Excitation Mechanisms of Rare Earth Ions Embedded in GaN Thin Films

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The AlGaN material system has attracted much recent attention as an excellent host medium for rare earth elements (RE). Thin films doped with Er, Eu, Tm, etc. have been processed into visible (blue, green, red) and infrared electroluminescent devices. These prototype devices are currently being studied for possible applications in full color displays and in optical communications. We have performed a systematic study of the optical and electronic excitation of various Er and Eu ions in GaN thin films. The RE ions were incorporated into the films through in-situ doping during molecular beam epitaxy. The GaN:RE samples exhibited a variety of emission lines in the visible and infrared regions. Three different mechanisms have been observed for optical excitation of the RE ions: above-bandgap pumping through the generation of electron-hole pairs, below- bandgap resonant pumping of the 4f levels, and below-bandgap non-resonant pumping through defect levels in the films. The different optical excitation techniques lead to different emission spectra and to different thermal quenching characteristics of the visible and infrared luminescence. For example, above-gap pumping of GaN:Er thin films produced green (537nm) and infrared (1535nm) emission spectra. The infrared emission lines (1535nm) exhibited less than a 10integrated PL intensity from 10K to 500K. However, the integrated PL intensity of the green emission lines showed a 40room temperature. The integrated PL intensity of red emission from GaN:Eu decreased even more rapidly (factor of 20) over the same temperature range. Temperature dependent lifetime measurements suggest that non- radiative decay processes only weakly affect the intra-4 luminescence of both systems at room temperature. A comparison of the emission characteristics under optical and electronic excitation will be discussed along with the luminescence dynamics and implications for electroluminescence device applications.