



Hybrid Two-dimensional Semiconductor Heterostructures based Photonic Devices

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Abstract

Tunable light-matter couplings in dissimilar constituents (metal & semiconductors) play a leading role in the development of two-dimensional (2D) quantum hybrids along with their applications in Si-compatible photonics. Wafer scale, vertical 2D/3D hybrid heterojunctions using 2D metal dichalcogenides layers and nanocrystals have been realized on 3D Si platforms. The heterojunctions exhibit excellent photodiode characteristics suitable for multifunctional devices with significantly enhanced spectral response, making them attractive for Si CMOS compatible photonic devices. The integration of PbS QDs with MoS₂ leads to a hybrid heterostructure exhibiting two color band and tunable infrared photoresponse using a single device. On the other hand, novel PVP coated Ag^o intercalation induced synthesis has led to the formation of an intercalated impurity-free n-WS₂ layer with reversed conductivity and plasmonic enhancement. Stabilized Ag- nanoparticles embedded n-WS₂ has been used to fabricate plasmon enhanced silicon compatible broadband heterojunction photodetector. On the other hand, the detailed pump-probe investigations demonstrate the ultrafast generation and evolution of individual bright exciton-plasmon polaritons (bright plexcitons) in self-assembled size-tunable Au nanostructure-layered WS₂ hybrids. A remarkably robust Rabi-splitting energy (~ 250 meV) and comparatively higher stable plexciton formation time (~ 7.0 ps) are realized for both the plexcitons, validating the strong-coupling conditions of polariton formation. The diverse ultrafast light-matter coupling phenomena for layered TMDs and their plasmonic hybrids are attractive for next generation quantum photonic devices.

Prof. Samit K. Ray is currently a Professor in the Department of Physics, IIT Kharagpur. He has previously served as the Director S. N. Bose National Centre for Basic Sciences, Kolkata, and Dean (Post-graduate & Research Studies), Head, Department of Physics and founder Head, School of Nanoscience and Technology, IIT Kharagpur. His research interests are in the area of semiconductor nanostructures, quantum dots, photovoltaics and nanophotonic devices. Prof. Ray is a fellow of the National Academy of Sciences India, Indian Nation Academy of Engineering, West Bengal Academy of Science & Technology and is the recipient of INSA Young Scientist Award, UGC Homi Bhabha Award, MRSI Superconductivity & Materials Science Senior Award.etc. He has published more than 325 research papers in peer reviewed journals, seven book chapters and co-authored a book on “Strained Silicon Heterostructures: Materials and Devices” published by IEE, UK.