BLUE AND GREEN LED STRUCTURES INVESTIGATED BY PHOTOLUMINESCENCE FREQUENCY DOMAIN TECHNIQUE

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This paper reports the results obtained on applying the photoluminescence frequency domain technique as to investigate blue and green light emitting diode (LED) structures, thus representing the entire spectra for the InGaN LEDs. Our group earlier has applied this method while investigating carrier dynamics in GaN at extremely low excited carrier densities [1]. To the best of our knowledge, it is the first time the method is yet used to measure InGaN multi-quantum well (MQW) structures. Moreover, we applied both, the LED and the laser diode (LD), to excite resonantly the MQW with modulated light and exceeded to cover a broad range of excitation power density (1-500 mW/cm^2). This method allowed us to extract lifetimes straight from the nanoseconds up to the tens of microseconds. To analyze the activation mechanisms measurements down to 10 K temperatures were performed. The non-equilibrium charge carrier lifetime dynamics was investigated by applying a model with single exponential and stretch exponential decay depended on the sample and on the measurement condition. The oneness of this method is to study the transient processes in structures under very low non-equilibrium charge carrier densities at an un-saturated recombination channel condition.

378 nm LED and 405 nm LD were used as excitation sources in the experiments. The LED or LD emission intensity and, hence, the PL signal, were modulated in the frequency range from 1 Hz to 100 MHz. The time evolution was extracted using Fourier-transform analysis. The three investigated InGaN/GaN LED structures were MOCVD grown on sapphire devoted to a characteristic wavelength 460, 500 and 530 nm consisted of a standard sequence of epilayers: buffer layer – unintentionally doped GaN, *n*-type GaN, active layer – MQW of a typical 3 nm width and >20 % In, *p*-type GaN.

Analysis revealed that increasing excitation intensity leads to exponential recombination channels fractional intensity decrease and stretch-exponential recombination channel fractional intensity increase, it starts to dominate at excitation power density 200 mW/cm^2. Experimental data show that increasing indium content (highest for 530 nm) leads to more pronounced stretch-exponential decay. It can be attributed to more defined local indium content or well thickness fluctuations. Temperature dependency measurements revealed that for the temperatures up to 150 K there seems to be no activation behavior in charge carrier lifetimes while excitation power density does not exceed 200 mW/cm^2. We observed for 530 nm sample decay time shifting from 60 ns (@150 K) down to 10 ns (@RT). It confirms that experiment was carried out in an un-saturated recombination channel regime, then nor excitation power density nor temperature doesn’t influence carrier lifetime. In our presentation we will show complementarity of frequency domain measurements results with measurements carried out under high excitation power density regime, such as TR-PL, light induced transient grating techniques using ps and fs lasers.

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REFERENCES:

[1] J. Mickevicius, “Carrier dynamics in GaN at extremely low excited carrier densities”, Solid State Communications, Vol. 145, pp 312-315, 2008.