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FEMTOSECOND PUMP-PROBE STUDIES ON CARRIER DYNAMICS IN InGaN/GaN QUANTUM WELLS WITH INDIUM AGGREGATED QUANTUM DOT STRUCTURES

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Abstract—*Temperature-dependent pump-probe measurements were conducted for observing the process of carrier relaxation into localized states of quantum dots, which were formed through indium aggregation in InGaN/GaN quantum well structures of various parameters.*

Because of the large lattice mismatch between GaN and InN (up to 13 %), their miscibility is quite low, leading to the phenomena of indium aggregation and phase separation through the process of spinodal decomposition. The indium-rich cluster formation in InGaN compounds results in potential fluctuations and hence the effect of carrier localization. In this paper, we report the experimental results of fsec carrier dynamics based on pump-probe measurements of various InGaN/GaN quantum well samples with various quantum well widths, nominal indium contents, and under various thermal annealing conditions. Quantum dot structures in some of the samples have been confirmed with material analyses. Five samples of the same nominal indium content but different well widths at 2, 2.5, 3, 3,5, and 4 nm were prepared and referred to as samples w20, w25, w30, w35, and w40, respectively. The growth temperatures were 1010 and 720 °C for GaN and InGaN, respectively. As-grown samples were thermally annealed in a quartz tube furnace at different temperatures ranging from 800 to 900 °C in nitrogen ambient for 30 min. From the room-temperature probe intensity profiles of sample w25 annealed with temperature 800°C for 30 min under pumping at different wavelengths, one can see that at a wavelength (418 nm) within the PL spectrum, the transmission intensity drops slowly from its peak. The early-stage faster decay (with calibrated decay times shown in the figure) is supposed to be due to carrier relaxation through phonon interaction such that quasi-equilibrium condition is reached. The extended slower decay is attributed to carrier recombination under the quasi- equilibrium condition and its decay time is in the psec-nsec range. During this process, the interaction with acoustic phonons also occurs. At shorter wavelengths for pumping, carrier relaxation to lower energy states becomes faster and more significant. In these situations, the residual carriers become fewer. Fig. 1 shows the relative transmission intensity profiles of probe of the same sample pumped at 395 nm at various sample temperatures. It is interesting to see that the oscillations due to acoustic phonon interaction occur only in the temperature range from 100 to 150 K. Also, the LO phonon effect can be observed only when the sample temperature is below around 200 K. This phenomenon deserves further investigation. Furthermore, from Fig. 1 one can see that the level of extended slow decay decreases with increasing temperature. This trend can be attributed to the effective thermal relaxation of carriers into lower-energy states as the pump photon energy is much higher than the PL emission levels.

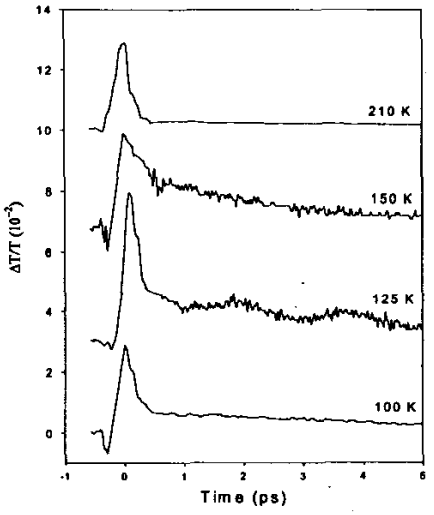

Fig. 1

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