

Far UVC LED Project

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Primary CNF Tools Used: Heidelberg MLA, Angstrom e-beam evaporator, PT770 etcher, GCA i-line stepper

Abstract:

Far UVC light (~ 222 nm or ~ 5.6 eV) is excellent at disinfecting the air and surfaces indoors, while being relatively harmless to humans. Light emitting diodes (LEDs) are efficient devices with a small footprint; they can be made to be $\sim 10\times$ to $100\times$ smaller than the width of a human hair. There are several challenges in realizing far UVC LEDs requiring. Thus, developing and researching these devices has far reaching implications and relevance for disinfection technology. At the CNF, we are developing a process for AlGaIn based p-n diodes on bulk AlN substrates towards far UVC LEDs for commercial disinfection applications.

Summary of Research:

LEDs are p-n diodes which involve direct bandgap semiconductors, typically crystalline in nature. To emit in the ~ 5 eV to 6 eV range, aluminum gallium nitride (AlGaIn) is an excellent material candidate with widespread research already existing particularly in the UV A,B,C regimes (235 to 400 nm) [1-3]. In this project, we developed a process to turn crystalline material epitaxially grown at Visium Ultralabs into fully functional LEDs at the CNF, starting with wavelengths in the far UV-C (200 nm - 235 nm) regime. The cross section of the epitaxially grown structure is shown in Figure 1.

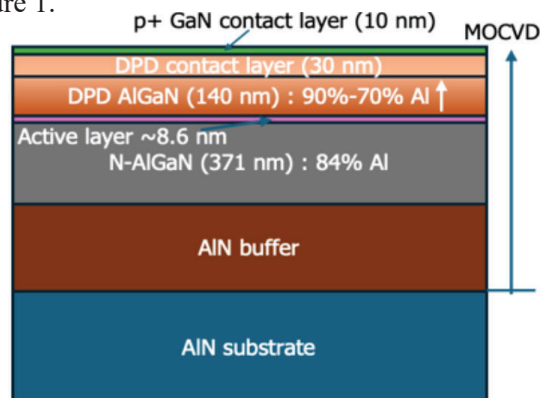


Figure 1: Cross section of epitaxially grown LED heterostructure based on aluminum gallium nitride (AlGaIn).

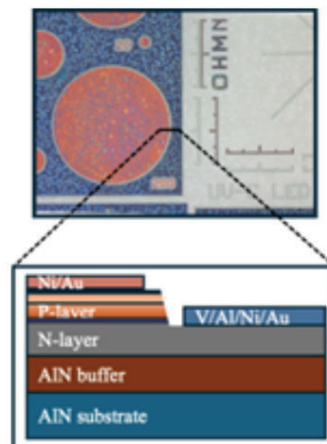


Figure 2: Top view optical image of LEDs and cross section schematic.

The structure essentially comprises p-type and n-type AlGaIn layers with high Al composition ($>70\%$ on average across the thickness) grown on an AlN substrate. These substrates provide a wide range of advantages including low dislocation density, superior thermal management, and high crystal quality. The structure was then processed in the cleanroom by dry etching, metal deposition by electron beam evaporation and rapid thermal annealing to form LEDs as indicated in Figure 2. Here, a top view optical image along with a cross section is shown. Subsequently, these LEDs were tested by electrical probing and the current-voltage (I-V) characteristics are shown in Figure 3. The diode seems to exhibit a turn ON voltage between 5-6 V, characteristic of high-quality high AlGaIn p-n diodes. The reverse leakage is also exceptionally low, with the current close to the noise floor of the instrument over a wide range of voltages. Subsequently, these diodes were tested for electroluminescence by flowing different currents and observing the light emission spectrum which is shown in Figure 4. These LEDs made at the CNF are a great initial demonstration of functionality and are the first of many more to come.

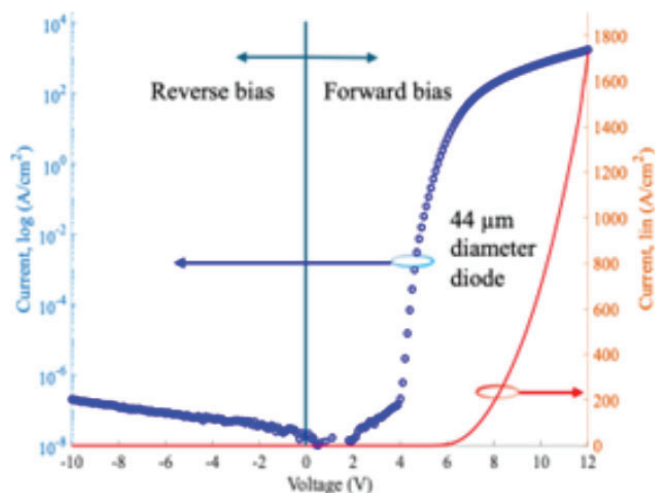


Figure 3: Current-voltage (I - V) characteristics in the log (left) and linear (right) scales, showing low reverse leakage and high on current.

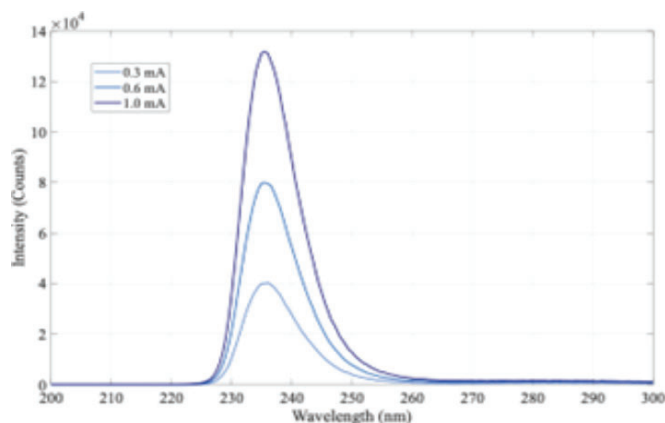


Figure 4: Electroluminescence spectra at different current injection for the processed LEDs.

Conclusions and Future Steps:

We have demonstrated functional LEDs emitting in the UV-C regime, a significant step towards developing efficient ~ 222 nm emitting devices for disinfection. Ongoing effort and future work involve wafer-scale processing of LEDs on AlN substrates, optimization of n-type and p-type contacts, and packaging.

References:

- [1] Dabing, et al. Adv. Opt. Photonics. 10.1 (2018): 43-110.
- [2] Kneissl et al. Nat. Photonics. 13.4 (2019): 233-244.
- [3] Jing, et al. Adv. Electron. Mater. 11.1 (2025): 2300840.