MAR11-2010-000848

Abstract for an Invited Paper
for the MAR11 Meeting of
the American Physical Society

Efficiency Droop in III-nitride LEDs: a differential carrier lifetime analysis

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GaN-based LEDs suffer from a phenomenon known as efficiency droop, which causes a (non- thermal) roll-over of the IQE at high current density, and whose underlying physical origin is not well understood. Identifying the correct process is of importance, as it dictates which strategies can be employed to quench or mitigate droop. Among the most often cited hypotheses are: localization effects related to InGaN alloy fluctuations, leakage effects, and Auger scattering. In this contribution, we will present recent experimental results which aim at testing these scenarios. We will first show why droop appears to be a bulk-like phenomenon, rather than transport-related. We will present PL measurements to illustrate how droop scales with carrier density, and biased-PL measurements which quantify the magnitude of the leakage current. In a second part, we will present differential carrier lifetime measurements, which aim at characterizing the various recombination processes in InGaN heterostructures. We will review recently published results, which show that droop is caused by the onset of a high-order non-radiative process, and confirm that lifetimes are quantitatively compatible with the hypothesis of Auger scattering. Finally, we will present new lifetime measurements on QW samples with various In contents, and discuss how the variations in droop can be explained by the impact of piezoelectric fields on the carrier lifetime.