SSL *Postings*

U.S. DEPARTMENT OF ENERGY

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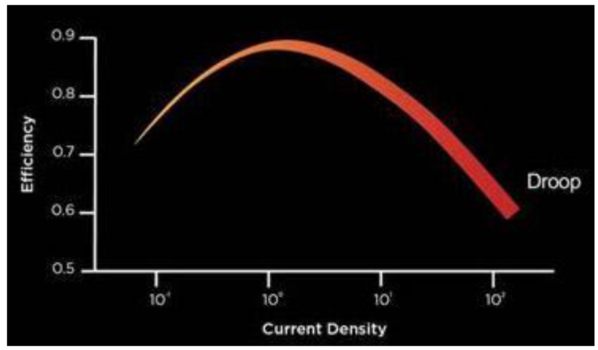
The Droop Phenomenon

The topic of droop comes up quite a bit when discussing LED lighting R&D. But exactly what is droop, and why do we care about it?



Simply put, droop is a phenomenon in which GaN-based LEDs (blue and white emitters) lose efficiency as current density is increased. The underlying physical cause is most likely something called Auger recombination, which occurs when energized charge carriers in the LED active region recombine but, instead of emitting light, energize a neighboring charge carrier, thus generating heat. The rate of Auger recombination increases exponentially with the number of charge carriers, so the phenomenon is much stronger at higher current operation.

Okay, so why do we care so much about droop? In a nutshell, we care because it poses a dilemma for LED lighting manufacturers. They can choose to maximize LED efficiency by under-driving LEDs (i.e., driving them at lower current densities), but that requires the use of more LEDs, which raises the cost of the lighting product. Alternatively, they can choose to minimize LED costs by using fewer LEDs and driving them harder, but then they'll suffer consequences of reduced efficiency (including potential higher operating temperature effects). So you can see that droop imposes a tradeoff on LED lighting manufacturers, essentially forcing them to choose between cost and efficiency.

What can be done about that? There are several approaches to reducing or mitigating the impact of droop. One approach is to redesign LED active regions to minimize carrier density within them. This reduces droop, but manufacturers have discovered that it's very difficult to maintain LED material quality with these low-droop designs. Thus, while droop may be reduced, the peak efficiency of the LED is also reduced, resulting in a net degradation of performance. The DOE SSL R&D Program is currently supporting two R&D projects—one at Lumileds and the other at the University of California, Santa Barbara—that are exploring the tradeoffs between material quality and droop as well as the fundamental physics of the droop phenomenon.

There are also more exotic approaches to mitigating droop. For example, the use of a laser device structure instead of an LED to pump a phosphor to make white light would essentially remove the impact of droop. Lasers have clamped charge carrier density, so droop doesn't exponentially increase at higher operating current. However, with lasers there's also a tradeoff between peak efficiency and droop reduction, plus there are complications involved with using lasers for lighting. Researchers are working on both the peak efficiency of lasers and ways to integrate them into lighting products.

Another interesting approach to mitigating droop is to use tunnel junctions to vertically stack multiple LED junctions on top of each other. Essentially, you would have multiple LEDs in series, which would increase voltage but keep current low. This would enable higher light output from an area of LED material, while keeping the applied current—and resulting droop—low.

However it's accomplished, eliminating or reducing droop will have a significant impact, making LED lighting products more efficient, less expensive, and easier to manufacture. And by allowing LEDs to be run harder with less generated heat, it can also enable improved lighting performance in terms of beam control, as a result of the increased light output per area. Research on droop is not only yielding practical benefits in terms of lighting efficiency and cost, but is also broadening our understanding of semiconductor physical phenomena, such as Auger recombination, carrier dynamics, and device structure-material property relationships. That's why droop continues to be an important research focus area for the DOE SSL Program.

Best regards,
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As always, if you have questions or comments, you can reach us at postings@akoyaonline.com.