Correlations between MOVPE recipes, materials properties, and performances of blue and green LED structures

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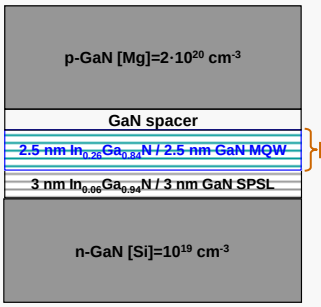
Motivation for the study:

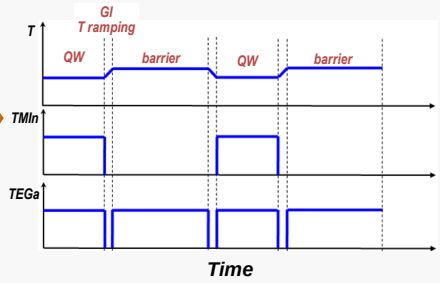
- indium composition profile in the active region may differ significantly from the "nominal" one due to the surface segregation, affecting device characteristics
- process conditions (temperature, pressure, flow rate, etc.) and special procedures, like indium pre-deposition, growth interruption, and temperature ramping, should be adjusted to grow epitaxial structure with desired properties, but "recipe-device" correlations are not straightforward

Goal of the study: to establish coupled *process-device modeling* and estimate the effect of the process recipe on the indium composition distribution in the active region of a blue LED structure and its performance

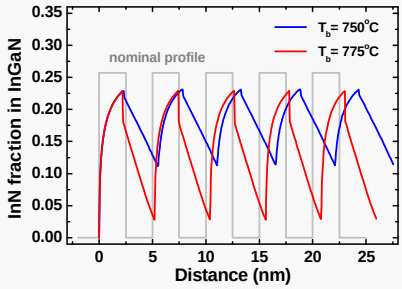
Nominal LED structure



Recipe: temperature and precursor supply variation

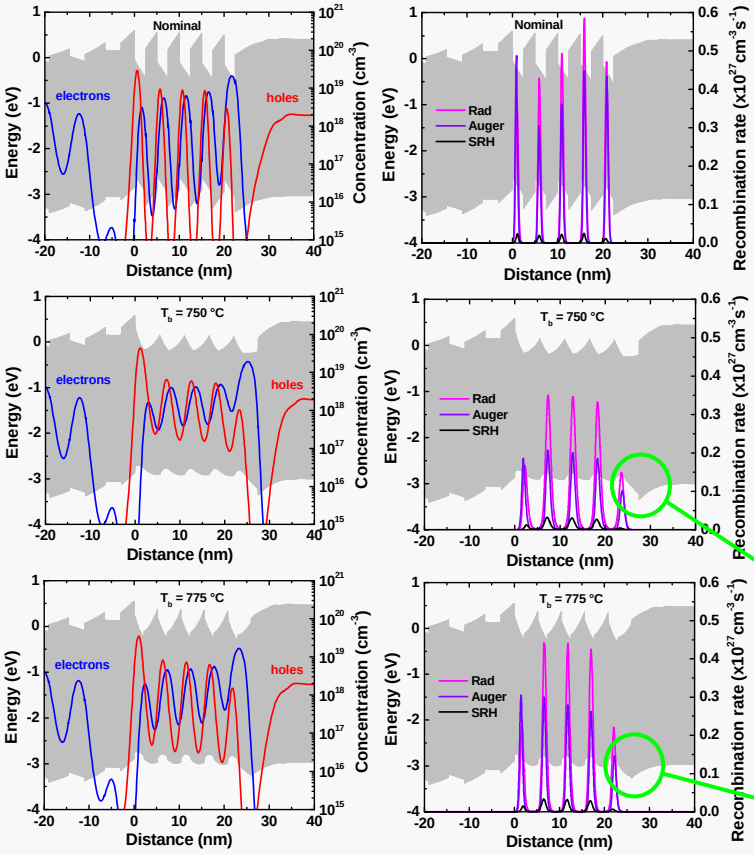


Effect of GI and temperature ramping on the composition profile



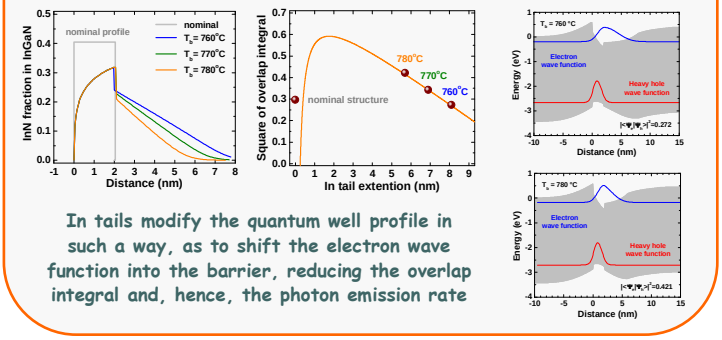
In composition profile is far from the nominal one: extended In "tails" in the barriers are predicted; growth interruption (GI) and barrier growth temperature affect strongly the In content distribution

Operation of blue LED structures at the current density of 50 A/cm²



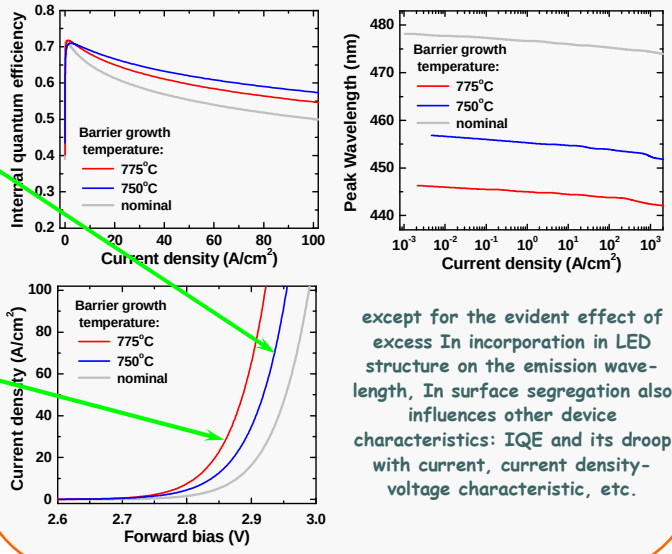
In incorporation in the barriers (i) widens effectively QW, thus reducing electron and hole concentrations and (ii) makes the radiative recombination rate more uniformly distributed in the central wells. All this suppresses Auger recombination in the structure, increasing IQE.

Effect of In surface segregation on overlap of electron and hole wave functions in green SQW



In tails modify the quantum well profile in such a way, as to shift the electron wave function into the barrier, reducing the overlap integral and, hence, the photon emission rate

Recipe effects on LED characteristics



except for the evident effect of excess In incorporation in LED structure on the emission wavelength, In surface segregation also influences other device characteristics: IQE and its droop with current, current density-voltage characteristic, etc.

Conclusions:

- electrical and optical characteristics of LED structures of the same nominal design depend on the recipe of the MOCVD process due to In surface segregation
- detailed modeling of LED structure growth with account of segregation effects coupled with modeling of device operation may be helpful for both optimization of the epitaxy conditions and better understanding of technological impact on the device characteristics and performance