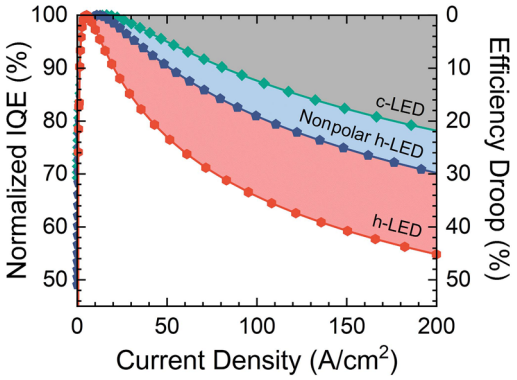
Going cubic halves the efficiency droop in InGaAlN light-emitting diodes

Currently, it is widely accepted that the large Auger coefficient is the main cause for the large (~50%) efficiency droop in traditional hexagonal-phase InGaAlN light-emitting diodes (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.



Normalized internal quantum efficiency (IQE) (left *y*-axis) and efficiency droop (right *y*-axis) as a function of current density are plotted. Red hexagons and green rhombuses refer to the hexagonal-phase (h-) and cubic-phase (c-) InGaAlN light-emitting diodes (LEDs), whereas blue pentagons refer to the nonpolar h-LED grown on m-plane GaN substrates. Credit: *IEEE Transactions on Electron Devices*.

In a recent publication of *IEEE Transactions Electron Devices* (https://doi.org/10.1109/TED.2022.3167645), Can Bayram, Jean-Pierre Leburton, and Yi-Chia Tsai at the University of Illinois in Urbana-Champaign have shown 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 nonpolar h-LEDs was attributed to the decrease of carrier leakage from an active region overlooking the interplay between internal polarization and Auger recombination. Recent experiments suggest that the efficiency droop reduction in nonpolar h-LEDs is due to carrier delocalization—a situation different from polar h-LEDs—that results in stronger electron–hole wave function overlap, lower quantum-well carrier densities, and lower Auger recombination rates. The research team found that large carrier effective mass promotes carrier localization and degrades the band-to-band optical transition matrix element.

According to this new interpretation, the researchers have shown that switching from polar h-LEDs to c-LEDs quenches the efficiency droop from 45% to 22% (i.e., a 51% reduction) due 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.

Source: University of Illinois at Urbana-Champaign