for p-type contact, and allowing efficient current spreading. By preventing electron overshoot past quantum wells, it disables carrier recombination in undesired regions of the heterostructures, increasing injection efficiency and opening new possibilities in heterostructure design. A clear experimental assessment of the impact of the polarization-induced electric fields and their relative orientation with the p-n diode junction fields on LED performance was possible by comparing bottom and top tunnel junction designs [2].

Finally InGaN-based bottom-TJ is used to construct first monolithically grown p-type-down LD on Ga-polar bulk GaN substrate. Unique advantages of that design will discussed.

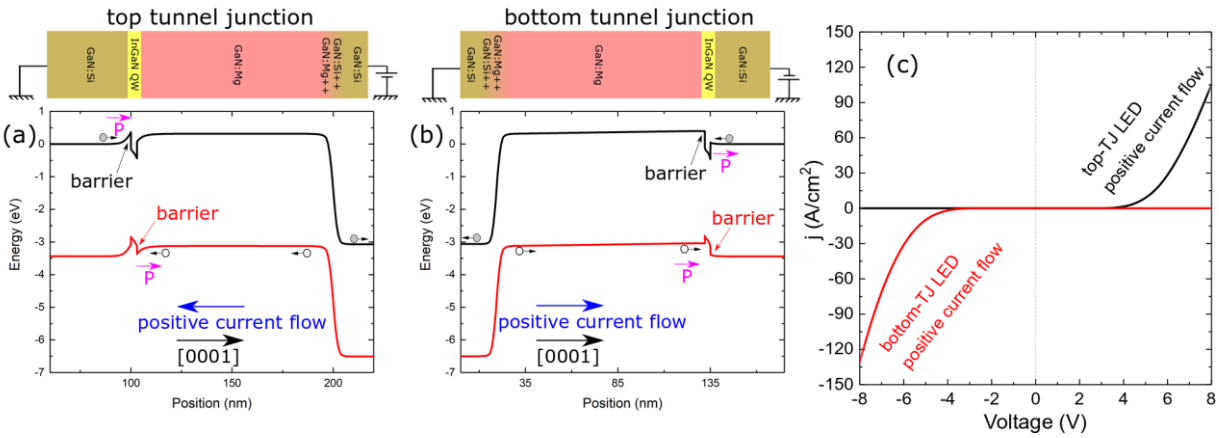

Fig. 1. Schematic energy band diagrams for forward biased single LEDs utilizing top-TJ (a) and bottom-TJ (b) geometries, respectively. The growth is performed in the [0001] direction, proceeding from left to right. Filled and empty circles with arrows denote carrier flow direction for electrons and holes, respectively. Polarization in the vicinity of the quantum well is marked. (c) Experimentally obtained current densities as a function of external bias for LEDs utilizing the top-TJ (a) and the bottom-TJ (b).

[1] M.J. Grundmann, U.K. Mishra, Phys Status Solidi C, **4** (2007) 2830.
[2] H. Turski, S. Bharadwaj, H. Xing, D. Jena, Polarization control in Nitride Quantum Well Light Emitters Enabled by Bottom Tunnel-junctions, in: arXiv e-prints, (2018).

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