# Photodetectors based on few-layer 2D semiconductors and their heterostructures

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In recent years, researchers have leveraged the unique physical properties of layered two-dimensional (2D) van der Waals (vdW) materials, such as a wide range of thickness-tunable bandgaps, excellent light-matter interaction and facile fabrication of heterostructures with defect-free heterointerfaces, for several optoelectronic applications. This webinar will describe recent results from our group on engineering the photodetection performance of phototransistors based on 2D vdW transition metal dichalcogenide (TMD) semiconductors and their heterostructures.

Photoresponsivity and speed of few-layer TMD photodetectors are fundamentally traded-off with each other by modulation of the effective trap concentration, as shown through electrostatically gated supported and suspended $ReS_2$ photodetectors.[1] This trade-off can be attenuated by nearly 2× using an electrostatically tunable in-plane p-n homojunction integrated laterally with a $WSe_2$ phototransistor, enabling enhanced photoresponsivity (>100 A/W), and high detectivity (>$10^{12}$ Jones) along with switching speed in the μs range at the same time.[2] Beyond single-TMD photodetection, TMD/TMD heterostructures offer the possibilities of self-powered photodetection and photovoltaic action in addition to interlayer interface effects. Few-layer $WSe_2/ReS_2$ p-n heterostructure diodes are shown to form a type-II, near-direct, IR interlayer bandgap resulting in enhanced photocurrent and IR photodetection, besides a substantially large open-circuit voltage and short-circuit current.[3] Similarly, engineering the band alignment from type-II to type-III in a $WSe_2/SnSe_2$ p-n heterodiode helps realize a high negative responsivity of $2 \times 10^4$ A/W with a fast response time of ~1 μs due to a tunneling photocurrent.[4] Further, the ability to electrostatically [4] or spectrally [5] switch the photocurrent polarity from positive to negative values in 2D heterostructure photodetectors could enable multi-functional optoelectronic devices in the future.

**References**

[1] K. Thakar, B. Mukherjee, S. Grover, N. Kaushik, M. Deshmukh, S. Lodha, ACS Applied Materials and Interfaces, 10, 42, 36512 (2018).
[2] S. Ghosh, A. Varghese, K. Thakar, S. Dhara, S. Lodha, Nature Communications, 12, 3336 (2021).
[3] A. Varghese, D. Saha, K. Thakar, V. Jindal, S. Ghosh, N. V. Medhekar, S. Lodha, Nano Letters, 20, 3, 1707–1717 (2020).
[4] S. Ghosh, A. Varghese, H. Jawa, Y. Yin, N. V. Medhekar, S. Lodha, ACS Nano, 16, 4578−4587 (2022).
[5] H. Jawa, A. Varghese, S. Ghosh, S. Sahoo, Y. Yin, N. V. Medhekar, S. Lodha, Adv. Functional Materials, 2112696 (2022).

**Bio**: Prof. Saurabh Lodha is an Institute Chair Professor at the Department of Electrical Engineering, Indian Institute of Technology (IIT) Bombay in India. He graduated from IIT Bombay in 1999 with a B. Tech (EE) followed by a Masters (ECE) and PhD (ECE) from Purdue University, USA, in 2001 and 2004 respectively. From 2005-2010 he worked at Intel Corporation in Portland, USA, on the research and development of 45, 32 and 22 nm Si CMOS technologies. He joined IIT Bombay in 2010 where he is also the PI of the IITB-OSU Frontier Research Center. His research interests span devices and materials in the areas of advanced CMOS technologies, 2D (opto)electronics and gallium oxide power electronics. He was awarded the Swarna Jayanti fellowship (2017) and the young career award (2020) by the Department of Science and Technology, Govt. of India. He has (co-)authored 85 peer-reviewed journal publications and 8 patents. He is a Fellow of the Indian National Academy of Engineering (INAE) and a senior member of IEEE.