Radiative and nonradiative recombination of m-plane GaN thin films

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We investigated the ultrafast time-resolved photoluminescence (TRPL) study of m-plane GaN thin films grown on γ-LiAlO2 substrates by molecular beam epitaxy. The TRPL was measured by a time-correlated single-photon counting instrument with temporal resolution of 150 ps using laser pulses of pulsewidth 100 fs and energy 4.5 eV from a Ti:sapphire laser. Three different N/Ga ratios of 57, 43, and 33 of GaN samples were studied in this work and designated as sample A, B, and C, respectively. The X-ray diffraction pattern verified that these samples grow along (1100) direction. Two major PL peaks were found in all the three GaN samples with different N/Ga ratios. One of the major peaks was contributed by defects. The PL at the band gap energy was found first blue-shift below 100 K and then red-shift as temperature increases. The measured PL lifetimes are in few nanoseconds at 14K and become as short as few hundreds picoseconds at room temperature.

The radiative ($\tau_r$) and nonradiative ($\tau_{nr}$) recombination times can be derived from measured lifetimes $\tau$ with the equation: $\tau^{-1}=\tau_r^{-1}+\tau_{nr}^{-1}$. We found that the internal quantum efficiency as well as the nonradiative recombination rate decreased with N/Ga ratio may be due to the large defect concentration in high N/Ga ratio. As shown in Fig. 2, the radiative recombination rate was constant below 100 K in all samples and was dependent on temperature with $T^{-3/2}$. The temperature dependence of radiative recombination time is consistent with theoretical prediction. The carrier localization, for both holes and electrons, is responsible for the blue-shift in PL spectra and constant of radiative rates below 100 K.