Deep UV LEDs for Fluorescence-based Detection of Biological Agents

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Motivation—Optical sources with emission from 280 - 340 nm are actively being sought for fluorescence-based detection of biological agents such as anthrax. Semiconductor sources emitting at these short wavelengths, although not currently available, would enable a new generation of light weight, low cost chem/bio detectors and hand-held detection systems. Although nitride-based emitters are currently the most promising candidates for emission below 300 nm, significant improvements in device output power and lifetime are still needed.

Accomplishment—LEDs with emission at 280 nm require the growth of AlGaN layers with Al concentrations of 50% or more. Compared to GaN, AlGaN layers grown on sapphire typically have higher densities of threading dislocations, lower mobilities, and lower n- and p-type doping levels. Although considerable progress has been made in the growth of AlGaN alloys, our LED epitaxial structure and device processing is designed to minimize the impact of these materials issues.

As shown in Fig. 1, our UV LEDs are designed with transparent base layers for improved light extraction. The n-AlGaN layer is grown as thick as stress will allow without cracking (1 mm) in order to improve lateral current spreading. The active region contains five 2.8 nm $Al_{0.36}Ga_{0.64}N$ quantum wells with $Al_{0.47}Ga_{0.53}N$ barrier layers. The p-side of the device includes a p-$Al_{0.47}Ga_{0.53}N$ layer that is graded down to a p-GaN contact layer. Although the p-GaN is absorbing below 370 nm, this layer has a much higher hole concentration than can be achieved with p-AlGaN, which results in better p-contacts and lower overall device voltage.

LED devices are fabricated using standard optical lithography to define features. Inductively-coupled plasma etching is used to expose the n-AlGaN for n-contact deposition. The top of the LED mesa is fully covered by the p-contact so that lateral transport through p-type material is not required. As shown in Fig. 2, interdigitated contacts are used to reduce the lateral current spreading distance in the n-AlGaN layer resulting in lower device voltages. LEDs are flip chip bonded to Si or SiC submounts which, in addition to improving light extraction, also helps with heat dissipation.

Electroluminescence spectra for an LED emitting at 295 nm are shown in Fig. 3. The defect emission at 330 nm, which is undesirable for fluorescence-based sensing, is 25 times weaker than the 295 nm emission (100 mA data). Further work is needed to eliminate this deep level contribution. As shown in Fig. 4, this 295 nm LED has an output power of 366 μW (CW) at 100 mA at 14.6 Volts, which is the highest power reported from a single device in this wavelength range. Recent effort towards shorter wavelengths has resulted in LEDs with emission as short as 275 nm.

Significance—LEDS with emission from 280 - 340 nm will enable handheld fluorescence-based chem/bio detectors with a low false alarm rate and excellent discrimination against common materials such as fuel fumes and exhaust. UV LEDs may also be used for nuclear materials detection, non-line-of-sight communication, as well as purification and sterilization applications.

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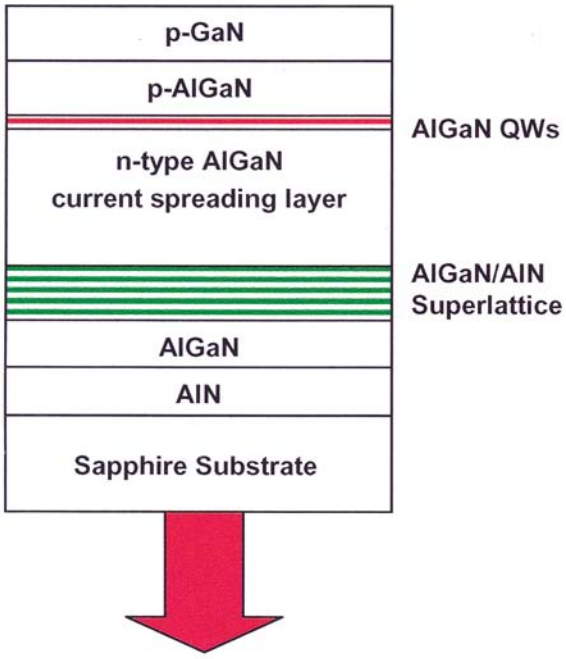

Figure 1. Schematic showing the structure used for the 295 nm LED. This bottom emitting structure utilizes transparent AlN and AlGaN base layers for improved light extraction through the sapphire substrate.

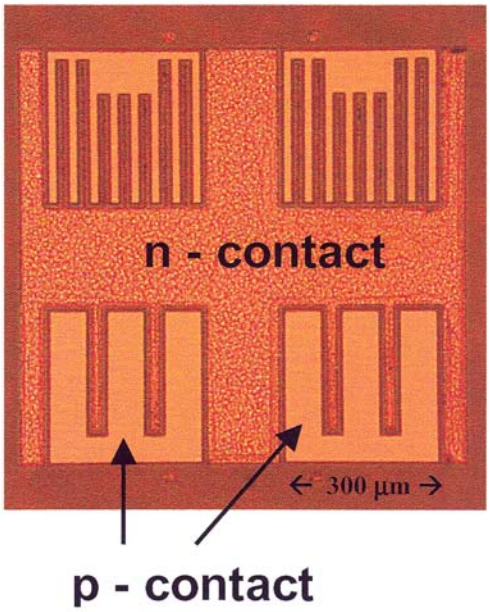

Figure 2. Optical microscope image showing two LED designs with interdigitated contacts. The thin fingers reduce the distance that current must spread through the n-AlGaN, which leads to reduced device voltages.

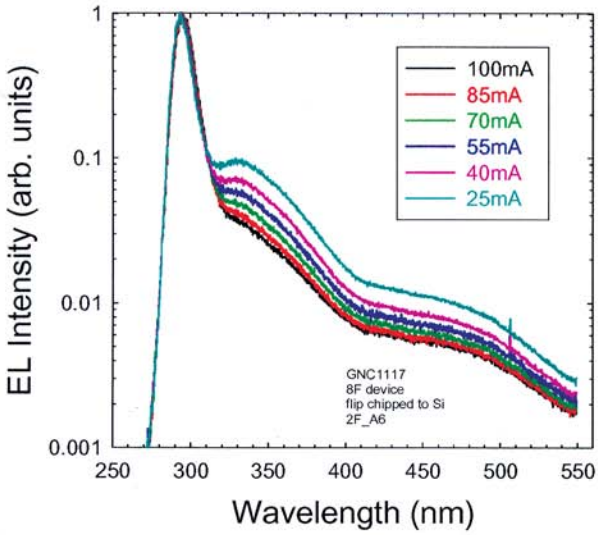

Figure 3. Normalized electroluminescence intensity showing emission at 295 nm. At 100 mA, the defect emission (330 nm) is 25 times weaker than the QW emission (295 nm).

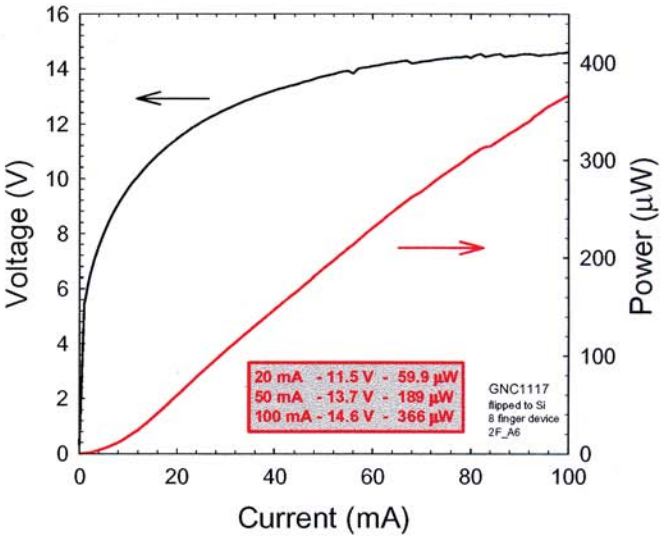

Figure 4. Light output power vs. current and current vs. voltage curves for a 295 nm LED. The maximum measured output power is 366 µW (100 mA, 14.6 V).