Ultrafast carrier dynamics in GaN bandtail states

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GaN and related materials have attracted a great deal of interest in recent years for their applications in light emitters/detectors in the green to ultraviolet (UV) wavelength regions [1]. Many research groups have devoted to the realization of blue-to-green light-emitting-diodes and laser diodes by using GaN related materials [1]. A fundamental understanding of the physical mechanism leading to stimulated emission and lasing in GaN is important. Recently there has been a considerable amount of attention focused on the role of the bandtail localized states on the stimulated emission and lasing process. Although there exists a sizable amount of data to support the strongly located states recombination as the mechanism leading to spontaneous emission in these materials, the reported results for stimulated emission are varied [2]. In this talk, we would like to report our studies of the carrier dynamics of these bandtail localized states in an unintentionally doped GaN thin film. While the deep localized states show isolated behaviors, the carriers in shallow bandtail states thermalize within 100 fs, indicating strong coupling with the above-bandgap states.

The GaN sample was grown by MOCVD on a doubleside polished c-plane sapphire substrate. After annealing the substrate and deposition of a nucleation layer, unintentionally doped GaN layer of 2 μm thickness was grown. On top of the 2 μm-thick layer, another 3 μm-thick GaN layer was deposited by lateral overgrown technique. A transmission measurement indicates that the fundamental bandgap of this sample is around 365 nm at room temperature. The studies were performed using femtosecond ultraviolet (UV) pulses frequency-doubled from the output infrared pulses from a Kerr-lens modelocked Ti:sapphire laser using a 500 μm-thick BBO crystal. 180 fs pulse-width was measured by using two-photon-absorption type autocorrelation in a bulk GaN sample [3]. We have first studied the distribution of bandtail states by open aperture Z-scan techniques [4]. Strong absorption saturation behaviors were observed at the foci of the Z-scan traces with 373-368 nm below bandgap UV pulses. The density of states σ of these bandtail states can thus be related to the measured effective negative two photon absorption coefficient β as $\beta \propto -\sigma / h\nu$ [4]. Figure 1 shows the measured β versus wavelength. A fitting (dashed line) with the bandtail states distribution described by Chakrabory and Biswas [5] using 70 meV impurity screening potential is also shown in Figure 1 for comparison.

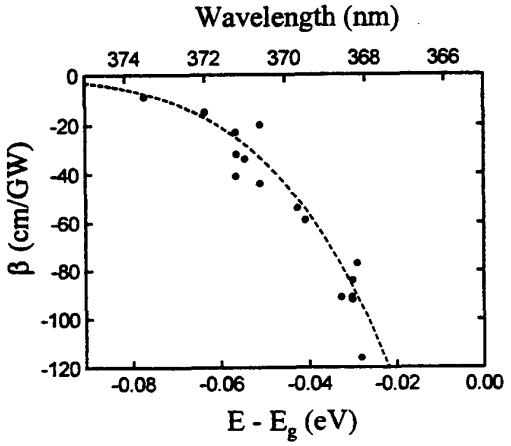

Figure 1. Measured absorption saturation versus wavelength using open aperture Z-scan techniques. The dotted line is a fit.

The carrier dynamics of the bandtail states were studied with UV femtosecond pulses by using standard pump-probe transmission measurements. A step like response (positive transmission increase) was observed for the measured trace using a wavelength longer than 380 nm. This indicates isolated carriers associated with deep bandtail states. However, when the wavelength was tuned to shallow bandtail states, fast transients appear. Figure 2 shows the measured transient absorption saturation using a wavelength of 370 nm. After the initial absorption saturation, a

fast relaxation on the order of or less than 300 fs was observed. This fast time constant should be attributed to the fast carrier thermalization within the high density bandtail states or even with the above-bandgap states. This fast process is followed by a slower process with a time constant on the order of 1.5 ps and a step-function-like response. The 1.5 ps component might be related to the redistribution of the carriers within the bandtail states or capturing into even deeper states. When we tuned our probing wavelength toward the deeper bandtail states, the initial fast component gradually disappeared and the time constant of the slower component got longer. Figure 3 shows an example transient absorption saturation trace measured using an intermediate wavelength of 374 nm. A longer decay time on the order of 5 ps was observed. This longer relaxation might be related to the capture of carriers into deeper localized states. More detailed analysis will be presented. This work is sponsored by National Science Council of Taiwan, R.O.C. under Grant No. 892112-M-002-003.

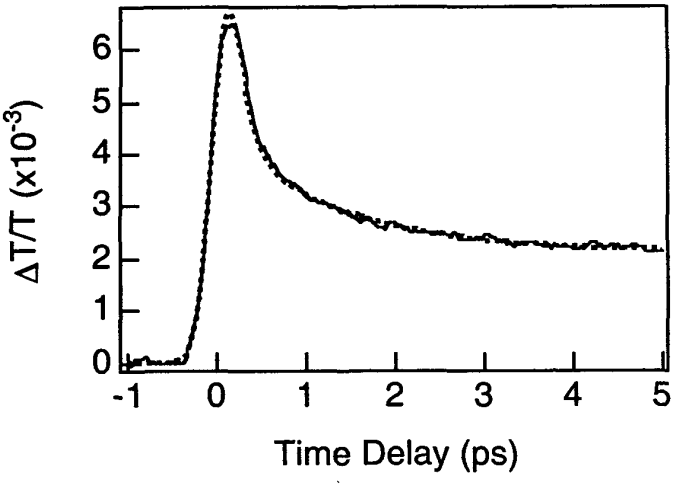

Figure 2. Measured transient absorption saturation at a wavelength of 370 nm. The dotted line is a convolution fit.

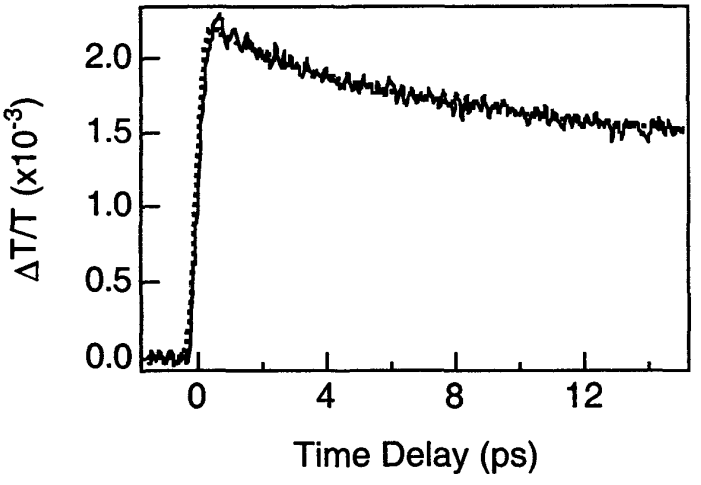

Figure 3. Measured transient absorption saturation at a wavelength of 374 nm. The dotted line is a convolution fit.

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