Thermally dependent processes in nitride laser diodes.

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One of the most important goals of laser diode (LD) structure optimization is to obtain devices with high optical power and good thermal stability. Under their normal operating conditions laser diodes are subjected to self-heating, what often results in their reduced performance. This is why it is crucial to have good understanding of thermally dependent processes taking place in nitride LDs.

We have studied the transport mechanisms of carriers in nitride laser diodes, in particular: the injection of carriers and their escape from quantum wells (QWs). Both of these processes are strongly dependent on the device temperature. In order to identify the major trends in the thermal processes, we studied a number of laser diodes with different quantum structures. They differed in quantum wells depth, and in the position of a crucial part of a nitride laser diode - an Electron Blocking Layer (EBL). We measured the intensity of optical emission - electroluminescence (EL), threshold current and differential efficiency of laser diodes as a function of driving current and temperature. All devices were grown by MOCVD (metalorganic chemical vapor deposition) on bulk GaN crystals obtained via ammonothermal synthesis.

We have found out that the temperature behavior of the laser diode system depends whether the device is actually lasing or not. Below lasing threshold the efficiency of carrier injection into quantum wells is determined by Mg acceptor ionization, a distance between p-layer and QWs and finally thermal escape of electrons from quantum wells. Above lasing threshold (very fast recombination in the quantum wells) thermal ionization of acceptors mostly counts. As the above-mentioned mechanism are partially tunable by changing the quantum wells composition, doping and geometrical design of the laser diode, we can engineer to large extent a temperature response of the whole system.

As a result we show that not only the depth of quantum wells change the thermal stability of optical emission but also we found that the distance between EBL and QWs is of the critical importance. The Fig. 1 below shows that relatively similar structures may be characterized by totally opposite thermal behavior. We will show that we can learn from this also about the connection between the nonradioative recombination and laser diode degradation.

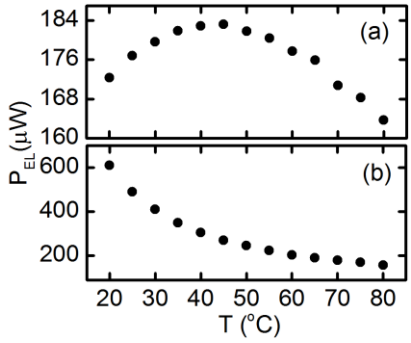

FIG. 1 Optical power of electroluminescence as a function of temperature for a device with large (a), and short (b) distance between quantum wells and electron blocking layer.