Confocal Microscopy and TRPL Spectroscopy Study on Spatial Variation of PL in Blue-emitting InGaN/GaN MQWs

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Indium gallium nitride (InGaN) based light emitting diodes (LEDs) are of great interest to engineers and scientists, as a result of their advantages such as low energy consumption, small size, and good durability. Blue-emitting InGaN LEDs are usually made from InGaN/GaN multi-quantum wells (MQWs) epitaxially grown on *c*-plane sapphire substrate. Regardless of the high threading dislocation density (up to 10^{10} cm^{-2}) introduced by lattice mismatch, InGaN/GaN MQWs show high internal quantum efficiency. It is usually believed that the high efficiency is the result of nanoscale bandgap fluctuations in quantum well layer, which are caused by fluctuations in indium content [1] or well thickness [2].

In the present work, confocal microscopy and time-resolved photoluminescence (TRPL) spectroscopy were employed to study the PL spatial distribution and carrier lifetime in InGaN/GaN MQWs. Tested samples contained four-period MQWs grown on *c*-plane sapphire substrate using metalorganic chemical vapor deposition. Confocal microscope image, taken with a bandpass filter to collect near bandedge emission (NBE), show inhomogeneous PL distribution, as is seen in Fig. 1. PL spectrum taken at bright region and dark region show that bright region has not only larger PL intensity, but also red-shifted peak position, as is seen in Fig. 2. This shows that the bandgap in bright region is narrower than that in dark region. Since narrower bandgap can localize carriers and stop them from reaching nonradiative recombination centers, narrower bandgap region is brighter, as what is observed. By repeating the measurement on a group of samples grown under different conditions, it is seen that the average brightness of the confocal microscope image is related with the bandgap difference between bright region and dark region in the image, as is seen in Fig. 3. The larger the bandgap difference is, the brighter the image is, and as a result the brighter the MQW sample is.

TRPL was measured at both bright region and dark region of samples. Figure 4 shows the TRPL data for one sample. Effective PL lifetime was calculated based on the method introduced in Ref. [3]. Calculation shows that effective PL lifetime in bright region is longer than that in dark region, which supports our previous conclusion that there are less nonradiative recombination in bright region, based on the relation $1/\tau_{PL,eff}=1/\tau_R+1/\tau_{NR}$. It is also found out that MQW sample brightness is related with effective PL lifetime, as is shown in Fig. 5. Sample brightness increases when effective PL lifetime increases.

References:
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2. D. M. Graham, A. Soltani-Vala, P. Dawson, J. Appl. Phys., 97, 103508 (2005)
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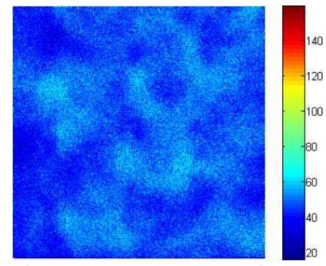

Fig. 1 Confocal microscope image taken on InGaN/GaN MQW sample with bandpass filter (445/40 nm) to collect NBE. Image is 20 µm × 20 µm.

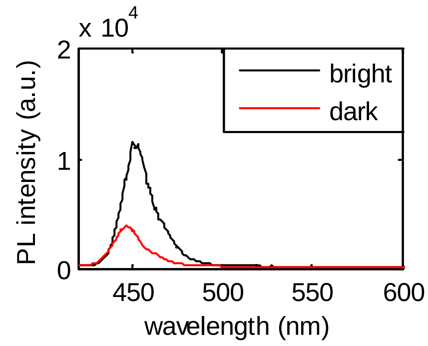

Fig. 2 PL spectrum of bright region and dark region in Fig. 1.

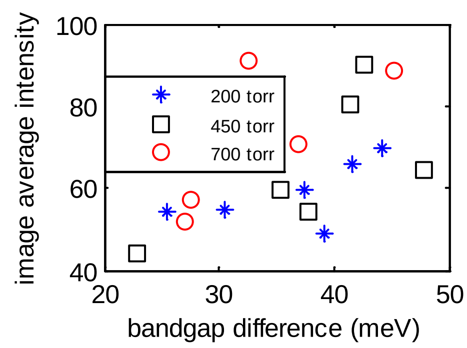

Fig. 3 Confocal microscope image average intensity vs bandgap difference between bright region and dark region. Different symbols shows MQW samples grown under different pressure.

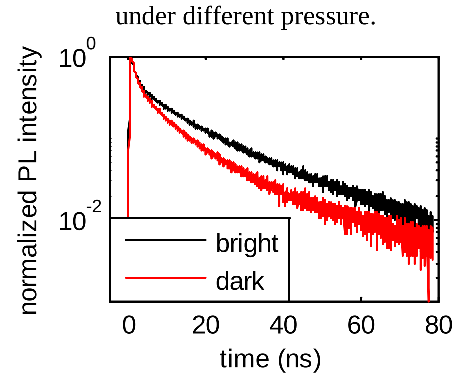

Fig. 4 TRPL of sample in both bright region and dark region.

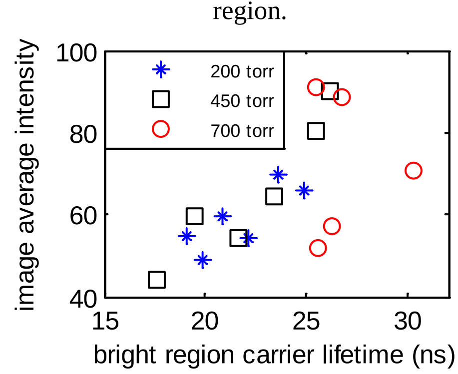

Fig. 5 Confocal microscope image average intensity vs bright region effective PL lifetime. Different symbols shows MQW samples grown under different pressure.