Differential charge carrier lifetime in InGaN LEDs under working conditions

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Investigation of non-equilibrium charge carrier dynamic properties in a light-emitting diode (LED) under working conditions is of essential importance, since none of the extrapolation methods either from the relative low or high charge carrier supply will give better insight into the processes of LED structure. Optimization of the LEDs requires a deeper insight into the charge carrier transport across the LED structure, electron-hole recombination mechanisms and competition of various recombination channels determining internal quantum efficiency (IQE) of the structures. The ABC-model considering three recombination mechanisms – the Shockley-Read-Hall recombination via defects (coefficient *A*), the bimolecular recombination (coefficient *B*) and the Auger recombination (coefficient *C*) – is a commonly used tool to interpret the processes related to IQE. Evaluation of these coefficients paves the way towards understanding of fundamental mechanisms limiting the LED efficiency and practical optimization of the LED structures.

In this work different InGaN/GaN LEDs, emitting in blue, cyan and green spectral regions, were investigated under working conditions by small-signal photoluminescence frequency-domain lifetime measurement (FDLM) technique. Main advantage of this technique is that it combines LED operation under DC injection with resonant optical excitation slightly perturbing the non-equilibrium charge carrier density in the LED active region. Important is that the latter avoids uncertainty to attribute the extracted differential charge carrier lifetime to a specific non-equilibrium charge carrier concentration. FDLM technique confirmed its capability of extracting the ABC recombination coefficients, however, when carried out in a wide range of LED operating current a discrepancy between the DLT measured at lower current (less charge carrier density injected) and that predicted by the ABC-model has been revealed. To overcome the problem charge carrier escape from the quantum well as one of the important factors, which may let to define correctly the recombination coefficients of the ABC-model, was suggested. A more pronounced carrier escape observed for the relative shallower quantum wells of the blue LED may serve as a preliminary experimental proof. An extended study of charge-carrier localization and delocalization in the LEDs structures comprising a system of radiative and several non-radiative recombination channels has been performed by resonantly photo-excited small-signal photoluminescence FDLM.

This research was funded by a grant (project FLINGO No.M-ERA.NET-2/2016) from the Research Council of Lithuania.