Analysis of Current Leakage in AlGaN-based Deep-Ultraviolet Light-Emitting Diodes

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The current injection efficiency is generally assumed to be unity at low injection current densities in group III-nitride-based light-emitting diodes (LEDs). However, this is not the case for AlGaN-based deep-ultraviolet (DUV) LEDs. The external quantum efficiency (EQE) is relatively easy to measure quantitatively and is given by the product of current injection efficiency (CIE), internal quantum efficiency (IQE), and light extraction efficiency (LEE); but it is difficult to separate the CIE and IQE. We have presented a method to extract the CIE from the measured EQE data.[1] The results show that the CIE is only approximate 50% at low injection current density at room temperature for DUV-LEDs with an emission of 267 nm. This value is much lower than the expected value of 100%.

In this talk, we report the study on the current leakage mechanism. The characteristics of two DUV-LEDs grown on sapphire and bulk-AlN substrates were examined. The TDD at the active layers is less than 10^6 cm^{-2} in the sample on AlN substrate and is higher than 10^9 cm^{-2} in the sample on sapphire substrate. The CIE of both LEDs were evaluated. The results suggest the CIE is dependent on TDD. The I-V characteristics were also measured under reverse and forward bias. The current leakage in reverse bias was severe. Two resolvable p-n junctions were clearly observed in forward bias in sapphire samples that have severe current leakages. The diode-like behavior with turn on voltage of approximately 4V should stem from the p-n junction of DUV-LEDs. Another rectification behavior with variable turn on voltage (~2V in the figure) in different devices may be corresponding to the current leakage pathways. The I-V characteristics at low bias represent that the current leakage paths have diode-like behaviors involving potential barriers. Additionally, the CIE is almost independent on the current injection density, which indicates that the current leakage mechanism is much more complex beyond the hypothesis that leakage arises from the spillover of electrons due to the insufficient barrier height of the electron blocking layers. We will reveal a direct relationship between the TDD and the current leakage properties in the DUV-LEDs. More details will be present at the conference.

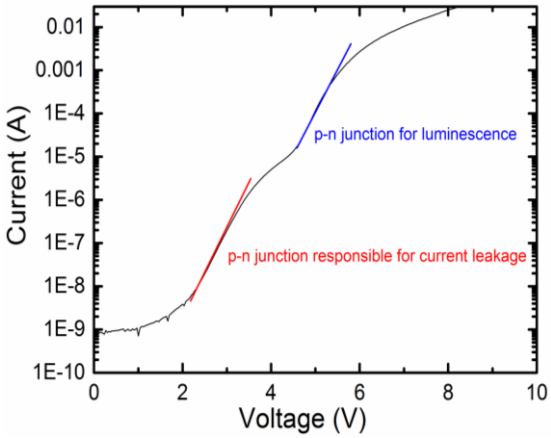

Fig. 1. Forward-bias I-V characteristics of DUV-LED grown on sapphire substrate

1. G. D. Hao, N. Tamari, T.Obata, T. Kinoshita, and S. Inoue, Opt. Express 25, A639 (2017).