



## Novel Hybrid 2D-3D heterostructures for photo detection applications

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### Abstract:

Melding of two-dimensional (2D) materials with conventional three-dimensional (3D) materials is leading to new, versatile, and robust photodetector devices. We have developed devices utilizing reduced graphene-oxide on gallium nitride material and graphitic carbon-nitride on silicon. The devices demonstrate significant enhancement in the performance in terms of their figure-of-merits parameters as compared to the respective parent platforms. The main aim of this talk is to propose a new generation of low-cost, high performance photodetectors with enhanced device performance as compared to current prevalent technologies. Carbon Nitride in its graphitic form (g-C<sub>3</sub>N<sub>4</sub>) is often referred as a next generation material for energy harvesting devices, storage, photo-catalyst and in particular optoelectronic applications. The inherent semiconducting nature, chemical inertness and tunable bandgap have leveraged the g-C<sub>3</sub>N<sub>4</sub> with unique properties for device fabrication when compared to graphene. Our first study is based on monolithic integration of self-doped, highly exfoliated g-C<sub>3</sub>N<sub>4</sub> (2D) with Si (3D), which demonstrates operability in self-powered mode showing high response and recovery speed along with an ultra-broadband spectral response from 250-1650 nm, furthering the inherent response of commercial Si DH photodetector (250-1100 nm). The same device displays for the first time, a broad range binary photoswitching behavior from 250 to 1350 nm. Here, we show for the first time, how g-C<sub>3</sub>N<sub>4</sub> could be utilized to develop a highly efficient Si integrated self-powered photodetector. Gallium Nitride (GaN; 3D) generally shows persistence photoconductivity behavior and/or large leakage current limiting its applications in extreme environments. However, charge compensated highly resistive GaN (HR-GaN) when integrated with thin (few 10s of nanometer thick) reduced graphene-oxide (r-GO; 2D) as an overlayer can create unique properties for applications in harsh environments, working upto ±200 V bias and 120 °C with long-term stability over 18 months. The results of our study are relevant to the audience because we show for the first time a solution-cast rGO (soft 2D material) integrated with high-resistive GaN leading to a long-term stable device that could withstand high-temperature and high-voltage environments, suitable for future smart-sensors.

### Biography:

Nisha Prakash received her Ph.D. degree in Engineering Sciences from Academy of Scientific & Innovative Research, at



CSIR-National Physical Laboratory campus, India in 2020. She received her B.Tech. degree in Electronics & Communication Engineering in 2004 and M. Tech degree in VLSI Design in 2008 from Guru Gobind Singh Indraprastha University, India. Her current research interests include the application of two-dimensional (2D) and three-dimensional (3D) materials for realization of energy efficient optoelectronic devices.

### Publication of speakers:

- Nisha Prakash et al, “Long-term, high-voltage and high-temperature stable dual-mode, low dark current broadband ultraviolet photodetector based on solution-cast r-GO on MBE grown highly-resistive GaN”, *Advanced Optical Materials*, 1900340 (2019)
- Nisha Prakash et al, “Edge-contact large area hetero-structure fast photodetector utilizing two-dimensional r-GO on three-dimensional GaN material interface”, *Sensors and Actuators A: Physical*, 111720, Vol-3 (2020)
- Nisha Prakash et al, “Binary Multifunctional Ultrabroadband Self-Powered g-C<sub>3</sub>N<sub>4</sub>/Si Heterojunction High-Performance Photodetector”, *Advanced Optical Materials*, 1800191 (2018).
- Nisha Prakash et al, “Ultrasensitive self-powered large area planar GaN UV-photodetector using reduced graphene oxide electrodes”, *Applied Physics Letters* 109, 242102 (2016)
- Nisha Prakash et al, “The impact of RF-plasma power in carrier relaxation dynamics of unintentional doped GaN epitaxial layers grown by MBE”, *Optical Materials*, Vol54, pp. 26-31 (2016)

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