Going cubic halves the efficiency droop in InGaAlN light-emitting diodes

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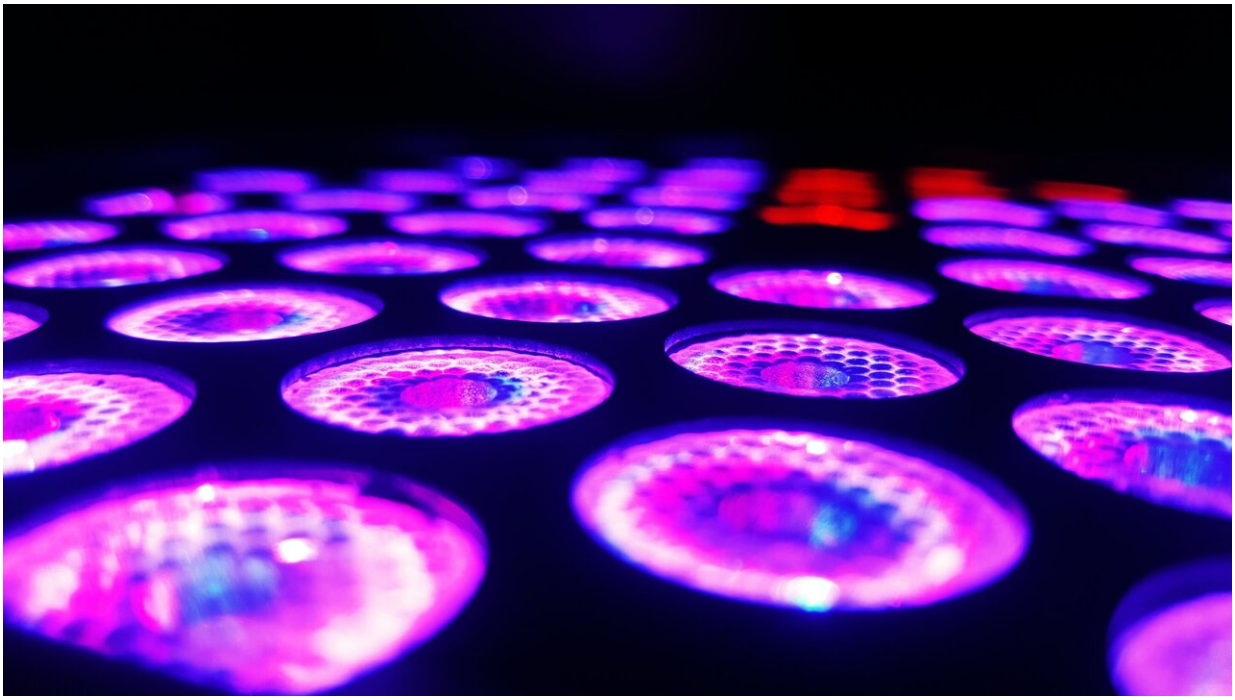

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Today, it is widely accepted that the large Auger coefficient is the main cause for the large (~50%) efficiency droop in traditional hexagonal-phase InGaAlN LEDs. Yet, this explanation is inadequate to account for the low efficiency droop in gallium arsenide- and gallium phosphide-based LEDs, as those have similar Auger coefficients.

In *IEEE Transactions on Electron Devices*, Can Bayram, Jean-Pierre Leburton and Yi-Chia Tsai at the University of Illinois at Urbana-Champaign show that the coexistence of strong internal polarization and large carrier effective mass accounts for ~51% of the efficiency droop under high current densities in hexagonal-phase green InGaAlN LEDs (h-LEDs) compared to cubic-phase InGaAlN green LEDs (c-LEDs).

Previously, the efficiency droop reduction in non-polar h-LEDs was attributed to the decrease of carrier leakage from active region, overlooking the interplay between internal polarization and Auger recombination. Indeed, recent experiments suggest that the efficiency droop reduction in non-polar h-LEDs is in fact due to carrier delocalization, (a situation different than in polar h-LEDs) that results in stronger electron-hole wavefunction overlap, lower quantum well carrier densities, and lower Auger recombination rates. The team found out that large carrier effective mass promotes carrier localization and degrades band-to-band optical transition matrix element.

According to this new interpretation, the researchers show that switching from polar h-LEDs to c-LEDs quenches the efficiency droop from 45% to 22% (i.e. a 51% reduction) thanks to polarization elimination and effective mass reduction. It is further found that the quantum efficiency of c-LEDs is much immune to the Auger electron-hole asymmetry, the increase of Auger coefficient, and thus efficiency degradation mechanisms. Hence, cubic-phase InGaAlN green LEDs offer an appropriate solution to quench the efficiency droop.

More information: Yi-Chia Tsai et al, Quenching of the Efficiency Droop in Cubic Phase InGaAlN Light-Emitting Diodes, *IEEE Transactions on Electron Devices* (2022). DOI: 10.1109/ted.2022.3167645