Mėlynų ir žalių šviestukinių struktūrų tyrimas žadinant violetiniu lazeriniu diodu dažninės skyros metodu

Blue and green LED structures investigated in frequency domain using violet LD as an excitation source

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In this work carrier lifetime investigations by applying photoluminescence frequency domain technique to investigate blue and green light emitting diode (LED) structures, thus representing wide spectra for the InGaN LEDs were performed. Similar measurements have been carried out in GaN at extremely low excited carrier densities [1], as low as 1 mW/cm^2 by using UV LED as an excitation source. For these measurements we applied laser diode (LD), to excite resonantly the MQW‘s in the sample investigated with modulated light. This allowed us to cover a broad range of excitation power density (1-500 mW/cm^2). 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 a superposition of exponential and stretch exponential decay depended on the sample and on the measurement condition. The uniqueness of this method is the possibility to study the transient processes in structures under very low to 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 for the measurements. The LED or LD emission intensity and, hence, the PL signal, were modulated in a wide frequency range from 1 Hz to 100 MHz. This allowed us to extract lifetimes from the nanoseconds up to the tens of microseconds. The time evolution was carried out using Fourier-transform analysis. The three investigated InGaN/GaN LED structures were MOCVD grown on sapphire devoted to a characteristic wavelength 450, 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 an Indium content depending on the wavelength, p-type GaN.

Analysis revealed that while increasing the excitation intensity, exponential recombination channels fractional intensity decreases and stretch-exponential recombination channel fractional intensity increases, thus it starts to dominate at excitation power density of 200 mW/cm^2. Experimental data indicate that increasing Indium content in the sample (highest for 530 nm) leads to more pronounced stretch-exponential decay. It is believed that such behavior can be attributed to more pronounce well thickness fluctuations. Temperature dependency measurements of both green samples revealed that for temperatures up to 150 K there is no activation behavior in charge carrier lifetimes while excitation power density does not exceed 200 mW/cm^2. For the 530 nm sample we observed a decay time shift from 60 ns (@150 K) down to 10 ns (@RT). The blue sample showed activation at 80 K temperature, confirming lower potential fluctuations. These results confirm that the experiments were carried out in an un-saturated recombination channel regime.

In our presentation we will show comparability of the frequency domain technique with measurements carried out under high excitation power density regime, such as TR-PL, light induced transient grating techniques using ultrafast laser pulses.

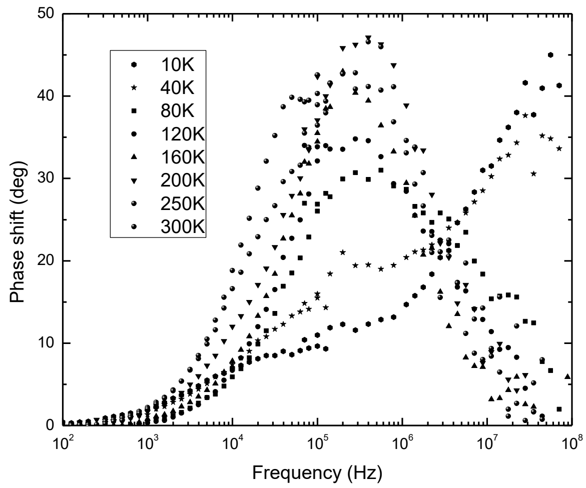

Fig. 1 Blue InGaN/GaN LED structure frequency response curves as a function of sample temperature.

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Reference

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