Growth, Characterization, and Application of High Power III-Nitride Ultraviolet Emitters

Jung Han, S. –R. Jeon, M. Gherasimova,
Yale University, New Haven CT 06520
Y.-K. Song, and A. V. Nurmikko
Brown University, Providence RI 02912
L. Zhou, W. Goetz, and M. Krames
Lumileds Lighting, LLC
San Jose, CA 95131

The intense attention in III-nitride research towards ultraviolet light emitting diodes (UV LEDs) with emission wavelength below 360 nm is fuelled by applications including chemical/biochemical analysis, solid-state lighting, high-density optical storage, and covert communication. We report on the design, growth, and fabrication of high power UV LEDs in the 320-340 nm range whose capabilities and utility have been demonstrated in their application to time-resolved fluorescence spectroscopy of organic and biomolecules on sub-nsec time scale. Quaternary AlGaInN multiple quantum well active regions are embedded into AlGaN p-n diodes, which are grown on AlN buffer layers on c-axis sapphire substrates. Structural characterizations performed using AFM, XRD, and TEM underline the importance of AlN buffer layers. Time-resolved photoluminescence (PL) from cryogenic to room temperatures (RT) is employed to probe the recombination mechanisms and efficiency of the quantum wells. An increase of PL decay lifetime during initial temperature rise suggests a substantial presence of radiative recombination; subsequent decay of lifetimes toward RT is relatively small and a lifetime on the order of 450 psec is typically observed at RT. Devices with optical apertures ranging from 10-100 um were fabricated and flip-chip mounted for high power cw measurements. Near 340 nm wavelength (Fig 1), we have measured output powers of 1 mW for 50 um device aperture at current densities of 0.8kA/cm^2 directly (perpendicular) off the chip, corresponding to an extrapolated internal quantum efficiency of 10%. Fully packaged, large-area chips (1x1 mm2) with heating sinking and encapsulation exhibit more than 50 mW of optical output at a current level of 1 Amp (Fig 2). The LEDs have been configured into high-speed operation by integrating them with a microwave strip line electrode configuration, whereby a device response of approximately 0.4 nsec has been measured at room temperature. Consequently, these high speed compact UV LED sources have been used to demonstrate time-resolved spectroscopic performance with organic (coumarin dyes), as well as the key biomolecule NADH, whose fluorescence decay time of approximately 0.5 nsec has been measured, influenced by the solvent environment (Fig 3). The result suggests that, at their present status of development, the sub-350 nm LEDs are nearing fruition in their integration as inexpensive, compact sources in UV-based photonic instrumentation. We will also discuss results in UV LED operation at 280 nm for Tryptophan detection, as well as the effort of using nanostructured active region from AlGaN.

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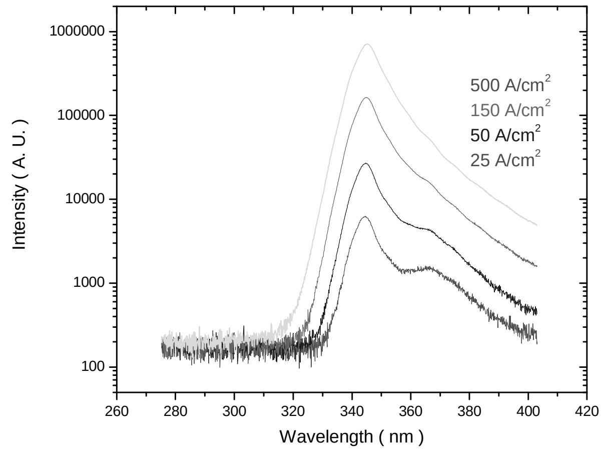

Figure 1. LED spectrum at different injection levels.

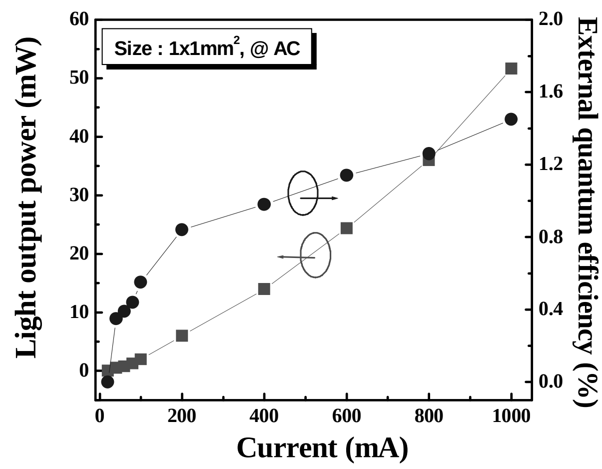

Figure 2. L-I of a fully packaged, large area LED.

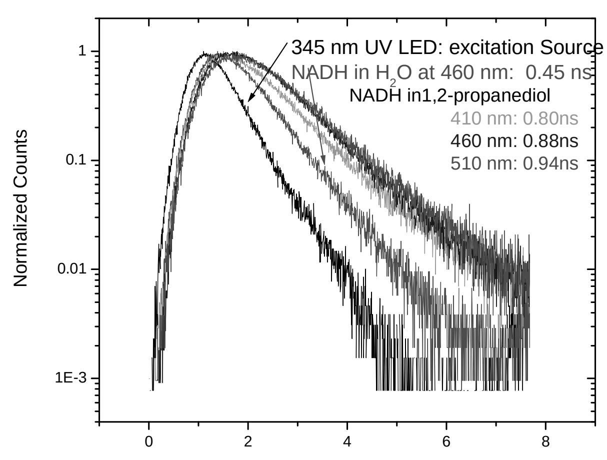

Figure 3. Time resolved fluorescence from NADH excited by 340 nm LED.