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SOLAR-BLIND QUANTUM WELL UV HEMTS

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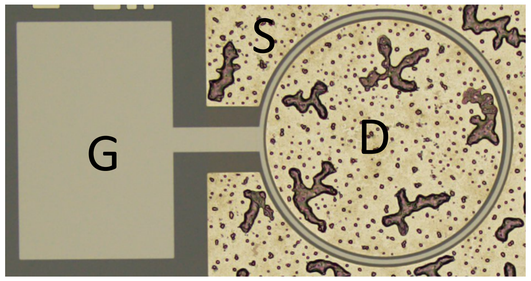
Abstract

The ability to detect ultraviolet (UV) wavelengths is of considerable interest for national security applications such as biological agent detection and communications. Although a wide range of materials have been used for this purpose, gallium nitride (GaN) and aluminum gallium nitride (AlGaN) are particularly promising. These materials have wide band gaps that are sensitive to ultraviolet wavelengths while being blind to less energetic light (commonly referred to as "solar-blind"). In addition, GaN and AlGaN are thermally robust can be used at higher temperatures compared to other UV sensitive materials.

The state of the art (SOA) approach to microelectronic UV detectors is to use silicon (Si) as the photoactive material. However, there are drawbacks to using Si as the UV photoactive material. At higher temperatures Si based sensors have a higher leakage current. Additionally, to achieve solar blindness in Si sensors, an external filter is needed to block the unwanted wavelengths from interacting with the Si and generating an electrical signal.

We present here a prototype detector that demonstrates good performance as an inherently solar blind photodetector.

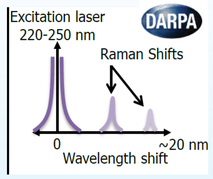


Top view of device

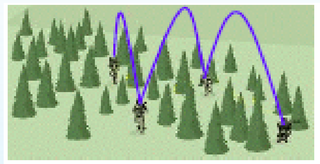
Motivation:

Solar blind UV detection is important for applications such as radio and biological agent detection.

Raman Spectroscopy
(biological agents)



Communication
(radio)

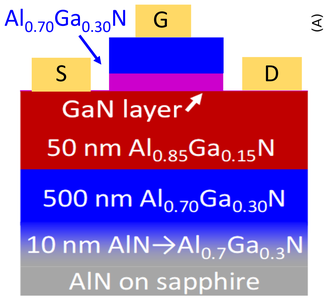


Solar Blind: 4.4eV-6.2 eV

Sample details

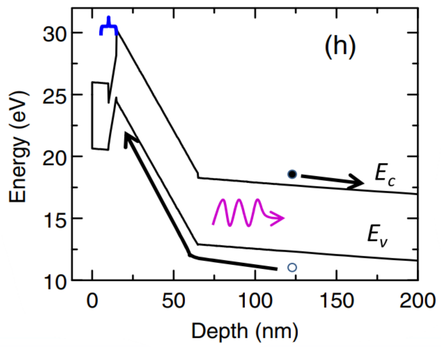
- Grown by Metalorganic Chemical Vapor Deposition (MOVCD) at Sandia National Laboratories on sapphire substrate

Material	Å	n/p	C.C
$Al_{0.68}Ga_{0.32}N$	100	uid	x
GaN	20	uid	x
$Al_{0.85}Ga_{0.15}N$	600	n	6.0E18
$Al_{0.68}Ga_{0.32}N$	5000	uid	x



- Ohmic Metal Stack: Ti/Al/Ni/Au (150/1000/150/500 Å) annealed for 30s at 1000 C in NV.
- Gate metal: 80 Å Ni

GaN Quantum Well

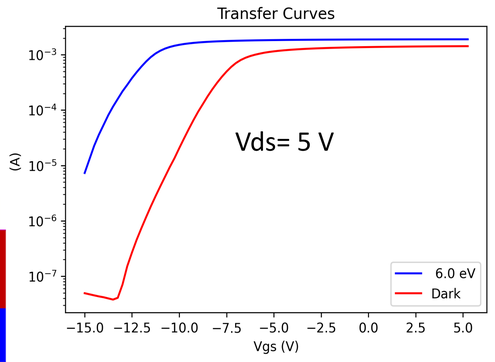


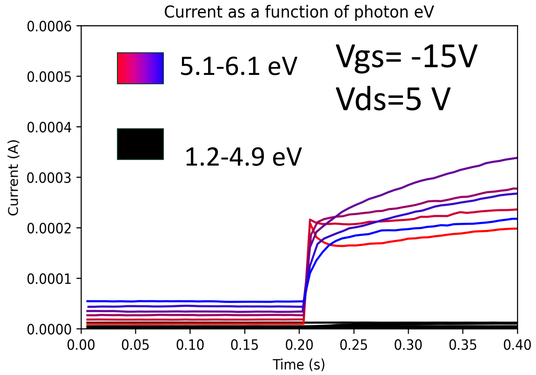
$Al_{0.85}Ga_{0.15}N$ acts as the photoactive layer; excitons separate and holes are captured at the $Al_{0.85}Ga_{0.15}N$/GaN interface. This results in the device being turned to the on state if incident photons are sufficiently energetic. If incident photons do not have adequate energy, then device remains in the off state.

Test setup

- Device is biased in the off state (Vgs=-15 V, Vds=5 V) and illuminated for 6 s.
- All devices tested in a dark room at room temperature (20 C).
- Light source: 150 W Xe lamp with ¼ m monochromator

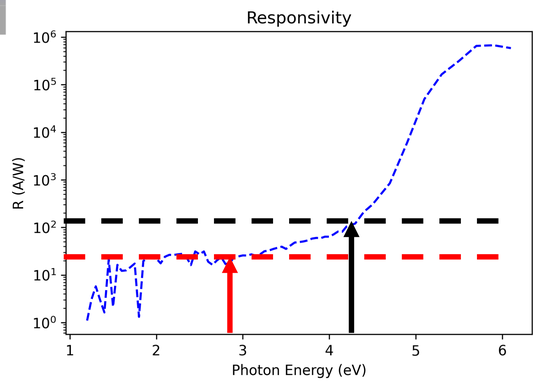
Results

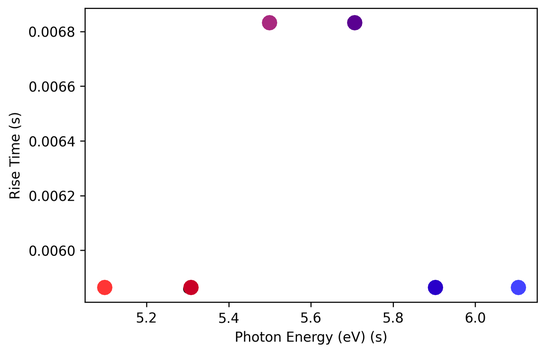




Off state at Vgs=-15 V

5.1 eV turn on indicates solar blindness and corresponds to the bandgap of the $Al_{0.85}Ga_{0.15}N$[2]





Solar blind Rejection ratio (SRR): 10^4

Visible blind Rejection ratio (VRR): $10^{4.6}$

Max rise times of ~7 ms

Next Steps:

Analysis of IV plots indicates that contact resistance is a bottleneck to device performance, currently novel contact materials are being examined to improve this aspect of the devices

There is evidence of sub-bangap eV photons generating signal, this may be due to the presence of the GaN quantum well or possible trap states. Alternative epitaxies are being examined.

Summary:

Solar-blind UV detection is key for a variety of applications. We have demonstrated a prototype of a solar-blind detector that uses an AlGaN HEMT structure.

We have demonstrated that this device has SRR of 10^4 and a VRR of $10^{4.6}$ confirming that it performs well as a detector in the solar blind range.

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References

1) Armstrong et al. (2019)
2) Hwang et al. (2002)