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Measurement of internal quantum efficiency and surface recombination velocity in InGaN structures.

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Gallium Nitride materials and alloys have already proven there usefulness as light emitting diodes and the recent reports of room temperature lasers. As refinements are required on the processing techniques to improve the material quality, a system of non-invasive testing needs to be implemented in order to test the quality of samples. We report the first measurements of the spectrally resolved absolute internal luminescence quantum efficiency and surface recombination velocity of an InGaN/GaN multiquantum well (MQW) structures.

The absolute external luminescence efficiency is calibrated with respect to a perfect 100% white Lambertian reflector. An optical model is used to obtain the internal efficiency of the MQW from the calibrated external efficiency. We use the "photon gas model" which requires that we take into account Fresnel transmission, absorption at the pump wavelength, photon recycling and the probability of a re-emitted photon finding the escape cone.[1]

The InGaN MQW was grown using MOCVD on a C-plane sapphire substrate.[2] The QW was optically pumped using the 325nm line of a continuous wave HeCd laser.[3] The absolute external quantum efficiency is measured by referencing the measured photoluminescence (PL) from the sample with the reading measured from the laser off of the perfect 100% White Lambertian Reflector(LR)[3]. Corrections for transmission through the optical setup and the detector efficiency at the different wavelengths were made in the calculations. Typical PL spectra are shown in Figure 1. Measured photoluminescence internal quantum efficiency ranges from 40 to 90 % for different samples.

In order to measure the surface recombination, we patterned the sample with polystyrene microspheres using natural lithography technique [4], and etched mesas through the active region by chemical assisted ion beam etching using micro spheres as a mask. The photograph of the surface is shown in Figure 2. The covered area is 21% and the diameter of the spheres is 0.95μm. The PL signal normalized for the unetched area is shown in figure 2 along with the PL spectrum of the sample prior to etching. As one can see from the graph, normalized PL is 3 time smaller. From analysis of the diffusion equation in cylindrical coordinates, we deduce that the surface recombination velocity needed for such a reduction must be on the order of 10^5 cm/s, based on the assumption that radius of the mesas is smaller than the diffusion length. However, such a high surface recombination velocity may be caused by damage due to the ion beam, so that

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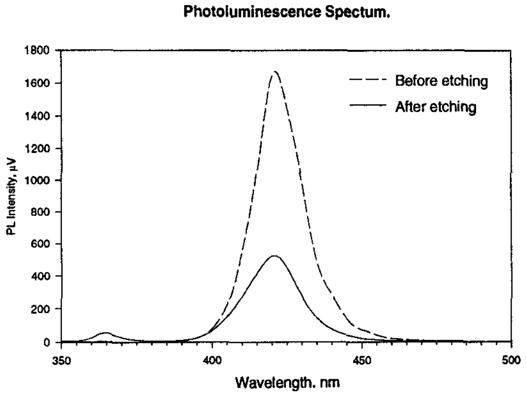

Figure 1: PL spectrum of the sample before (dashed line) etching and after (solid line). Spectra of the etched samples is normalized to accound for reduction in QW area due to etching.

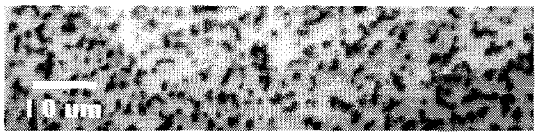

Figure 2: Photograph of the etched sample

another measurement will be needed following the cleaning of the surface with a photochemical etch.

In summary, we have developed a technique to make a consistent measurement for comparison between samples and provide an estimation of the internal quantum efficiency for GaN alloys. This technique provides a noninvasive tool for material growers to compare different materials. This procedure has also been applied to characterization of InGanAlP materials. Knowledge of surface recombination velocity are important for implementation of novel photonic bandgap structures which are limited by this mechanism.

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