PROJECT EVALUATION

FABRICATION AND TESTING OF

WS2 BASED PHOTODETECTOR

SUBMITTED BY

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SRICITY

Micro Sensors and Actuators

PROJECT TITLE:

Fabrication and Testing of metal disulfide WS2 based optical sensor

ABSTRACT:

In this project it is observed that sensitive towards 450nm compared to 532nm and in dark. Responsivity of this fabricated device at wavelength 450nm is 2.66 mA/W. detectivity is of 15847.45 jones. And analysed the rise and fall of the current vs time graph.

INTRODUCTION:

Photodetectors, converting incident light into electric signals, are of tremendous interest due to their applications in industry and military, such as biochemical analysis, industrial automatic control, missile warning and so on. Photodetectors can be categorized into the broadband and the selective photodetectors, corresponding to wide-spectrum and spectrally distinctive photoresponse.Compared to the photodetectors with the relatively narrow response, the broadband photodetectors have great potential applications for ultraviolet–visible-infrared (UV–vis-IR) light communication, memory storage, and wide spectral switch in a single optoelectronic device system.Recently, two-dimensional (2D) materials have emerged as an ideal platform for realizing a variety of optoelectronic devices due to their unique properties. Among these 2D materials, WS2 has been intensively studied in photodetection applications. For example, Yao et al. first demonstrated a multilayer WS2 film based photodetector, which exhibits good photoresponse properties in terms of a high responsivity[1]. Semiconducting heterostructures, which are formed by assembling two disparate semiconductors with different lattice structures, electronic properties, or

chemical compositions lay the foundation of modern electronics[4].Upon the construction of the heterostructures, bending or hybridization of the electronic band structures of both the two components occurs, leading to the charge transfer at the interface[4].

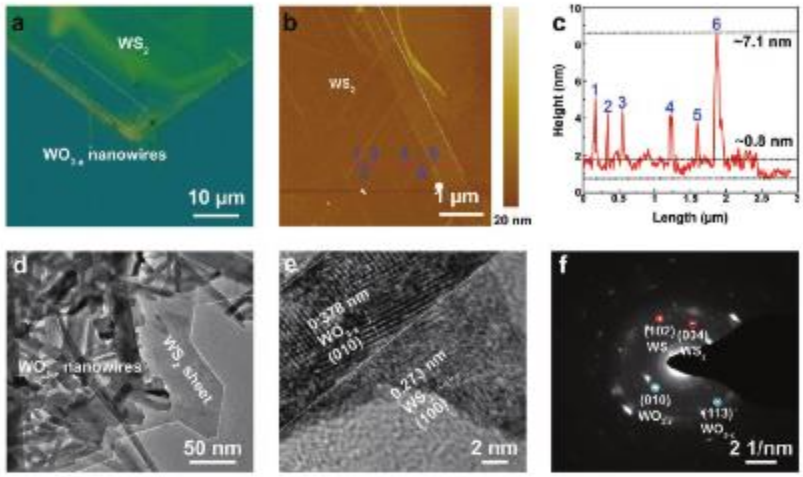


Figure 1. a,b) Optical image and surface morphology of WO_{3-x}/WS_2 vdW heterostructure. c) Corresponding height profile. Three dash lines are corresponding to WO_{3-x}, WS_2, and substrate, respectively. d) Low-resolution TEM image of WO_{3-x}/WS_2 vdW heterostructure, in which WO_{3-x} nanowires are uniformly stacked on WS_2 sheet. e) HRTEM of heterostructure. White dash lines indicate interface. f) Corresponding SAED of heterostructure.

Fig 1 optical image of WS_2

Layered transition metal dichalcogenides (TMDCs) (e.gWS_2 and MoS_2), hold high carrier mobility, a sizable band gap of 1–2 eV, and strong light matter interaction, which make these materials very prospective for optoelectronic devices. The weak van der Waals (vdW) bonds among the adjacent layers allow bulk TMDCs crystals to be effectively exfoliated, enabling direct deposition of such layered crystals by direct abrasion against the substrate. In addition, the high surface roughness and porous nature of cellulose fibers not only aid the adhesion of the deposited material but also

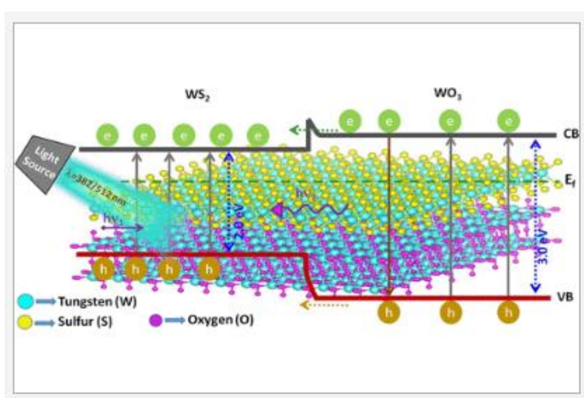


Fig2 [3]. PHOTO DETECTIVITY OF THE WS2/WO3

provides a larger photoactive area for optoelectronic devices as compared to conventional planar substrates[2].a strategic development of WS2/WO3 heterostructures by sputtering and chemical vapor deposition techniques to fabricate a metal–semiconductor–metal planar-structured Ag/WS2/WO3/Ag photodetector device with interdigitated Ag electrodes. A comparative study has been made based on the photodetector performance between the WS2/WO3 heterostructure and pristine WO3 and WS2 thin-film-based devices. WO3 and also reduces the recombination losses by absorbing the emitted radiation with WO3[2] Recently, the optoelectronic properties of vdW semiconducting heterostructures reach a new height by replacing one of the TMDs components with the transition metal oxides (TMOs).Apparently, such a replacement, particularly of the top component in the heterostructure, greatly enhances the long-term stability of the device as ultra-thin TMDs exhibit slow surface oxidation upon exposure in the ambient air environment. More importantly, oxygen vacancies, commonly existing in nanostructured TMOs, could introduce optically-active gap

states for enhancing the light absorption and the production of photogenerated carriers. However, the single-step synthesis of ultrathin TMOs/TMDs vdW heterostructures is challenging given the balance of oxidizing and reducing atmospheres for the growth of TMOs and TMDs, respectively.The quality of the heterostructure interface is critical here as any crystal distortions or defects can interfere with the charge transfer behavior significantly, hence leading to the strong demand of heterostructures governed by the van der Waals(vdW) force[4].we utilized the quantity-driven discrepancy of S reaction with precursors to realize the single-step CVD synthesis of a WO3−x/WS2 vdW semiconducting heterostructure. Particularly, S acts as a sulification agent to convert the precursor WO3 into WS2 in the presence of an excessive amount of S[4].

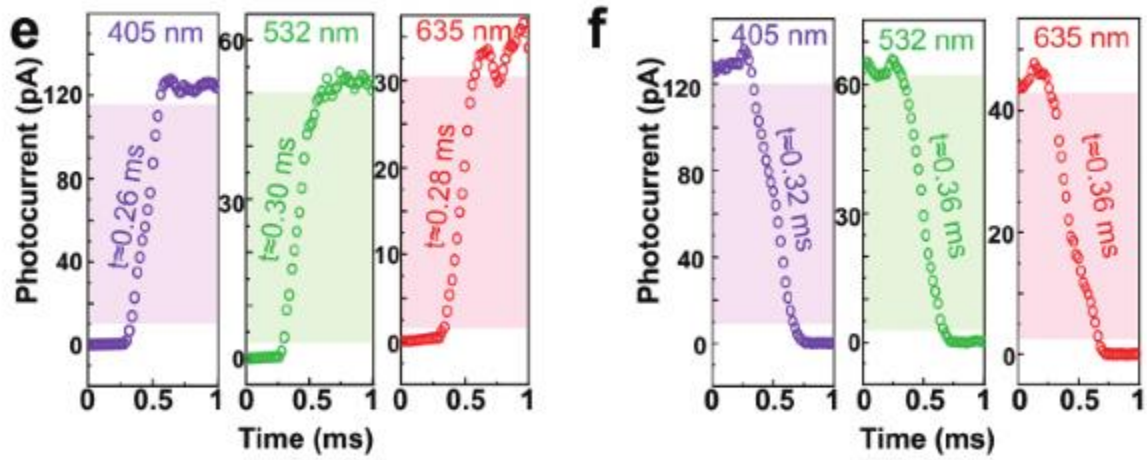


Fig 3 Time-resolved photocurrent with rise and fall time under different excitation wavelengths.

PROBLEM STATEMENT:

The main objective of this project is to develop photodetetor/optical sensor devices. Our second objective is finding the Time-resolved photocurrent with rise and fall time under different excitation wavelengths.finding the responsivity and detectivity for different wavelengths.

METHODOLOGY AND NEW FINDINGS:

For deposition of the Tungsten:

Equipment and Materials:

- Sputtering system (e.g., magnetron sputtering system)
- Tungsten target
- Substrate (e.g., silicon, glass, quartz)
- Argon (Ar) gas
- Vacuum pump
- RF or DC power supply
- Cleanroom environment (optional, depending on application)

Procedure:

- Substrate Preparation
- Load the Substrate into the Sputtering System:
- Pump Down the Chamber:
- Sputtering Process:

- Deposition onto Substrate:

For deposition of the Tungsten tri oxide:

  - Equipment and Materials:
- Tungsten wafer or substrate
- Oxidation furnace or system(cvd)
- Oxygen (O2) gas
- Thermocouple or temperature controller
- Cleanroom environment (optional, depending on application)

Procedure:
- Preparation of Tungsten Wafer:
- Load the Wafer into the Oxidation System(cvd)
- Establish Oxidizing Atmosphere:
- Heating and Oxidation:

For deposition of the Tungsten tri oxide:

  - Equipment and Materials:
- Oxidized tungsten wafer
- CVD furnace or system(cvd)
- Sulphur powder is kept in furnance
- Thermocouple or temperature controller
- Cleanroom environment (optional, depending on application)

Procedure:
- Preparation of Tungsten Wafer:
- Load the Wafer into the Oxidation System(cvd)
- Heating and sulphurisation

EXPERIMENTAL DETAILS:

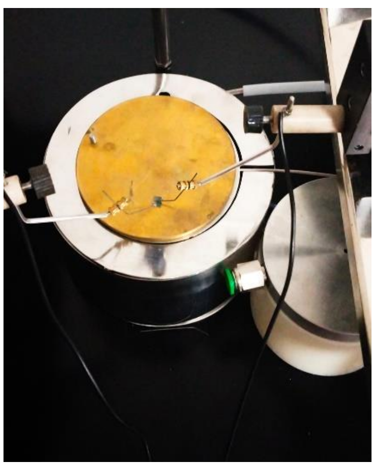
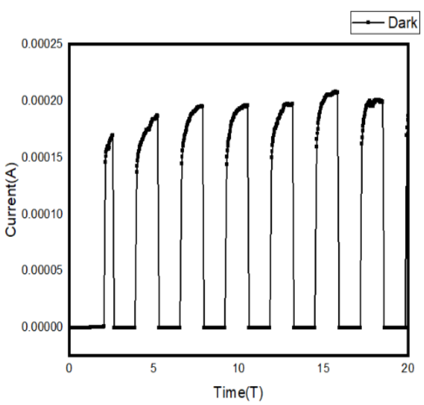
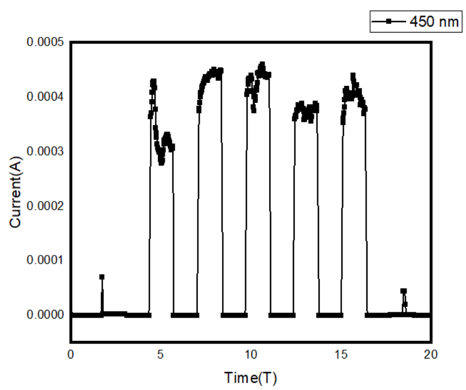


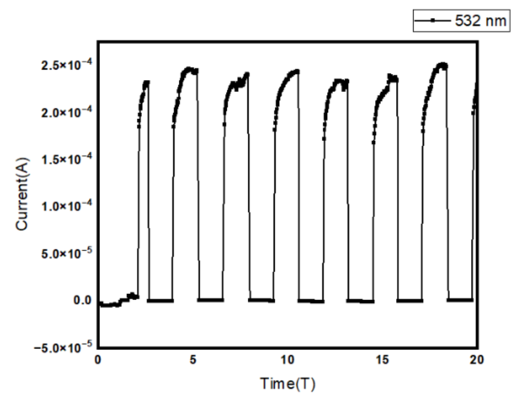
Fig 4 probing for taking measurements

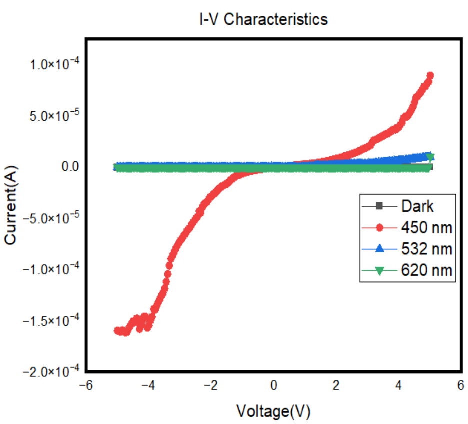
- p/Si<100>
- deposition of tungsten using sputtering for 30 mins
- oxidation of the substrate using CVD at 500^{o}c-550^{o}c for nearly 2 hours
- sulphurisation of the substrate using CVD at 750^{o}C.

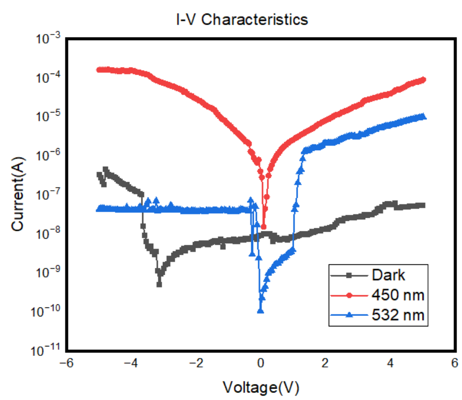
RESULT AND DISCUSSION:

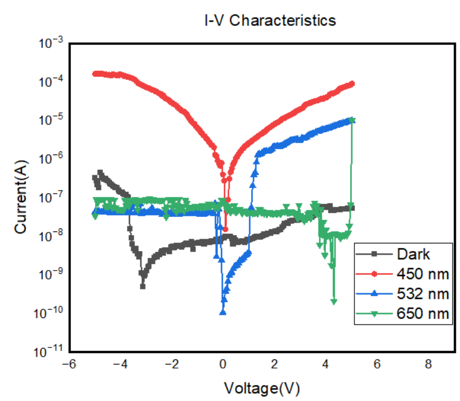












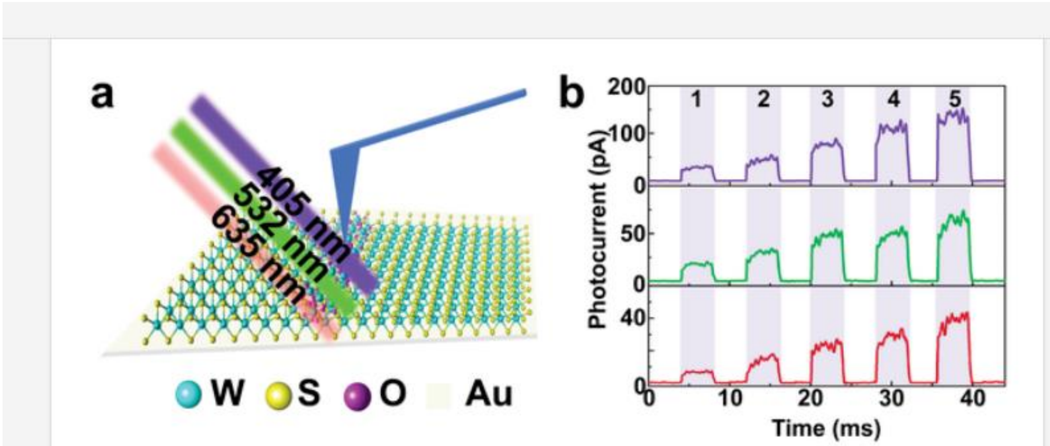


Fig 5 [3] graph of current versus time

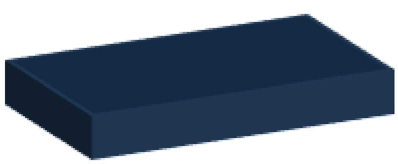
$$\text{Photoresponsity(R)} = \frac{I_{\text{ph}}}{P_{\text{in}} \times A} \tag{1}$$

$$\text{Detectivity(D)} = \frac{R \times \sqrt{A}}{\sqrt{2eI_d}} \tag{2}$$

$$\text{EQE(\%)} = R \times \frac{\text{hc}}{e\lambda} \tag{3}$$

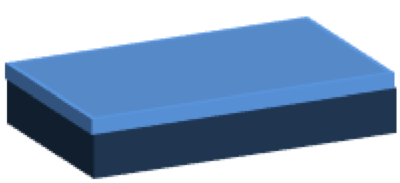
MECHANISM WITH DIAGRAM:

1.



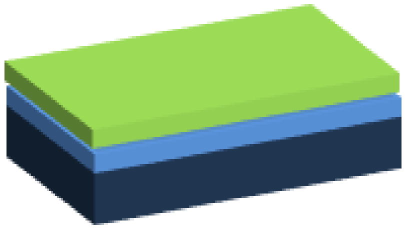
Silicon (si) substrates, don't hold the substrate with the bare hands. Handle it with care.

2.



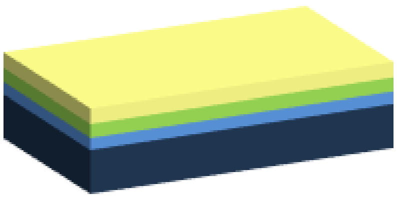
SiO_2 is spin coated on the double sides of the silicon substrate.

3.



A thin film of Tungsten is deposited on the Si substrate using DC magnetron Sputtering

4.



Oxidation of the tungsten Using CVD (chemical vapor deposition)

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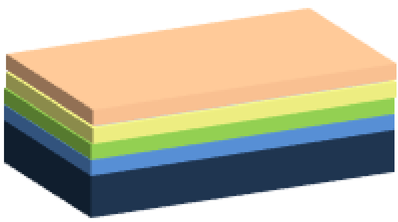
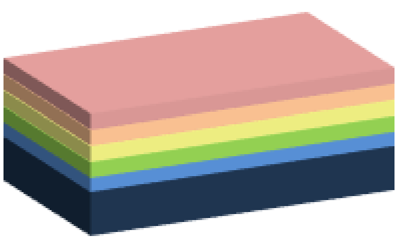


After oxidation of wafer

$2W + 3O_2 \rightarrow 2WO_3$

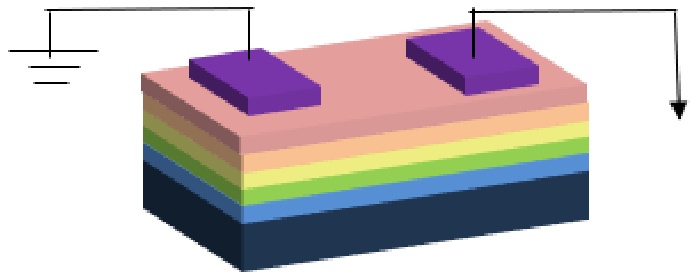
6.



$2WO_3 + 4S \rightarrow 2WS_2 + 3O_2$

Sulphurisation of WO_3

7.



Probing to the two of SMU(source measure unit).

APPLICATIONS:

WS2 sensing at 450 nm, 532 nm, and 652 nm can be applied in colorimetry for accurate color detection and in environmental monitoring for analyzing specific light wavelengths related to pollutants or contaminants.

CHALLENGES FACED:

Handling the sulfur during the fabrication and during testing the maintaining the surrounding environment silently. carefully Probe the device while doing the measurement.

CONTRIBUTION OF INDIVIDUAL TEAM MATES:

Divya.M- generated 3 origin file from the measured values. searched [1] and [3] reference paper. Calculated responsivity.

Jahnavi.O- measuring and taking values from the device, generated one origin file from the measured values
and searched [4] and [5] reference paper. Contributed in making report.

Sruthi.N-generated 2 origin file, searched [1] and [6] reference paper. Contributed in making report. Calculated detectivity.

FUTURE WORK:

In the future we are going to fabricate this device to increase the responsivity of this device and photo detectivity

CONCLUSIONS:

In summary we tested fabricated WS_2 using sputtering and CVD followed by Ag contacts. This fabricated WS_2 is useful in measuring the specific wave length of the light detecting the specific wavelength and environmental pollution

REFERENCES:

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[**2**].Solvent-free fabrication of broadband WS2 photodetectors on paper Wenliang Zhang1 , Onur Çakıroğlu1 , Abdullah Al-Enizi2 , Ayman Nafady2 , Xuetao Gan3 , Xiaohua Ma4 , Sruthi Kuriakose1 , Yong Xie 1,4* and Andres Castellanos-Gomez1

[3] WS2/WO3 Heterostructure-Based Photodetectors on SiO2/Si for Future Optoelectronics

P.V. Karthik Yadav And Y. Ashok Kumar Reddy*

[4] A Single-Step-Grown Semiconducting vdW Heterostructure of Tungsten Oxide–Sulfide for High-Performance Photodetection Guanyu Chen, Xinyi Hu, Mingwei Gu, Hao Wu, Keyu Chen, Hao Yu, Baiyu Ren, Zhong Li, Yange Luan, Tao Tang, Yinfen Cheng, Haibo Huang,* Liguo Chen,* Bao Yue Zhang,* and Jian Zhen Ou*

[5] Thermal Effects Associated with the Raman Spectroscopy of WO_3 Gas-Sensor Materials

Raul F. Garcia-Sanchez[†], Tariq Ahmido[‡], Daniel Casimir[†], Shankar Baliga[§] and Prabhakar Misra[*†]

[6] High-Efficiency Photodetector Based On CVD-Grown WS2Monolayer Rakesh K. Prasad1 , Koushik Ghosh2 , P. K. Giri2 , Dai-Sik Kim3 , Dilip K. Singh1* 1 Department of Physics, Birla Institute of Technology Mesra, Ranchi -835215, India 2 Department of Physics, Indian Institute of Technology Guwahati, Assam-781039, India 3 Department of Physics and Quantum Photonics Institute and Center for Atom Scale Electromagnetism, Ulsan National Institute of Science and Technology (UNIST), Ulsan-44919, Republic of Korea