Low-temperature study of nitride light-emitting diodes with tunnel junction

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Group-III nitride semiconductors gained extensive attention due to its band gap that spans the widest spectral range among semiconductors. This feature, together with direct bandgap, allows for design of high-efficiency and high-power optoelectronic devices such as light emitting diodes (LED) and laser diodes. Variety of possible applications can be further increased by devices such as multi-junction LEDs and VCSELs using tunnel junction (TJ) [1]. A TJ is used to inject holes into the p-type region of LED enabling the use of low resistivity n-type contacts on both sides of the device. Placing TJ below the active region allows to invert LED (invLED) structure and to bring active region closer to the top of the device (fig.1a). Such design improves injection efficiency, current spreading and allows for further integration of additional materials on top of it providing platform for numerous applications e.g. biomedical sensor [2].

To understand recombination and transport mechanisms in nitride invLED temperature-dependent measurements over a wide range (12–300 K) were performed. The devices consisted of bottom InGaN TJ, p-type AlGaN:Mg electron blocking layer and LED with an active region containing one or three InGaN/GaN QWs (Fig. 1a). To achieve high quality buried TJ plasma-assisted molecular beam epitaxy was used. Previously known effects such as phonon replicas and S-shape behavior in electroluminescence (redshift–blueshift–redshift) were observed (Fig. 1b) [3]. Performance of invLEDs obtained in this work presents valuable solution for on-chip low temperature excitation.

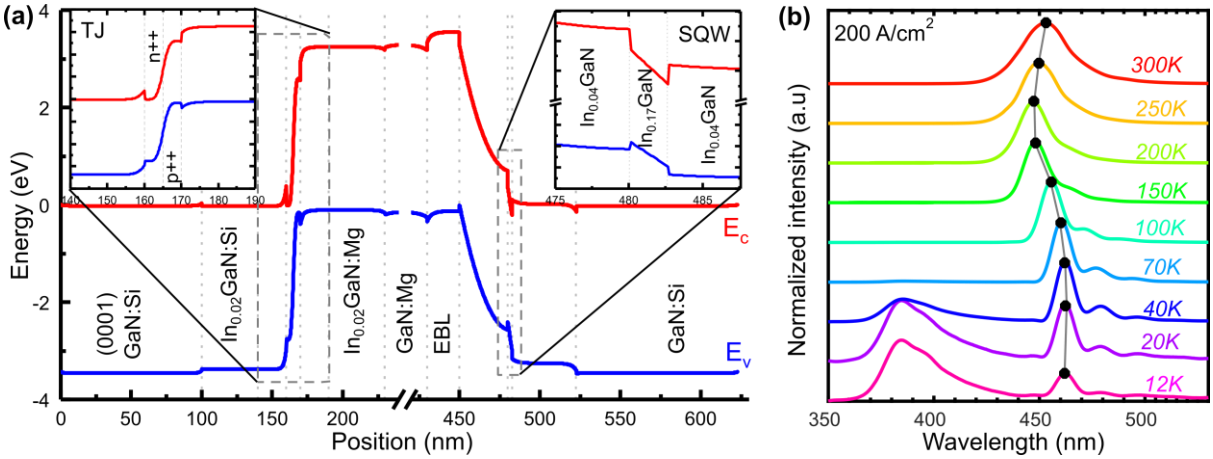

Fig. 1. (a) Band structure of invLED with TJ and single quantum well (SQW) inside insets at 300K. (b) Electroluminescence spectra of blue invLED measured at various temperatures.

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[3] I. E. Titkov et al., *IEEE Journal of Quantum Electronics*, **50**, 11, 911-920, (2014)

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