

Electronic Supplementary Information (ESI)

Infrared Tunable, Two Colour-Band Photodetectors on Flexible Platforms using 0D/2D PbS-MoS₂ Hybrids

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1. Materials & methods:

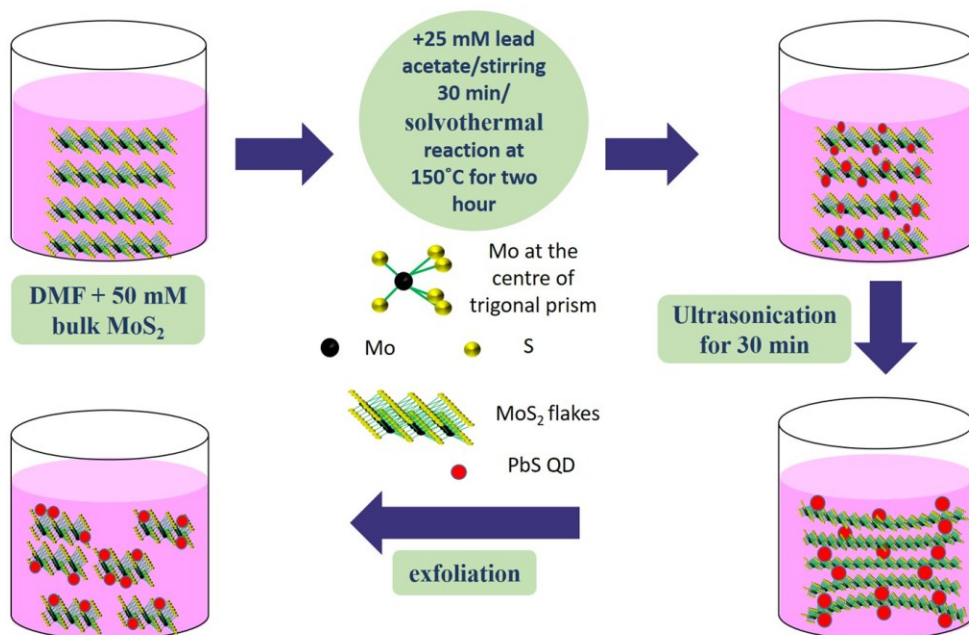
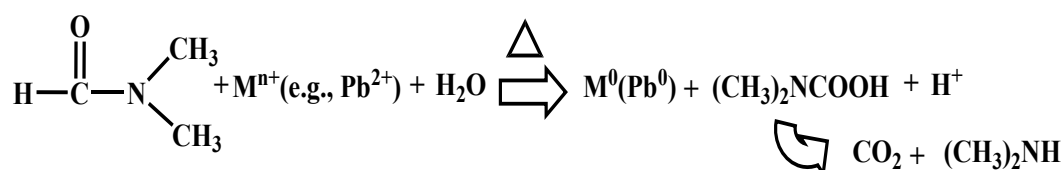


Fig.S1: Schematic representation of the synthesis of 0D-PbS/2D-MoS₂ hybrid nanostructures by solvothermal reaction, starting from bulk MoS₂ and lead acetate. The reduction mechanism scheme for lead acetate is presented using DMF as the reducing agent.

The morphology of as-synthesized PbS/MoS₂ hybrid nanostructures was characterized by field-emission scanning electron microscopy (FESEM) and transmission electron microscopy (TEM).

X-ray diffraction (XRD) patterns were recorded, using characteristic Cu-K α radiation with a normal θ -2 θ scan, ranging from 5° to 70°, to determine the structure and phase of synthesized samples. The investigation of chemical states, elemental and compositional analysis of the hybrids were carried out using X-ray photoelectron spectroscopy (XPS) equipped with an Al-K α X-ray source ($h\nu = 1486.6$ eV) and Auger electron spectroscopy (AES). Absorption studies of the hybrid samples were carried out by a fibre-probe absorption spectroscopy. Time-resolved photoluminescence measurements of the control MoS₂ layer and PbS/MoS₂ heterostructures were performed using a time correlated single photon counting (TCSPC) spectrometer [LifeSpec-II fluorescence life time spectrometer (Edinburgh Instruments) fitted with a PMT detector] with a 375 nm pulsed laser excitation source (EPL 375 series diode laser). Raman spectroscopy were carried out at room temperature using a 514 nm Ar⁺ laser source and an optical microscope with a 50 \times objective lens, in confocal mode.

2. Atomic force microscopy (AFM):

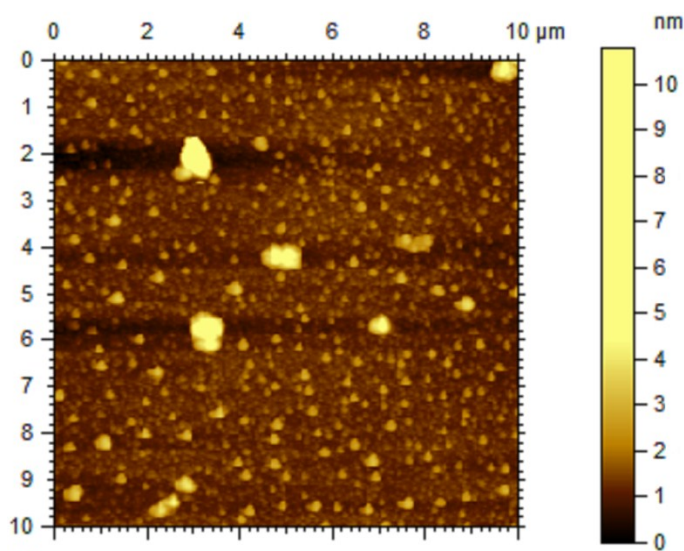


Fig. S2: Surface topography of the as-synthesized MoS₂ nanosheets exhibits the average thickness of the nanosheets is around ~8 nm with lateral dimensions between 200-300 nm, confirmed the 2D layer nature of the chemically exfoliated MoS₂.

3. X-ray photoelectron spectroscopy (XPS):

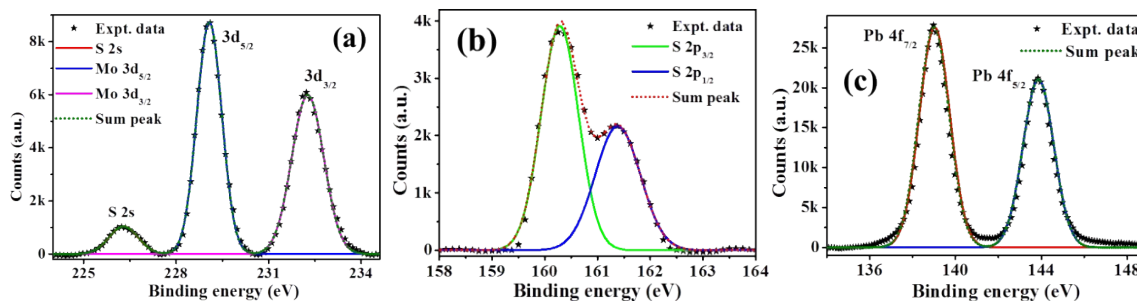


Fig.S3: High resolution core-level binding energy spectra for (a) Mo 3d, (b) S 2s and (c) Pb 4f electrons.

The stoichiometry and oxidation state of the synthesized PbS/MoS₂ hybrid nanostructures have been studied by using Al-K _{α} radiation of energy 1.4866 keV and the XPS spectra of Mo 3d, S 2p and Pb 4f core-level electrons are depicted in Figure S2 (a), (b) and (c), respectively. Mo 3d doublet peaks for 3d_{5/2} and 3d_{3/2} electronic states are centered at 229.0 and 232.3 eV, respectively, confirming the presence of Mo⁴⁺ state. Two well-resolved characteristic peaks of Pb located at the binding energy of 139.0 eV and 143.9 eV, are ascribed to Pb 4f_{7/2} and Pb 4f_{5/2}, respectively. The shift of binding energy of Pb 4f states towards a higher value by ~1 eV compared to the elemental Pb, infers the formation of Pb²⁺ state. Figure S2 (b) presents the S 2p spectra with doublet centered at 160.3 and 161.5 eV, attributing to the S 2p_{3/2} and S 2p_{1/2} states, respectively. A large binding energy shift of 3.8 eV for 2p_{3/2} line toward a lower value and the peak broadening, as compared to elemental S are observed. The reverse binding energy shift of S 2p electrons compared to that of Mo 3d and Pb 4f ones, reveal the formation of Mo-S and Pb-S chemical bonds. The observed peak positions of spin-orbit coupled Mo 3d, Pb 4f and S 2p electrons are in excellent agreement with reported values and support the formation of PbS decorated MoS₂. No discernible impurity is identified in survey scan, indicating that as-prepared hybrids are relatively pure.

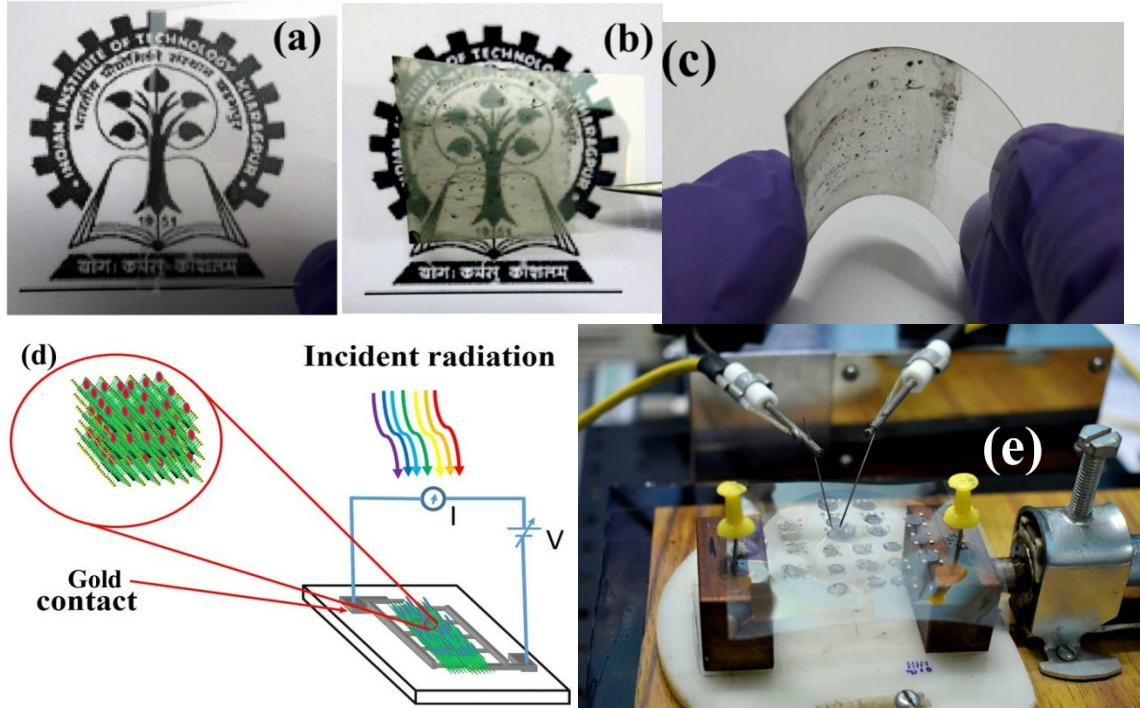


Fig.S4: Digital photographs of the (a) bare PET substrate on a background pattern, (b) a PbS/MoS₂ coated PET substrate on the pattern. (c) PbS/MoS₂ coated PET substrate in flexible condition, (d) Schematic diagram of the fabricated photodetector using PbS/MoS₂ hybrid heterostructures. (e) The indigenously developed measurement set-up in the laboratory for flexibility devices. The sample is mounted on a motor controlled unit to measure the device stability and repeatability with bending cycles. Several devices have been fabricated and measured in the ambient condition, to demonstrate the repeatable performance of devices.

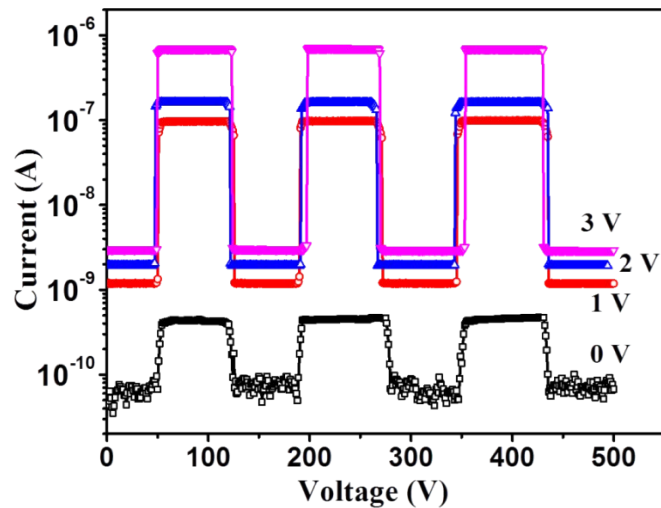


Fig. S5: Temporal current response of the device with sample-S1, for various applied bias (@514 nm 0.15 mW/cm²).