III-Nitride Light Emitting Devices driven with Alternating Current

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The III-nitride light emitting diodes (III-N LEDs) coated with phosphor are the most efficient white light sources for general lighting. However, standard LEDs require the direct current (DC) supply, while the power in the electric grid is distributed as alternating current (AC). The AC/DC converters are bulky and always a few percent of energy is lost to current rectification, thus substantial effort is being put to develop AC driven light sources [1].

In this work we propose a new design of an AC-driven bidirectional light emitting device (BD LED) grown by plasma-assisted molecular beam epitaxy (PAMBE). We focus on symmetrical structures presented in Fig. 1a, in which an efficient InGaN quantum well(QW) constitute the light emitting region and are surrounded by tunnel junctions (TJs) for efficient carrier injection. Fig. 1b and 1c show the BD LED band structures for positive and negative bias, respectively. Under the positive bias (Fig. 1b) the right-hand side TJ is reversely polarized, interband tunneling of carriers occurs and thus the holes are effectively injected into the QW. Simultaneously, the left-hand side TJ is polarized in the forward direction, so electrons are also injected to the QW. Under the negative bias (Fig. 1c) the right-hand side TJ is polarized forwardly, while the left-hand side TJ reversely. The carriers are still injected to the QW, but in this case they come from other sides of QW.

The time dependence of voltage and current during AC operation with the frequency of 60 Hz is shown in Fig. 2. Insets present images of BD LED under the -1 kA/cm^2 and 1 kA/cm^2 of current densities. For both polarities of applied voltage the light is emitted from the entire surface of BD LED. Moreover we also show, that BD LEDs can be vertically stacked in one epitaxial process in order to multiply the optical power achieved from a single device.

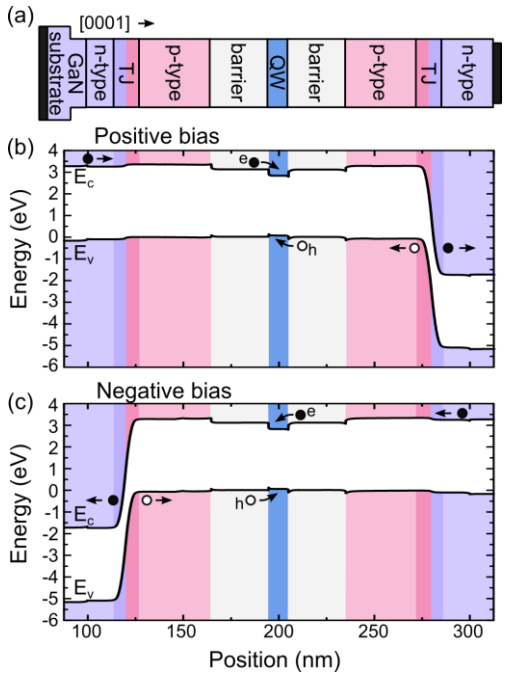

Fig. 1. a) Schematic structure of BD LED and its band diagrams under the b) positive and c) negative bias.

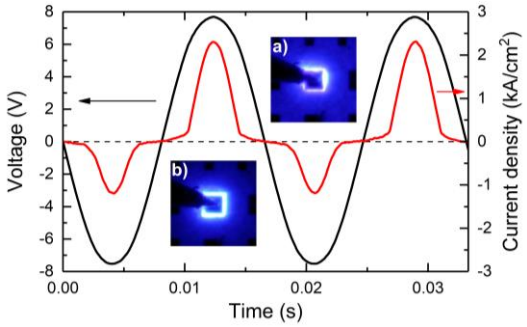

Fig. 2. The time dependence of voltage and current during AC operation of BD LED with the frequency of 60 Hz. a), b) photograph of BD LED under the 1 kA/cm^2 and -1 kA/cm^2, respectively.

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[1] L. Wang, et al., *Adv. Optical Mater.* **7**, 1801154 (2019)