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Auger Recombination in Indium Gallium Nitride: Experimental Evidence

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Progress in InGaN-based light-emitting diode (LED) technology has resulted in white-light emitters with efficiencies far exceeding those of conventional light sources such as tungsten-filament-based incandescence and mercury-vapor based fluorescence. Indeed, by now efficacies exceeding 150 lumens per Watt for InGaN-based phosphor-converted white LEDs are claimed, which represent a 90% energy savings compared to the conventional incandescent (i.e., "light bulb") solution. However, these high performance levels are obtained under conditions of very low forward current-density for the InGaN LED and do not represent true operating conditions (nor cost-effective utilization) for the device. In order to reduce the cost (and thus increase market penetration of) solid-state lighting, more lumens per unit of semiconductor area are required which in practice necessitates higher drive current densities. Unfortunately, at these higher driver current densities, the internal quantum efficiency of InGaN-based LEDs is observed to decrease significantly. In the fall of 2007, researchers at the Advanced Laboratories of Philips Lumileds were the first to propose Auger recombination as the root-cause mechanism in InGaN which was behind this "efficiency droop" [1]. They further proposed to circumvent the problem by employing InGaN-based active region designs that maintain low carrier density, and demonstrated an LED device design that reaches a maximum quantum efficiency above 200 A/cm2, compared to ~1-10 A/cm^2 for typical multiple-quantum-well heterostructures [2]. In this talk we will review the experimental evidence for Auger recombination in InGaN, beginning with the early work from 2007 and then considering additional work from more recent efforts to better understand the details behind this loss mechanism.

[1] Y. C. Shen, G. O. Müller, S. Watanabe, N. F. Gardner, A. Munkholm, and M. R. Krames, "Auger recombination in InGaN measured by photoluminescence", Appl. Phys. Lett. 91, 141101 (2007).
[2] N. F. Gardner, G. O. Müller, Y. C. Shen, G. Chen, S. Watanabe, W. Götz, and M. R. Krames, "Blue-emitting InGaN–GaN double-heterostructure light-emitting diodes reaching maximum quantum efficiency above 200 A/cm^2", Appl. Phys. Lett. 91, 243506 (2007).