AlInGaN-based Deep Ultraviolet LED Technology

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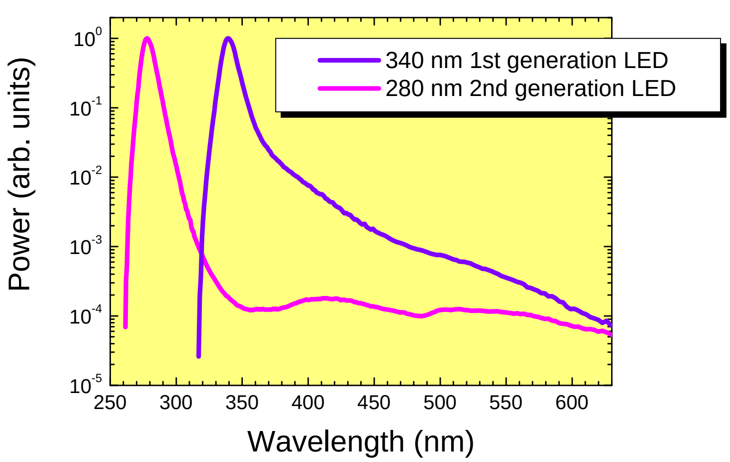
Abstract

Sensor Electronic Technology, Inc. (SET, Inc.) is emerging as a leading commercial supplier of Light Emitting Diodes (LEDs) with peak emission wavelengths below 365 nm. Recently, we have demonstrated 280 nm wavelength LEDs with the record 0.9% wall-plug efficiency capable to deliver CW power of 2 mW at 50 mA [1] current with maximum pulsed power up to 49 mW at 1.3 A current and 10 mW pulsed power at 265 nm wavelength. [2]

We will present our results on the development of Light Emitting Diodes (LEDs) with peak emission in the range from 265 nm to 365 nm and scale-up of this technology to 2" diameter wafers for volume manufacturing.

INTRODUCTION



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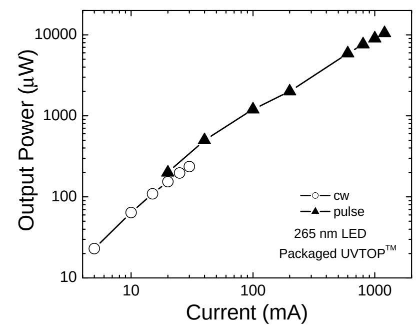
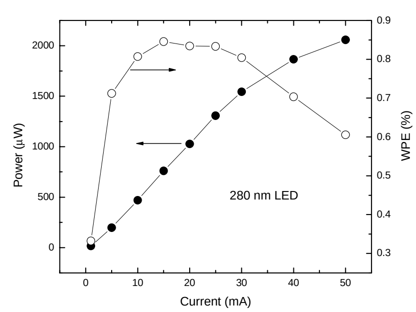


(b)

(c)

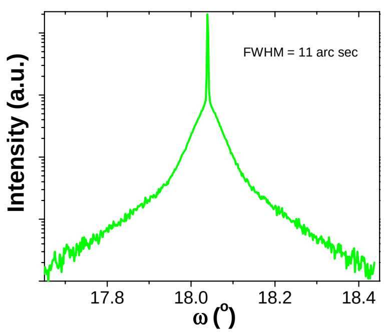


(d)

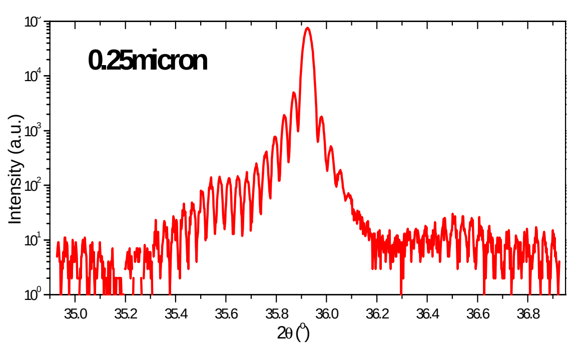
Fig. 1. (a) Electroluminescence spectra of 340 nm and 280 nm LEDs; (b) Output power of 265 nm LEDs; (c) UVTOP® with flat window packaging; (d) Output power and wall-plug efficiency of 280 nm UVTOP® devices

SET, Inc is developing deep ultraviolet LEDs (DUVs) technology using company's proprietary epitaxial growth tools capable to combine conventional MOCVD and novel Migration Enhanced MOCVD (MEMOCVD™) techniques. These growth tools are uniquely suited for deposition of high Al-content AlInGaN-based materials and heterostructures required for DUV fabrication. Technology scale-up to 2" diameter wafers has been followed by the transition to multi-wafer manufacturing using newly developed SET, Inc. MEMOCVD™ reactors with 3 x 2" capability.

The epitaxial AlN layers grown on sapphire substrates using our novel MEMOCVD technique demonstrated significantly improved material quality with FWHM of X-ray rocking curve measured along (002) less than 10 arcsec. Room temperature photoluminescence of AlN epitaxial nlayers exhibited, for the first time, emission line at 203 nm (6.11 eV), which is only 100 meV lower then a theoretical value of the energy band gap of bulk AlN.



(a)



(b)

Fig. 2. X-ray data for AlN buffers grown on (0001) sapphire substrates: (a) ω Scan along (002); (b) - 2θ - ω Scan along (002)

High quality AlN buffers enabled us to significantly improve the material quality and doping characteristics of AlGaN and AlInGaN contact layers and heterostructures in the active regions of the devices.

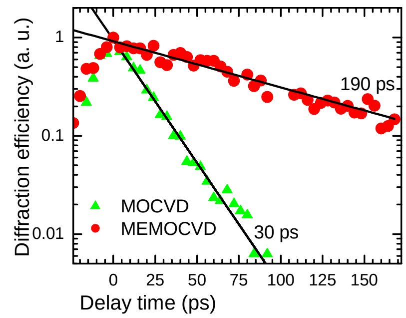


Fig. 3. Nonequilibrium carrier lifetime measurements in 26% AlGaN epitaxial layers using light-induced transient grating method. The layers grown over MEMOCVD AlN buffers exhibit carrier lifetimes more that six times longer than over conventional MOCVD AlN (30 psec). This points to a higher materials quality of AlGaN grown on MEMOCVD AlB buffer.

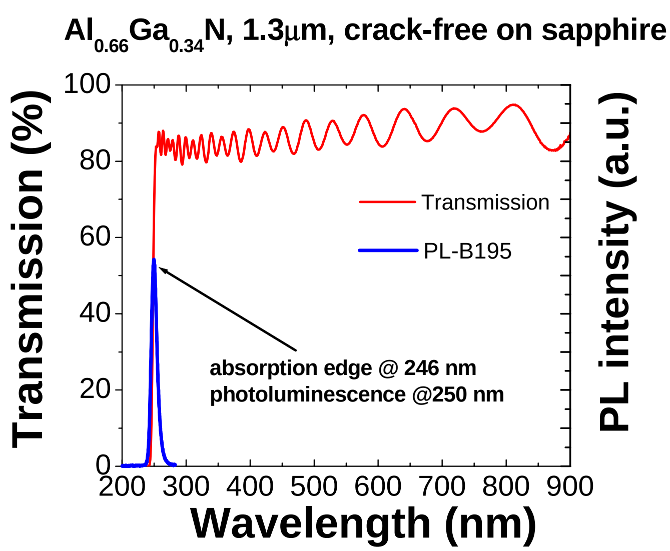


Fig. 4. Optical transmission and photoluminescence spectra of 66% n-type AlGaN grown on sapphire substrate using MEMOCVD growth technique.

We optimized growth regimes and conditions for deposition of doped high Al-content AlGaN layer with up to 70% of Al. We were able to achieve n-type doping of 66% AlGaN as high as $7x10^{17}$ cm^{-3} with electron Hall mobility close to 20 cm^2/Vs (Fig. 4).

SET, Inc. started sampling DUV LEDs under registered trademark UVTOP®. These light sources are expected to find numerous applications in bio-sensing, DUV spectroscopy and water and air purification/sterilization.

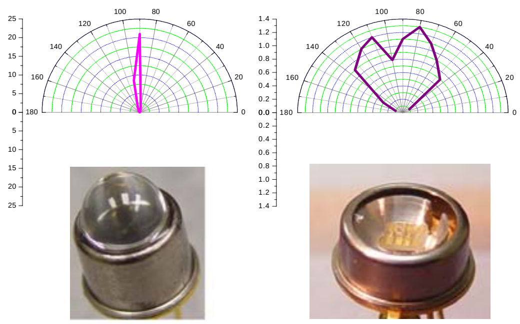


Fig. 5. Angular diagrams of two packaging solutions developed at SET, Inc. for deep UV LEDs with peal emission wavelengths in the range from 265 nm to 365 nm

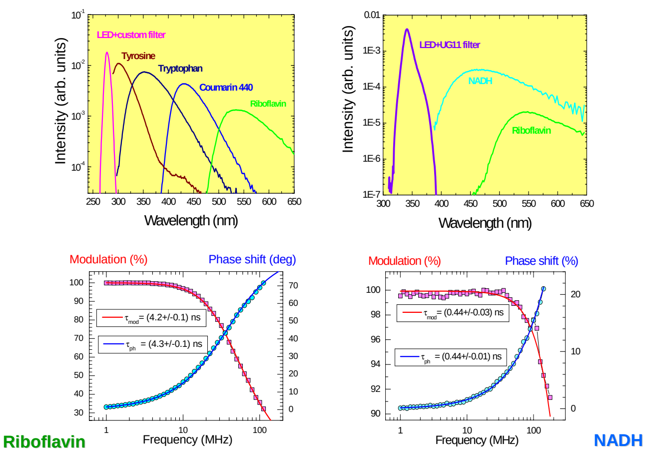


Fig. 6. Fluorescence lifetime measurements using 340 nm and 280 nm LEDs in frequency-domain spectroscopy [3]

Deep UV LEDs were used to demonstrate frequency-domain fluorescence lifetime measurements in a series of basic biological autofluorophores. Use of a harmonically modulated source for fluorescence excitation allows measurement of fluorescence lifetime by simple comparison between the excitation and fluorescence signals phase and modulation depth.

Our results demonstrate that a set of two UV LEDs (a 340-nm LED for coenzymes NADH and riboflavin and a 280-nm LED for aromatic acids tyrosine and tryptophan, respectively) can be used for real-time characterization of fluorescence decay profile in most biological agents. As seen from Fig. 6, although fluorescence spectra of NADH and Riboflavin are similar, the extracted fluorescence lifetimes for Antrax stimulant NADH was approximately 0.44 nsec whereas lifetime for riboflavin was almost ten times longer and close to 4.3 ns. Such characterization can find applications in compact UV-fluorescence based tools, for instance, those for sensing of airborne biological pathogens.

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ACRONYMS

DUV: Deep Ultraviolet
LED: Light Emitting Diode
MOCVD: Metal Organic Chemical Vapor Deposition
MEMOCVD: Migration Enhanced MOCV