InGaN multiple-quantum-well light-emitting diodes grown with an underlying superlattice for light detection

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With advances in the epitaxial growth, manufacturing processes and the chip-scale packaging technique, solid-state lighting based upon InGaN multiple-quantum-well light-emitting diodes (InGaN MQW LEDs) has emerged as the dominant technology for indoor/outdoor illumination, horticulture/car lighting, and advertising displays [1]. Apart from functioning as the light emitters, a p-i-n InGaN MQW LED can also be used as the photodiodes (PDs) under light illumination due to the presence of an electrical field at the pn junction facilitates the extraction of photogenerated carriers from the MQWs. For InGaN MQW PDs, it is known that the available photoresponse is mainly correlated with the MQW design such as the indium content, QW number, well/barrier width and so on [2]. In comparison with the normal InGaN LEDs having an 8-pair $In_{0.16}Ga_{0.84}N$ (2 nm)/GaN (12 nm) MQW, the influence of underlying $In_{0.8}Ga_{0.92}N$ (2 nm)/GaN (6 nm) superlattices (grown beneath the $In_{0.16}Ga_{0.84}N$/GaN MQWs) on optical and electrical property of the LEDs (denoted as the proposed InGaN LEDs) was investigated experimentally. As evaluated from the time-resolved photoluminescence (TRPL) analysis, we found that the carrier lifetime of ~5 ns can be obtained in $In_{0.16}Ga_{0.84}N$/GaN MQW containing LEDs while the lifetime of carriers is further reduced to ~1 ns as the underlying $In_{0.8}Ga_{0.92}N$/GaN superlattice (which also dominates the light emission process in proposed InGaN LEDs) was presented. Therefore, we speculate that highly efficient radiation and/or improved frequency response could be achieved in our proposed LEDs grown with an underlying superlattice. Although the carrier lifetime can be reduced in proposed InGaN LEDs, their light output power is lower than that of the normal LEDs. The reason for that is due to the larger dynamic resistance (i.e., 14 Ω versus 18 Ω @ 20 mA) in these LEDs with the increased number of the QWs. On the other hand, the proposed InGaN LEDs can exhibit a photoresponsivity (R_λ) of 0.09 A/W (6.2×10^{11} cm $Hz^{1/2}$ W^{-1} @ λ = 366 nm) and a UV to visible rejection ratio ($R_{366\ nm}/R_{480\ nm}$) of 2884 under light illumination without applied bias. In addition, when the light modulation frequency is as high as 76 MHz, these PD-like LEDs grown with an underlying superlattice still have good sensing capabilities. In optical wireless communications, we have successfully constructed a line-of-sight optical channel (L = 100 cm) with a data transmission rate of up to 250 Mbit/s (the corresponding bit error rate is as low as 8.8×10^{-8}) by using the near-ultraviolet laser diode and the proposed InGaN LED respectively as the optical transmitter and the receiver. These results are superior to those obtained by using the normal LEDs.

Reference

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