Rare Earth-Doped III-N p-i-n Light-Emitting Diodes

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We report on the successful synthesis and demonstration of rare earth (RE)-doped III-N *p-i-n* light-emitting diodes (LEDs). The device structures were grown through a combination of metal-organic chemical vapor deposition (MOCVD) and molecular beam epitaxy (MBE) on c-plane sapphire substrates. The AlGaN layers, with an Al concentration of ~ 12%, were prepared by MOCVD and doped with Si or Mg to achieve the n-type and p-type conductivity, respectively. The thickness of RE-doped GaN active regions, grown by MBE, ranged from 5 nm to 200 nm. Both Er and Eu rare earth-doped LEDs were fabricated. Doping concentration was estimated to be ~ 10^{18}-10^{19} cm^{-3}. The dual stage growth process was used to take advantage of the high quality of AlGaN layers produced by MOCVD and the *in situ* doping of Er or Eu during MBE growth. The multilayer structures, n-AlGaN/GaN:RE/p-AlGaN, were processed into LED devices using standard etching and contacting methods. A variety of LEDs with different sizes and geometric shapes were produced and tested under both forward and reverse bias conditions. Typically, the emission under reverse bias was 5-10 times more intense than that under forward bias. The LEDs displayed a number of narrow emission lines representative of the GaN:Er or the GaN:Eu system. While some current crowding was observed in the LEDs, visible emission was observed under ambient room conditions at 300 K. Emission spectra were recorded down to 10K and the intensity of all the emission peaks increased as the temperature was lowered. The L-I and I-V characteristics were systematically measured. The power output of the brightest LEDs was approximately 2.5 W/m^2 at 300 K. From the L-I characteristics the product of effective excitation cross-section and lifetime of GaN:Er LEDs was determined to be ~ 3.3x10^{-22} cm^{2}s. Using an experimental value of ~ 120 μs for the decay of the visible emission, excitation cross-section was estimated as ~ 3x10^{-18} cm^2 which is smaller than that in Er-doped SiO$_x$ based devices. Dislocations and carrier traps of the III-N materials may have reduced the estimated cross-section. In this talk we will also discuss visible displays implications of these LEDs.