How tunnel junctions changed our perception of III-N optoelectronic devices

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Recently, there has been increasing attention given to the interband tunnel junctions (TJs) for efficient carrier conversion between electrons and holes in nitride devices. Application of TJs creates more freedom in device design – e.g. eliminates the need for resistive p-type metal contact or enables vertical stacking of different devices. The main challenge in development of low resistance TJs in nitrides for metal organic vapor phase epitaxy (MOVPE) is still related to the activation of the p-type conductivity in buried Mg doped layers, which requires hydrogen removal. Unfortunately, hydrogen cannot efficiently diffuse through n-type regions, making the device design and processing (for lateral or vertical hydrogen removal) more complicated. One of the directions to overcome this issue is growth of III-N devices by plasma-assisted molecular beam epitaxy (PAMBE), since for PAMBE activation of p-type is not necessary.

In this work we demonstrate the recent progress in nitride devices with TJs grown by PAMBE. We discuss the conditions for the growth of low resistance nitride TJs with atomically flat morphology required for vertical integration of devices [1]. Incorporation of TJs to device structure (i) enabled vertical integration of multicolor LEDs and laser diodes (LDs) [2], (ii) allowed to control the current path in distributed-feedback LDs and micro-LEDs [3] and (iii) created possibility to design new architecture devices like inverted LEDs or LDs [4]. Inverted LEDs and LDs have the sequence of p and n type layers similar to the structures grown on “hypothetical” p-type (0001) GaN substrate, which is beneficial for high carrier injection efficiency, and enables operation at cryogenic temperatures. Efficient operation at liquid helium temperatures opened new perspective for single photon emission devices or optoelectronic devices based on Cooper pairs injection. Finally, we discuss the properties of bi-directional LEDs and continuous wavelength-tunable single quantum well LEDs.

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