

**Samit Kumar Ray**

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Professor Samit Kumar Ray is involved in the research and development of semiconductor quantum and heterostructures for nanoscale devices in collaboration with IIT Kharagpur. Plasmonic semiconductor nanostructures are being studied for use in multifunctional sensing and detector applications. The group is also working on the integration of 2D materials on Si platforms for photonic devices.

### Supervision of Research / Students

Projects of M.Sc./ M.Tech./ B.Tech./ Post B.Sc. students

1. Sumit Kr. Singh jointly with prof. A. K. Raychaudhuri, M.Tech. Project, IIT Kharagpur, Nanowire based Devices – completed.

### Publications in Journals

1. **S. K. Ray**, A. K. Katiyar and A.K. Raychaudhuri; *Topical Review: One-dimensional Si/Ge nanowires and their heterostructures for multifunctional applications-A review*; Nanotechnology; 2017; **28**; 092001.

2. A. Sarkar, A. K. Katiyar, S. Mukherjee and **S. K. Ray**; *Enhanced UV-visible photodetection characteristics of a flexible Si membrane-ZnO heterojunction utilizing piezo-phototronic effect*; J. Phys. D: Appl. Phys.; 2017; **50**; 145104.
3. R.K. Singha, S. Manna, R.Bar, S. Das and **S.K. Ray**; *Surface potential, charging and local current transport of individual Ge quantum dots grown by molecular beam epitaxy*; Applied Surface Science; 2017; **407**; 418.
4. N. Gogurla, S. C. Kundu and **S. K. Ray**; *Gold nanoparticle-embedded silk protein-ZnO nanorod hybrids for flexible bio-photonic devices*; Nanotechnology; 2017; **28**; 145202.
5. S. Mukherjee, S. Biswas, S. Das, and **S. K. Ray**; *Solution-processed, hybrid 2D/3D MoS<sub>2</sub>/Si heterostructures with superior junction characteristics*; Nanotechnology; 2017; **28**; 135203.

### Lectures Delivered

1. 2-D Materials based Optoelectronic Devices on Silicon Platforms – Intl. Conference on Fiber Optics & Photonics (Photonics-2016), IIT Kanpur, Dec. 2016.
2. Silicon Based Multifunctional and Green Photonic Devices – Intl. Conf. on Functional Materials, IIT Kharagpur, Dec. 2016.
3. Low Dimensional Structures for Silicon Photonic Devices – DAE Solid State Physics Symposium, Bhubaneswar, Dec. 2016.
4. Heterostructure Devices using 2D Materials on Silicon Platforms – IACS, Kolkata, Feb. 2017.
5. Silicon based Nanostructures for Photonic Devices - 4<sup>th</sup> Intl. Symp. Semiconductor Materials and Devices, Jadavpur Univ., 8-10 March, 2017.
6. Semiconductor Quantum Structures : Recent Trends – Bose Colloquium, S.N.Bose National Centre for Basic Sciences, Jan. 2017.
7. Strain and Band Engineering for Si/Ge based Heterostructure Devices, Synchrotron Techniques in Material Research, *Dooars*, 2<sup>nd</sup> – 5<sup>th</sup> February, 2017.
8. Excitements with Materials in Nanoscale - DST-JBNSTS INSPIRE Science Camp, March, 2017.

### Collaborations including publications (Sl. No. of paper/s listed in 'Publications in Journals' jointly published with collaborators)

#### National

Sl. Nos. 3, 4, 5

### Member of Editorial Board

1. Editorial Board member, Nanotechnology, IOP, UK

### Significant research output / development during last one year

#### General research areas and problems worked on

- Heterostructure and quantum devices
- Semiconductor and Oxide Nanostructures
- Nanoelectronic & Nano-photonic devices
- 2D/3D heterostructures

- Photovoltaic Materials and Devices
- Silicon Alloy Heterostructures
- Thin Film Technology

### Interesting results obtained

#### 1. Silk protein based biophotonic devices

Silk protein has been used as a biopolymer substrate for flexible photonic devices. We have demonstrated ZnO nanorod array hybrid photodetectors on Au nanoparticle-embedded silk protein for flexible optoelectronics. Hybrid samples exhibited optical absorption at the band edge of ZnO as well as plasmonic energy due to Au nanoparticles, making them attractive for selective UV and visible wavelength detection. The device prepared on Au-silk protein shows a much lower dark current and a higher photo to dark current ratio of  $\sim 10^5$  as compared to the control sample without Au nanoparticles. The hybrid device has also exhibited a higher specific detectivity due to higher responsivity arising from the photo-generated hole trapping by Au nanoparticles. Sharp pulses in the transient photocurrent have been observed in devices prepared on glass and Au-silk protein substrates due to the light induced pyroelectric effect of ZnO, enabling the demonstration of self-powered photodetectors at zero bias. Flexible hybrid detectors have been demonstrated on Au-silk/polyethylene terephthalate substrates, exhibiting characteristics similar to those fabricated on rigid glass substrates. A study of the performance of photodetectors with different bending angles indicates very good mechanical stability of silk protein based flexible devices. This novel concept of ZnO nanorod array photodetectors on a natural silk protein platform provides an opportunity to realize integrated flexible and self-powered bio-photonic devices for medical applications in near future.

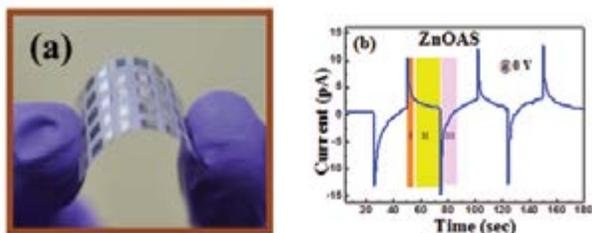


Fig.1 (a) Optical image of flexible biophotonic device fabricated on plastic substrate, (b) Transient photocurrent of the device due to light induced pyroelectric effect.

#### 2. Hybrid 2D/3D MoS<sub>2</sub>/Si heterostructures

Theoretical and experimental investigations of the hybrid heterostructure interfaces between atomically thin MoS<sub>2</sub> nanocrystals (NCs) on Si platform for their potential applications towards next-generation electrical and optical devices have been made. Mie theory-based numerical analysis and COMSOL simulations based on the finite element method have been utilized to study the optical absorption characteristics and light-matter interactions in variable-sized MoS<sub>2</sub> NCs. The size dependent absorption characteristics and the enhancement of electric field of the heterojunction in the UV-visible spectral range agree well with the experimental results. A lithography-free, wafer-scale, 2D material on a 3D substrate hybrid vertical heterostructure has been fabricated using colloidal n-MoS<sub>2</sub> NCs on p-Si. The fabricated p-n heterojunction exhibited excellent junction characteristics with a high rectification ratio suitable for voltage clipper and rectifier applications. The current-voltage characteristics of the devices under illumination have been performed in the temperature range of 10–300 K. The device exhibits a high photo-to-dark current ratio of  $\sim 3 \times 10^3$  and a responsivity comparable to a commercial Si photodetector. The excellent heterojunction characteristics demonstrate the great potential of MoS<sub>2</sub> NC-based hybrid electronic and optoelectronic devices in the near future.

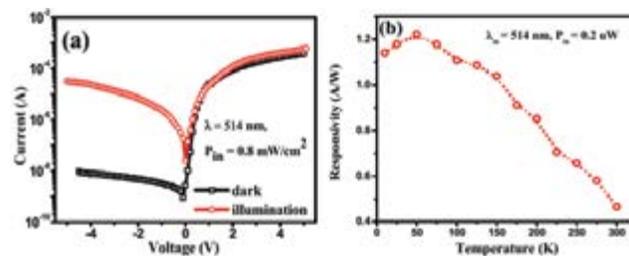


Figure 2: (a) Typical current-voltage characteristics of fabricated device, using  $\sim 3 \text{ nm}$  MoS<sub>2</sub> NCs on Si, under dark and illumination condition, recorded at 300 K. (b) Photoresponse behavior of the as-fabricated device as a function of operating temperature for 514 nm illumination.