Field and Localization Effects in InGaN Quantum Wells

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The high efficiency of InGaN based devices has been attributed to localization of excitons in in-plane potential fluctuations due to compositional inhomogeneities [1]. It is also known that built-in fields caused by piezoelectric- and spontaneous-polarization play a large role in these materials [2]. We present cathodoluminescence (CL) and electron holography studies on a series of single InGaN quantum wells with different well widths (d) to investigate the effect of fields and localization.

The room temperature CL peak position is shown as a function of well width in Fig. 1. In general, the emission energy decreases with well width, which is as expected. However, for d=10nm the emission energy is higher than for d=8nm. This suggests that the electric fields are reduced when d exceeds 8nm. The electrostatic potentials across the quantum wells were measured using electron holography and the field across the well was obtained. The field as a function of well width is shown in Fig. 2 and is found to decrease with increasing well width. There are two possible explanations for the reduction in field with increasing well width. One possibility is that there is an increased screening of the fields with increasing well width. Another possibility is that the InGaN layers relax with increasing layer thickness.

Time-delayed CL spectra were taken for d=6nm and d=8nm, and the normalized results are shown in Fig. 3. The electron beam was switched on at -130ns and was switched off at 0ns. For d=6nm the emission peak red-shifts when the electron beam is switched on and when it is switched off. For d=8nm the emission peak blue-shifts when the electron beam is switched on and red-shifts when it is switched off. The blue-shift-red-shift behavior for d=8nm can be explained in terms of carrier screening. When the electron beam is switched on, the carrier density increases. This causes the fields to be screened and the quantum well tilt to be flattened (reduced quantum confined Stark effect). The emission therefore shifts to lower wavelength. When the electron beam is switched off, the carriers recombine and so the screening is reduced and the bands become tilted again. This leads to a shift to higher wavelength. Carrier screening cannot explain the red-shift-red-shift behavior observed for d=6nm. This can be understood by considering carrier localization in in-plane potential fluctuations. As time passes, the carriers will drop into the lowest possible potential minima and so a red-shift is observed regardless of the carrier density.

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References

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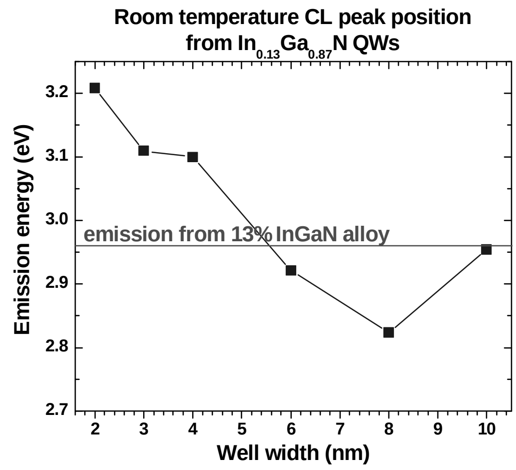

Fig. 1. Room temperature CL peak position versus well width. The shift to higher energy at 10nm suggests that the internal fields are reduced for large well widths.

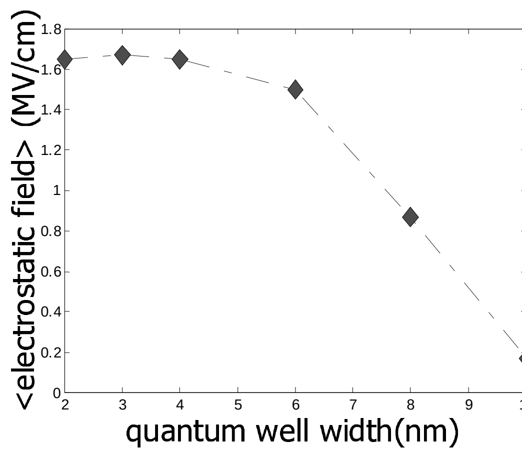

Fig. 2. Electrostatic fields obtained from electron holography decreases with increasing well width.

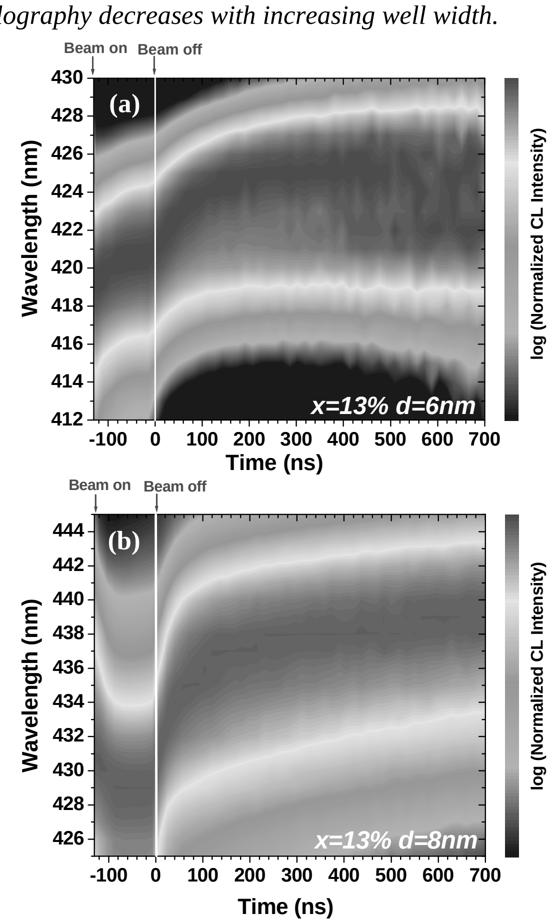

Fig. 3. Time delayed CL spectra for (a) d=6nm and (b) d=8nm. For d=6nm there is a red-shift when the electron beam is switched on and for d=8nm there is a blue-shift when the electron beam is switched on.