Tunable Picosecond AlGaN UV Photodiodes

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Efficient and ultrafast UV photodetection is needed when characterizing high-temperature plasmas and ultrashort UV laser pulses. Semiconductor-based photodetectors (PD's) have not been widely used for these applications because of their reduced absorption depths in the UV spectrum, making streak cameras the dominant choice in the industry. A new category of photosensors built on $Al_xGa_{(1-x)}N$ (where x varies from 0 to 1) alloy provide tunable band gaps in the entire UV spectrum. Changing x varies from 0 to 1 and adjusts the band gap from 361 nm to 200 nm. Consequently, one can select the spectral window of interest for photosensing.

Laterally oriented AlGaN thin films were used to fabricate photodetectors with interdigitated electrodes.[1] These detectors recorded <30-ps response times, making them suitable for diagnosing ultrafast UV laser pulses and laser–plasma interactions.

This summary reports the outcomes of the spectral studies of detectors fabricated on different $Al_xGa_{(1-x)}N$ thin films where x is 0 to 0.3 (Ref. 1). Measured spectral responsivities are in the range of 0.43 A/W, which is comparable to other semiconductor-based detectors in the visible and infrared regions like silicon and InGaAs. High-quality semiconductors are critical for achieving these results, hence material characterization with x-ray diffraction is recommended prior to fabrication. The University of Rochester is in collaboration with Sydor Technologies to make these detectors available to the public. Some of the AlGaN PD's reported in Refs. 1 and 2, as well as newly fabricated GaN (x = 0) PD's with the same design parameters given in Ref. 1, were investigated for a comparison of their spectral selectivity profiles. The objective of this investigation was to determine the spectral responsivity and the ultrafast characteristics of our $Al_xGa_{(1-x)}N$ detectors with x ranging from 0 to 0.3

Figure 1 portrays the temporal response of a Au intrinsic $Al_{0.1}Ga_{0.9}N$ circular asymmetric (CA) device under study and a silicon reference PD at 260 nm under 20-V bias voltage. The voltage response of the AlGaN detector was 1.4 V with a 33-ps rise time

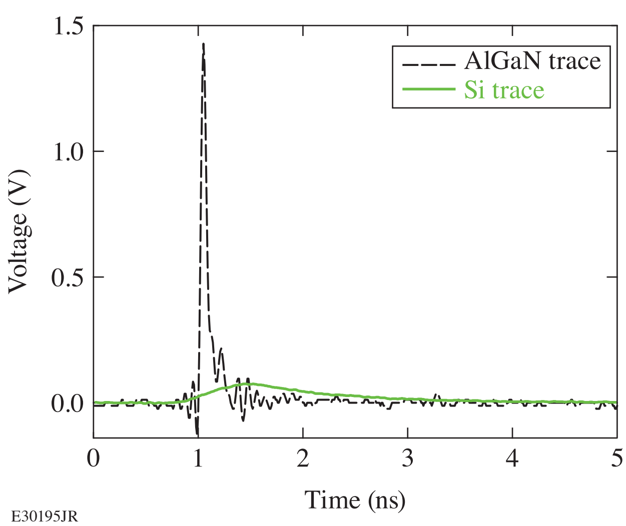

Figure 1
Au intrinsic $Al_{0.1}Ga_{0.9}N$ CA device response (black curve) under 20-V bias and Si reference detector (green curve) at 260 nm with rise times of 33 ps and 430 ps, and FWHM of 60 ps and 1.2 ns for AlGaN and Si PD's, respectively.

and a 60-ps full width half maximum. The pulse width of the device's temporal response increased from 26 ps (the resolution of the 12.5-GHz Tektronix oscilloscope) to 60 ps because of the delays introduced by the measurement system.[3]

The spectral responsivity of another AlGaN device that had 10% Al and rectangular asymmetric (RA) Pt (Ref. 1) metal contacts is depicted in Fig. 2. This detector's responsivity peaked at 315 nm with 0.43 A/W and a rapid cut off at 360 nm. The high responsivity supports the recorded external quantum efficiency of these photodiodes reported in Ref. 1. The responsivity dropped at shorter wavelengths because the absorption depth of photons within the AlGaN thin film reduced from 77 nm at 280 nm to 48 nm at 240 nm.

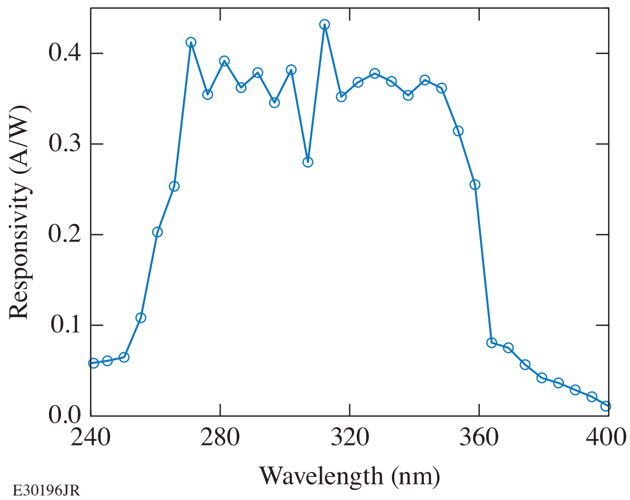

Figure 2
Pt intrinsic $Al_{0.1}Ga_{0.9}N$ RA device with spectral responsivity at 10-V bias voltage with peak responsivity of 0.43 A/W at 315 nm.

The spectral responsivity properties of another AlGaN UV PD that has 20% Al with CA Au metal is presented in Fig. 3. The data were measured under a 10-V bias voltage. This detector exhibited a maximum spectral responsivity of 0.033 A/W at 280 nm and a rapid cut off at 300 nm. The rising Al content implies that this diode will sense only deep UV wavelengths but a factor of 10 decrease in responsivity is recorded at 280 nm.

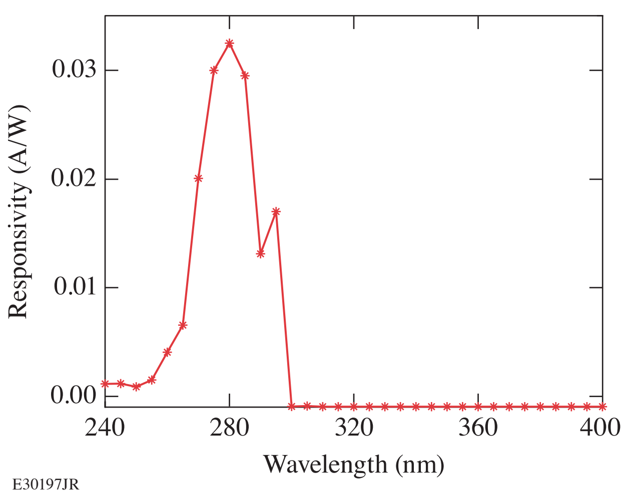

Figure 3
Au intrinsic $Al_{0.2}Ga_{0.8}N$ CA device with spectral responsivity at 10-V bias voltage with maximum responsivity of 0.033 A/W at 280 nm.

Summing up, the spectral responsivity of our AlGaN UV detectors in a metal–semiconductor–metal configuration was discussed. The results demonstrated that the applicability of AlGaN-based UV detectors in high-energy investigations of laser–plasma interactions, which have multiple sources of light in close proximity, require ultrafast and efficient UV photodetection. Finally, it is necessary to carefully select the Al composition that meets the spectral window that needs to be sensed as this determines if the realized PD will meet the application requirements.

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1. S. F. Nwabunwanne and W. R. Donaldson, IEEE J. Quantum Electron. **57**, 4000608 (2021).
2. S. Nwabunwanne and W. Donaldson, Proc. SPIE **12001**, 120010F (2022).
3. Y. Zhao and W. R. Donaldson, J. Mater. Res. **33**, 2627 (2018).