廣西師範大學
GUANGXI NORMAL UNIVERSITY

Self-Powered Flexible Polarization Photodetector with Two-Dimensional TMC Heterojunction

Presenter：康茜

Supervisor: Prof. Liu Jun

Date: Oct. 13, 2026

CONTENT

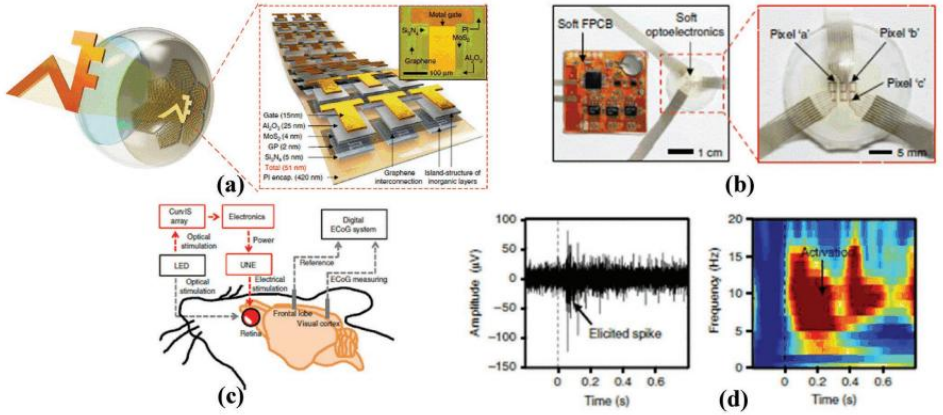
01 Introduction

02 WSe_2 / ReS_2 Heterojunction

Flexible Photodetecto

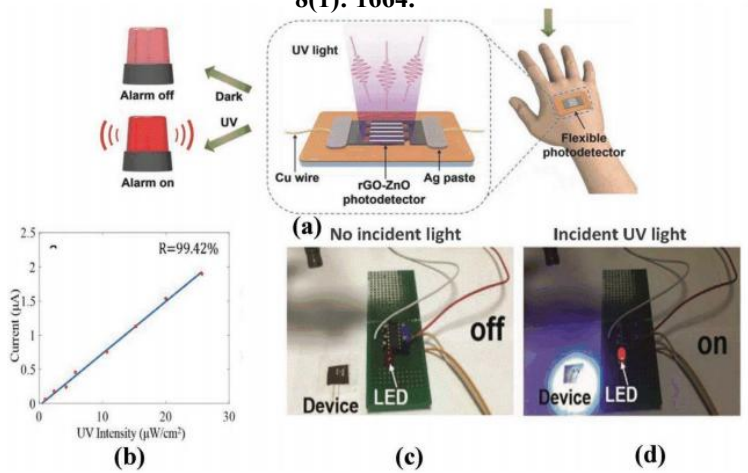
03 Summary

1.1 Introduction

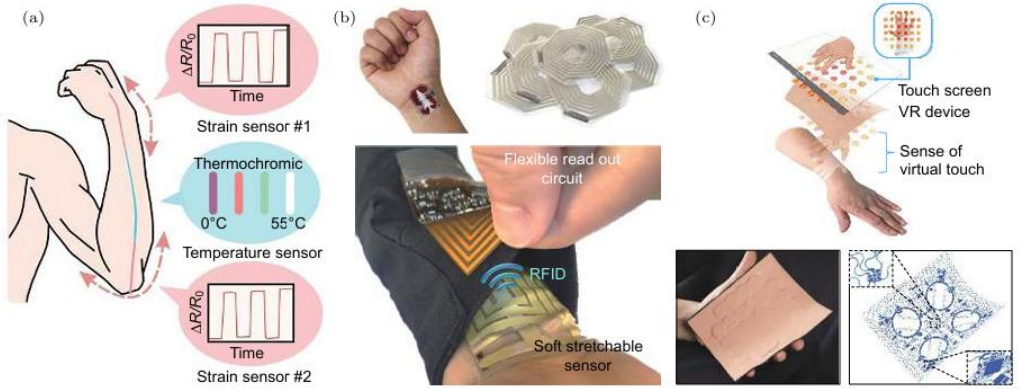


Choi C, Choi M K, Liu S, et al. Human eye-inspired soft optoelectronic device using high-density MoS2-graphene curved image sensor array[J]. Nature Communications, 2017, 8(1): 1664.

In recent years, flexible photodetectors have attracted intensive research interest, which can conform to curved surfaces for optical sensing. They exhibit great application potential in biomedicine, wearable electronics and environmental monitoring.

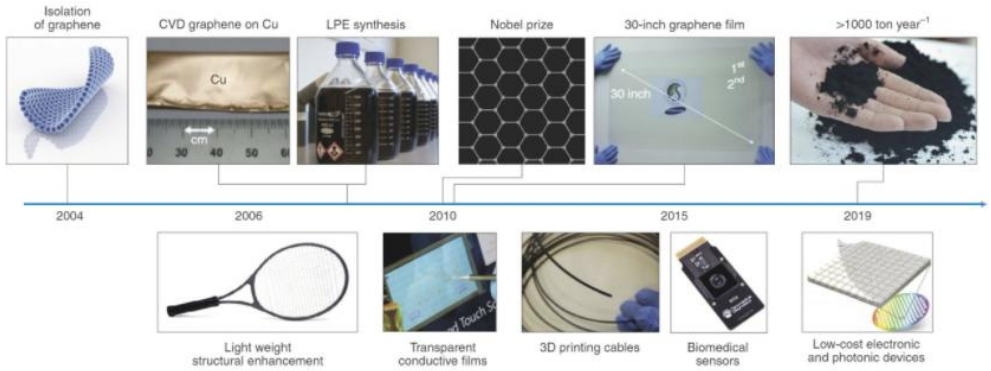


T. Dong, J. Simões, Z. Yang, Flexible Photodetector Based on 2D Materials: Processing, Architectures, and Applications. Adv. Mater. Interfaces 2020, 7, 1901657.



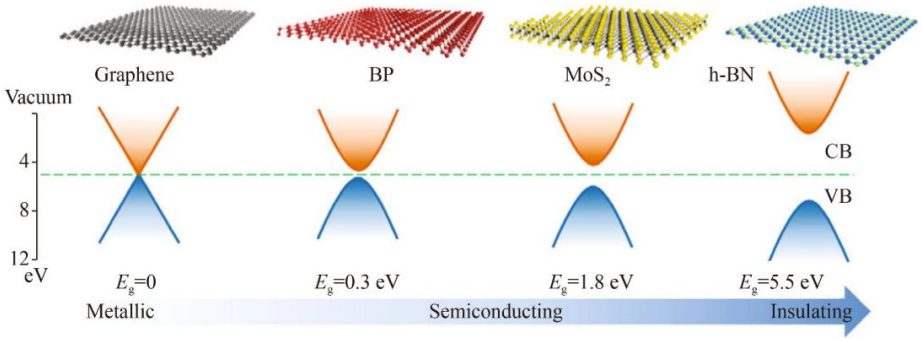
Citation: Tan Pu-Chuan, Zhao Chao-Chao, Fan Yu-Bo, Li Zhou. Research progress of self-powered flexible biomedical sensors[J]. Acta Physica Sinica, 2020, 69(17): 178704-1-178704-12.

1.2 Development of Two-Dimensional Materials



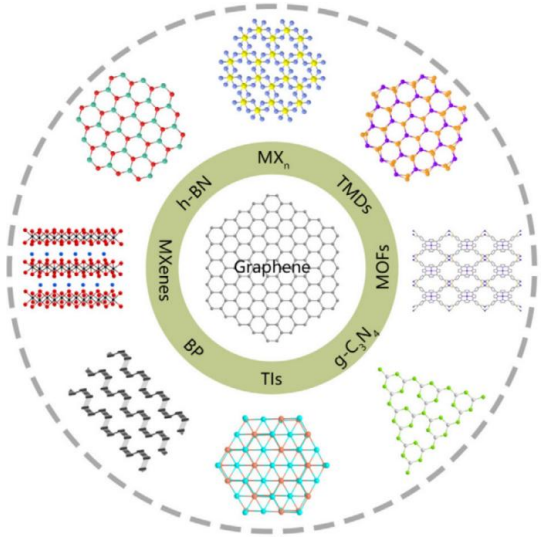
Origin and development of graphene and two-dimensional materials

Wei Kong, Hyun Kum, et al.Nature Nanotechnology volume 14, pages927–938 (2019)



Structures and energy bands of common two-dimensional materials

Wang et al. - 2024 - Photodetectors integrating waveguides and semicond

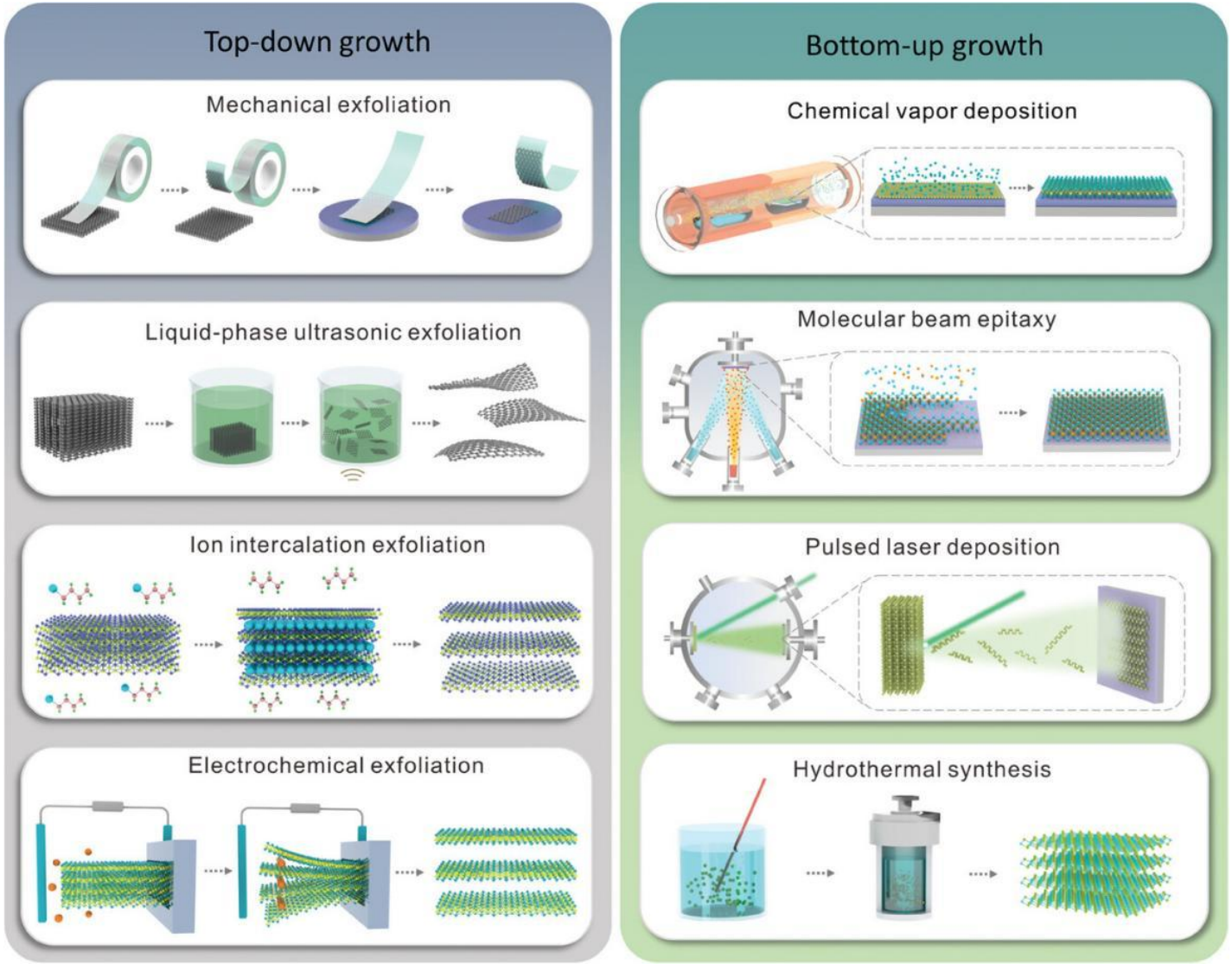


Spectral detection range of common two-dimensional materials

Zhang H. Ultrathin two-dimensional nanomaterials. ACS Nano 2015; 9 (10): 9451-9469

Two-dimensional (2D) materials possess atomic-thin thickness and unique optoelectronic properties. Among them, transition metal dichalcogenides (TMDCs) have layered structures similar to graphene and tunable bandgaps of 1–2.5 eV, overcoming the zero-bandgap limitation of graphene. TMDCs feature low cost, non-toxicity and excellent room-temperature stability, which are ideal candidates for flexible photodetectors.

1.3 Preparation Methods of Two-Dimensional Materials

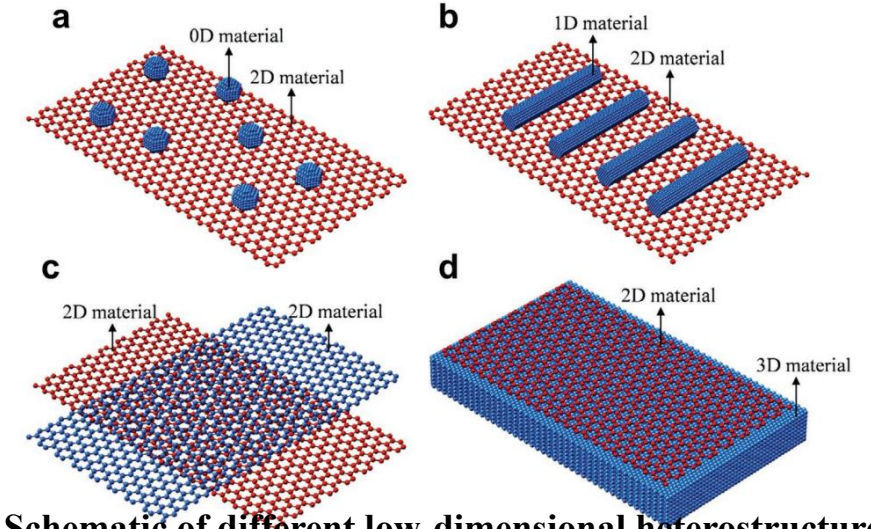


Preparation of two-dimensional materials by top-down and bottom-up methods

Li X, Liu K, Wu D, et al. Van Der Waals Hybrid Integration of 2D Semimetals for Broadband Photodetection[J]. Advanced Materials, 2025, 37(48): 2415717

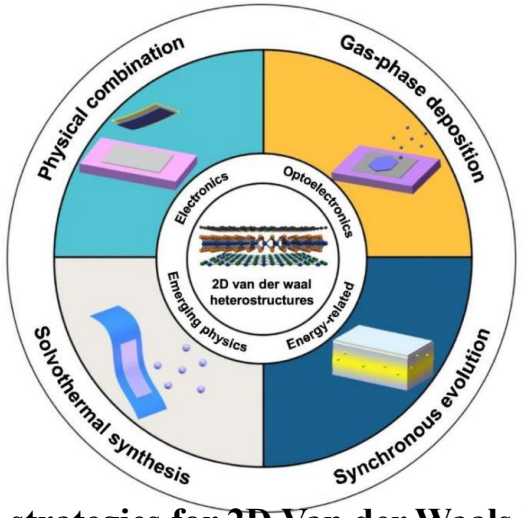
2D materials are mainly obtained via top-down exfoliation and bottom-up growth strategies. Top-down methods peel bulk crystals into thin nanosheets, while bottom-up techniques directly grow atomically thin films on substrates. These scalable methods support the fabrication of 2D-material-based flexible optoelectronic devices.

1.4 2D Van der Waals Heterojunction



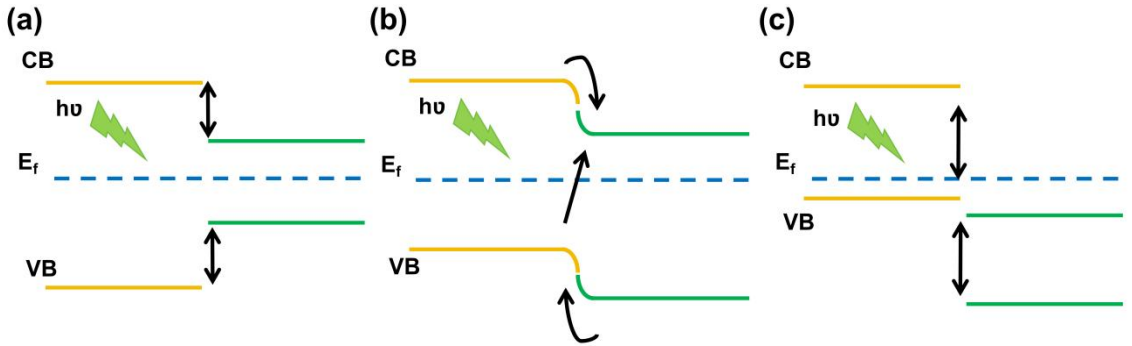
Schematic of different low-dimensional heterostructures

Wang H, Li Z, Li D, et al. Van der Waals Integration Based on Two-Dimensional Materials for High-Performance Infrared Photodetectors[J]. Advanced Functional Materials, 2021, 31(30): 2103106.



Synthesis strategies for 2D Van der Waals heterostructures

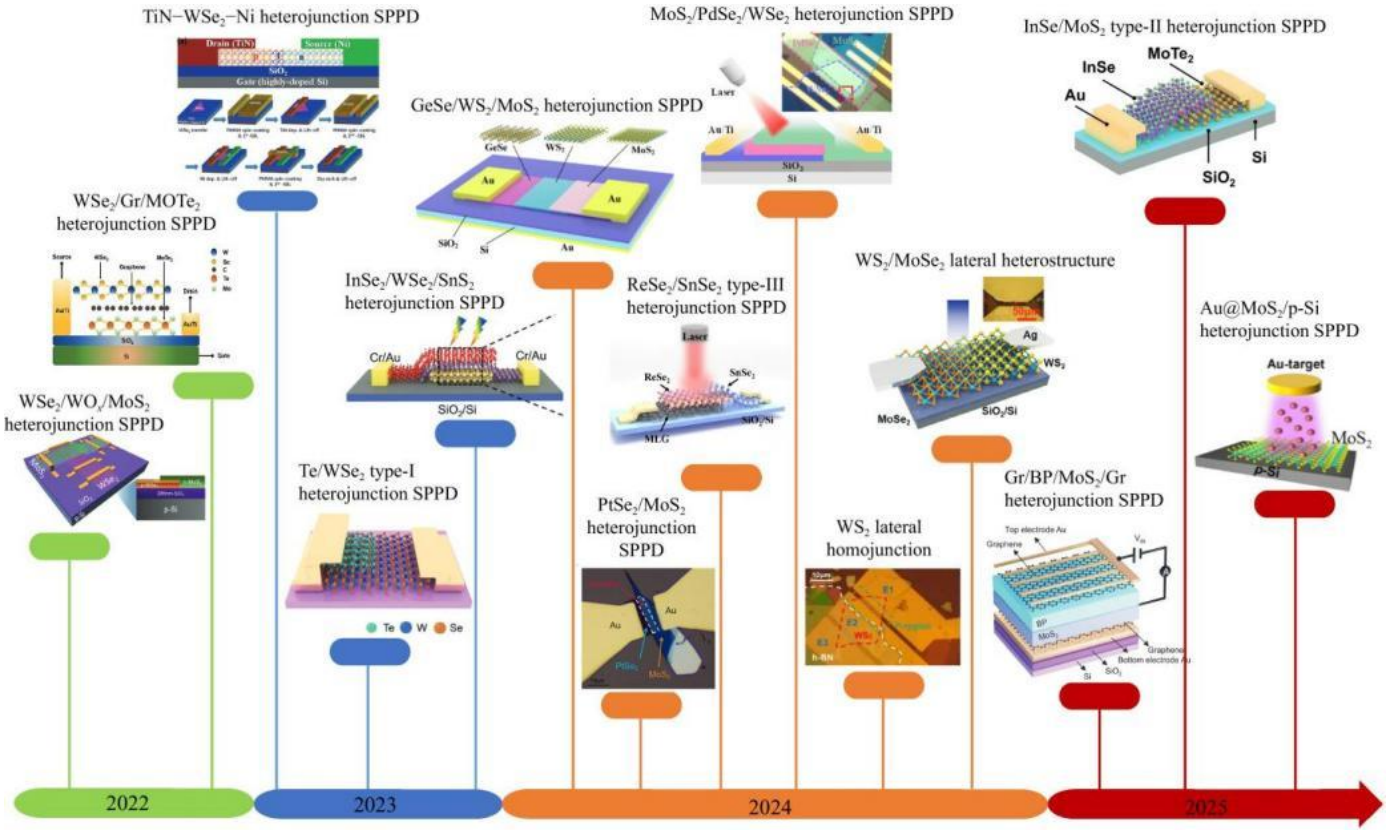
Qi J, Wu Z, Wang W, et al. Fabrication and applications of van der Waals heterostructures[J]. International Journal of Extreme Manufacturing, 2023, 5(2): 022007.



Schematic diagrams of Type-I, Type-II and Type-III band alignments

Van der Waals heterojunctions are constructed by stacking different 2D materials without lattice matching constraints. By regulating type-I/II/III band alignment, heterostructures can optimize carrier separation and transport. It is an effective strategy to break the performance bottleneck of single 2D materials.

2.1 Introduction Self-powered Photodetectors

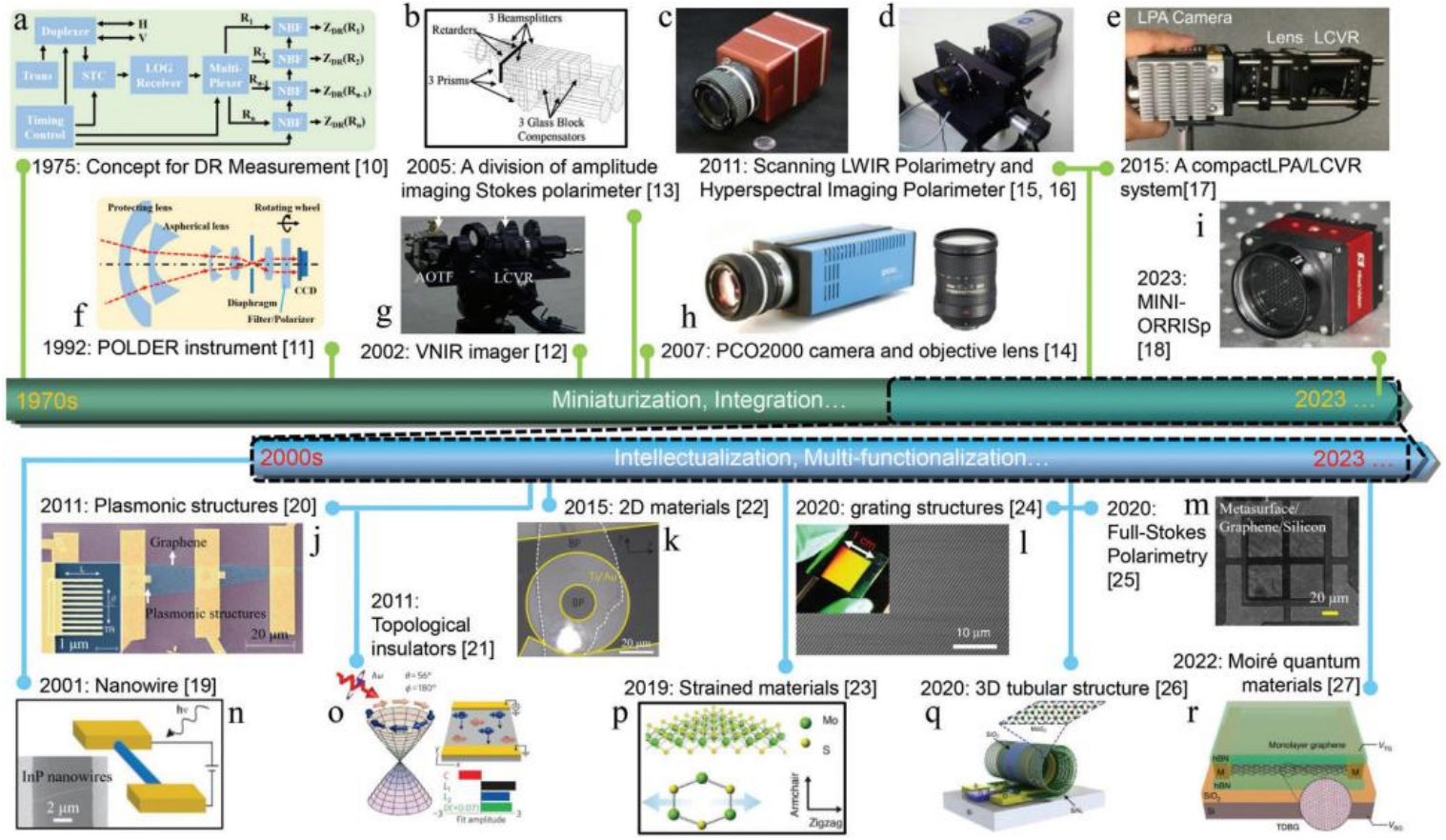


Summary of recent advances in self-powered photodetectors (SPPDs)

Self-powered photodetectors based on transition-metal dichalcogenides_ A heterojunction perspective

Self-powered photodetectors (SPPDs) can realize photodetection without external power supply. Benefiting from lightweight, miniaturization and ultra-low power consumption, they are highly suitable for wearable and portable optoelectronic systems

2.2 Introduction Polarization Photodetectors



Development and applications of polarization photodetectors (PPDs) since 2000

Xin W, Zhong W, Shi Y, et al. Low-Dimensional-Materials-Based Photodetectors for Next-Generation Polarized Detection and Imaging[J]. Advanced Materials, 2024, 36(7): 2306772.

Light is electromagnetic wave with intensity, wavelength, phase and polarization. Different from scalar optical parameters, polarization is a vector characteristic of light. Polarization photodetectors (PPDs) can capture polarization information, greatly enrich the dimension of optical detection.

1.5 Significance and Research Content

Significance

(1)TMDC van der Waals heterojunctions can overcome the inherent limitations of single 2D materials, promote carrier separation, and improve optoelectronic performance for photodetection.

(2)Polyimide (PI) film exhibits excellent flexibility, thermal stability and biocompatibility, which serves as an ideal substrate for wearable flexible photodetectors.

Research Content

Fabrication of WSe_2 /ReS_2 van der Waals heterojunction flexible devices on PI substrate, followed by systematic optoelectronic characterization of their photoresponse, self-powered and polarization-sensitive photodetection performance.

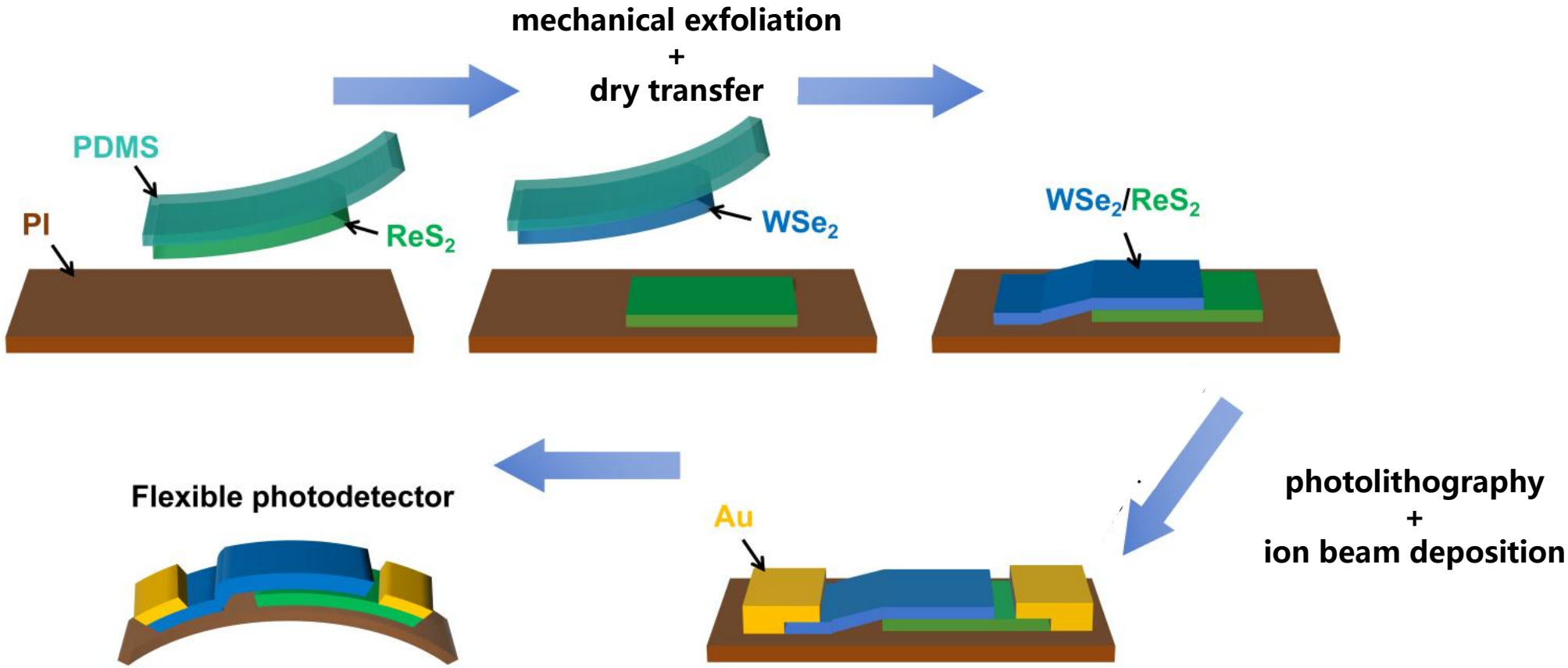
CONTENT

01 Introduction

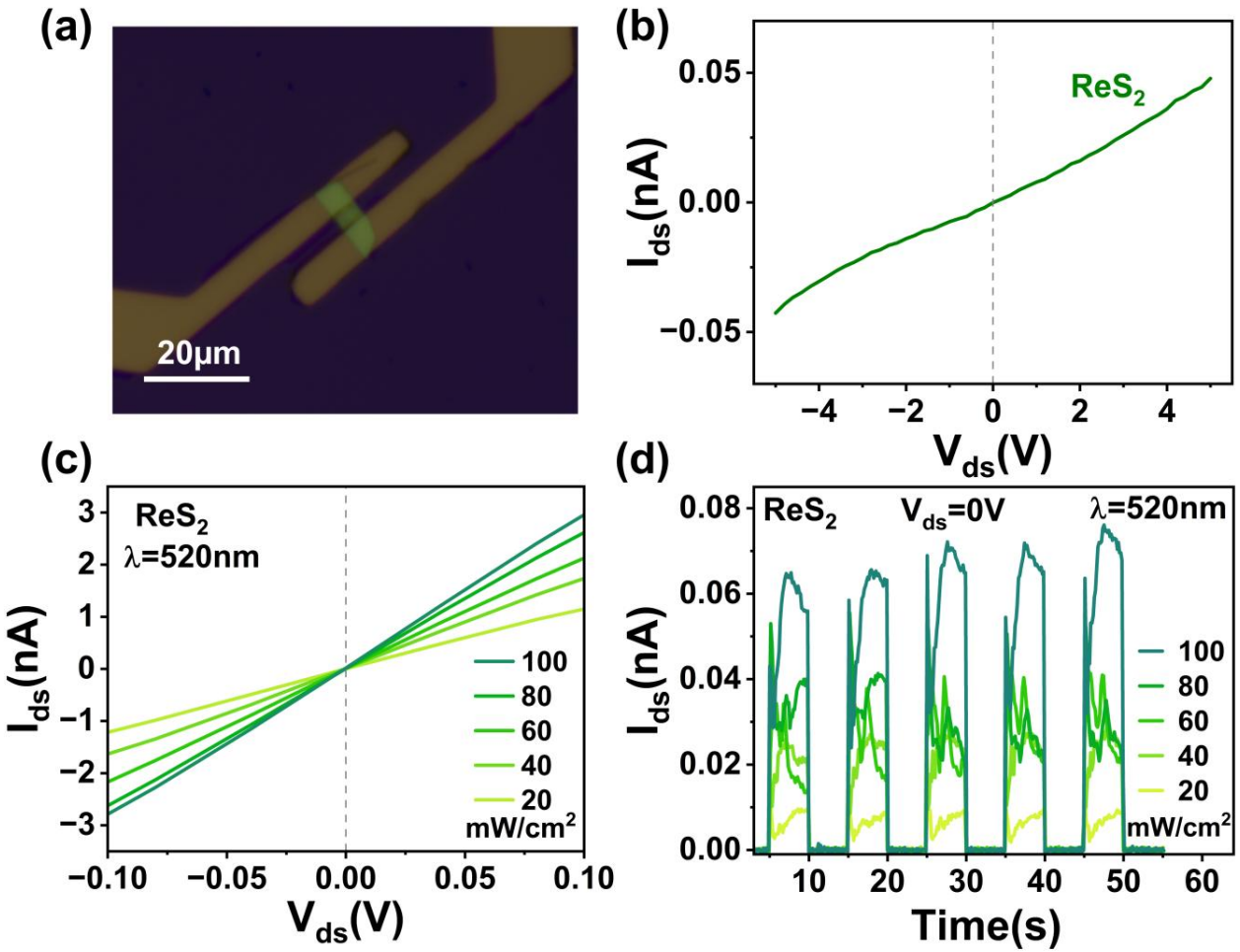
02 WSe_2 / ReS_2 Heterojunction Flexible Photodetecto

03 Summary

3.1 Device Fabrication Process



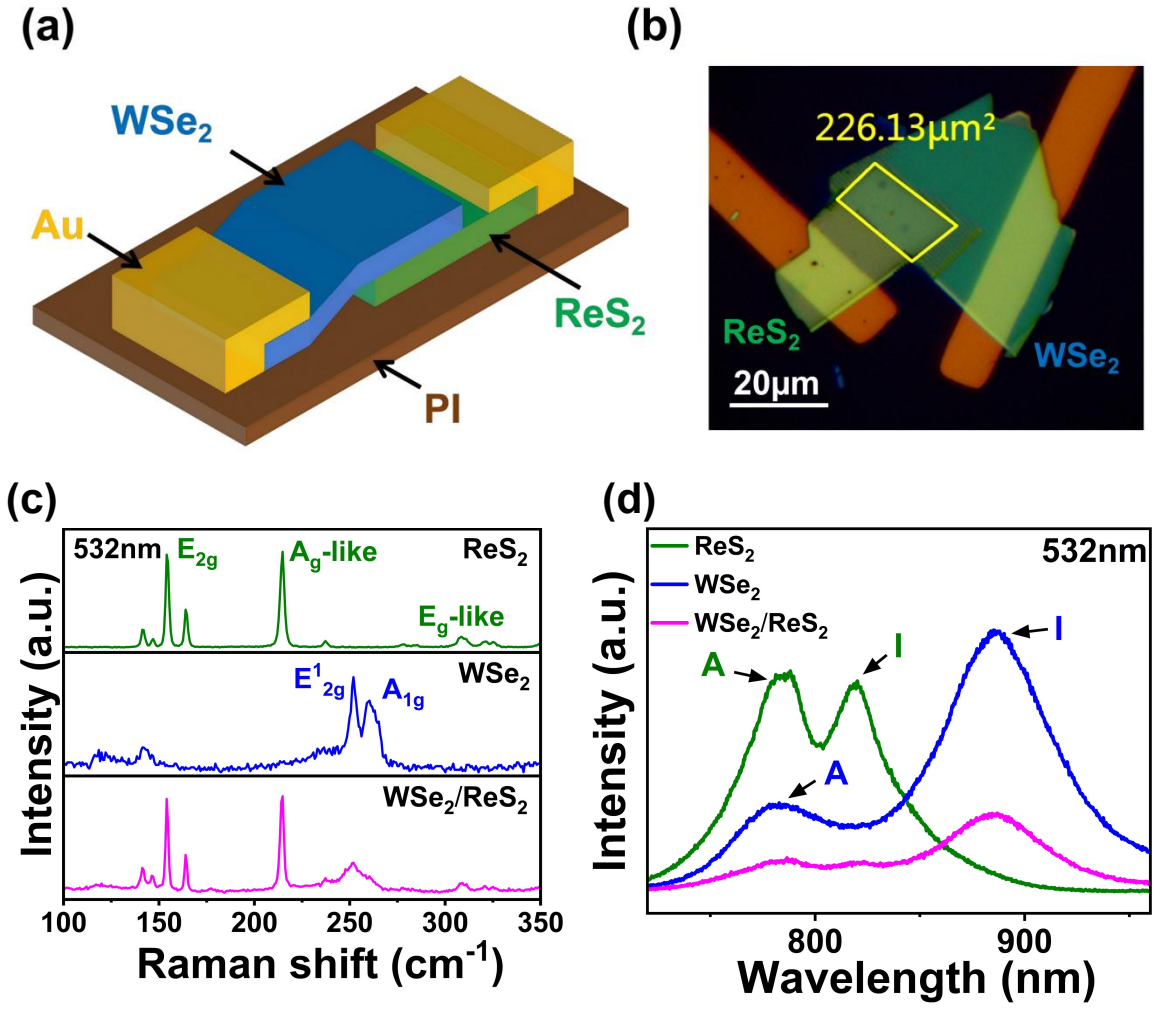
3.2 Optoelectronic Performance of Single ReS_2 Device



The single ReS_2 device shows Ohmic contact behavior. Under zero bias, its photoelectric conversion signal is weak and vulnerable to environmental noise, which cannot satisfy the demand for self-powered photodetection.

Fig.3.2 (a) Optical image of 2D ReS_2 photodetector; (b) Output curve of ReS_2 photodetector; (c) Ids-Vds characteristic curves of ReS_2 photodetector under 520 nm illumination; (d) Photoresponse time of ReS_2 photodetector under 520 nm illumination

3.3 Structural & Optical Characterization



In the overlapping region of WSe_2 /ReS_2 heterojunction, characteristic Raman peaks belonging to both ReS_2 and WSe_2 are clearly detected, which verifies the successful stacking of heterostructure.

PL quenching is observed in the heterojunction area. This phenomenon comes from efficient spatial separation of photogenerated carriers. The carrier separation suppresses radiative recombination and reduces PL intensity, demonstrating the built-in electric field effect in WSe_2 /ReS_2 van der Waals heterojunction.

Fig.3.3 (a) Schematic diagram of WSe_2/ReS_2 photodetector; (b) Optical microscope image of WSe_2/ReS_2 photodetector; (c) Raman spectra of ReS_2, WSe_2 and WSe_2/ReS_2 heterojunction; (d) PL spectra of ReS_2, WSe_2 and WSe_2/ReS_2 heterojunction

3.4 Working Mechanism of the Device

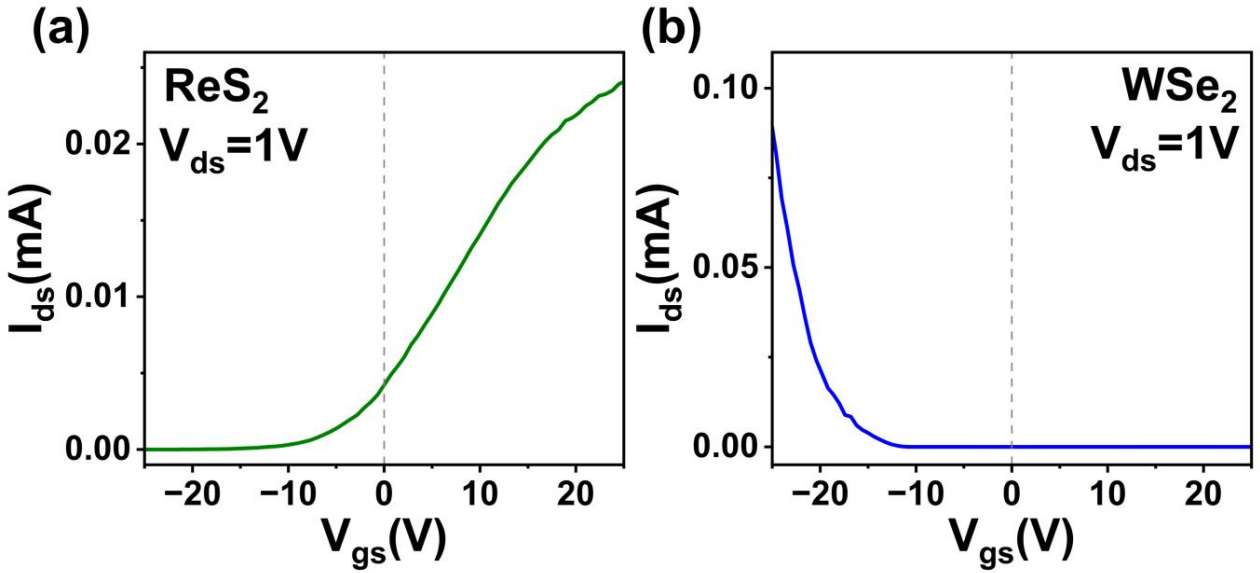


Fig.3.4 Transfer characteristic curves of ReS_2 (a) and WSe_2 (b) under dark conditions

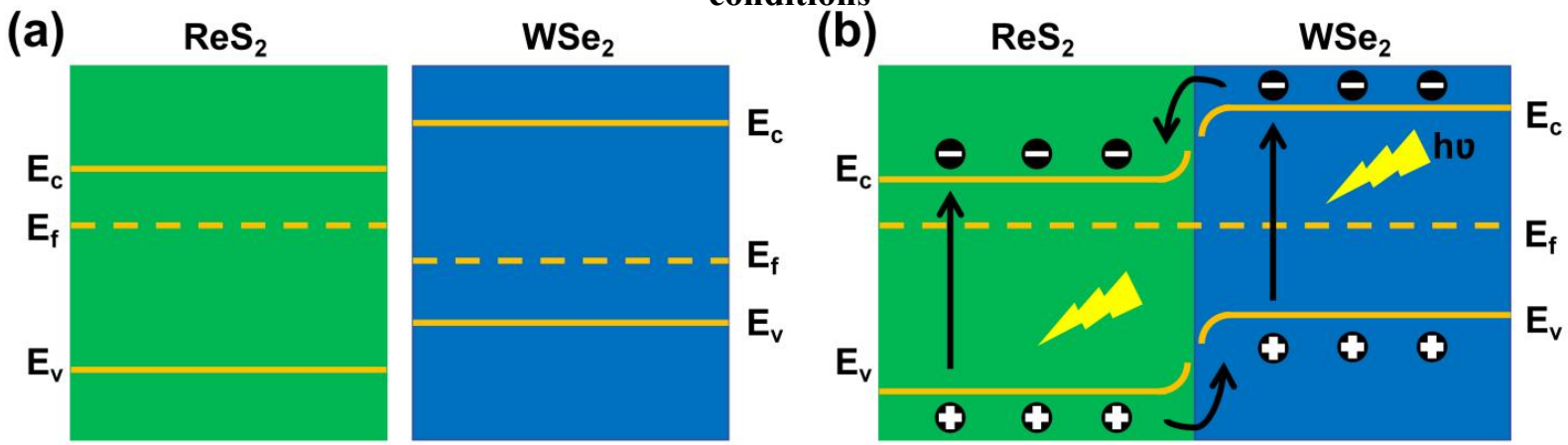
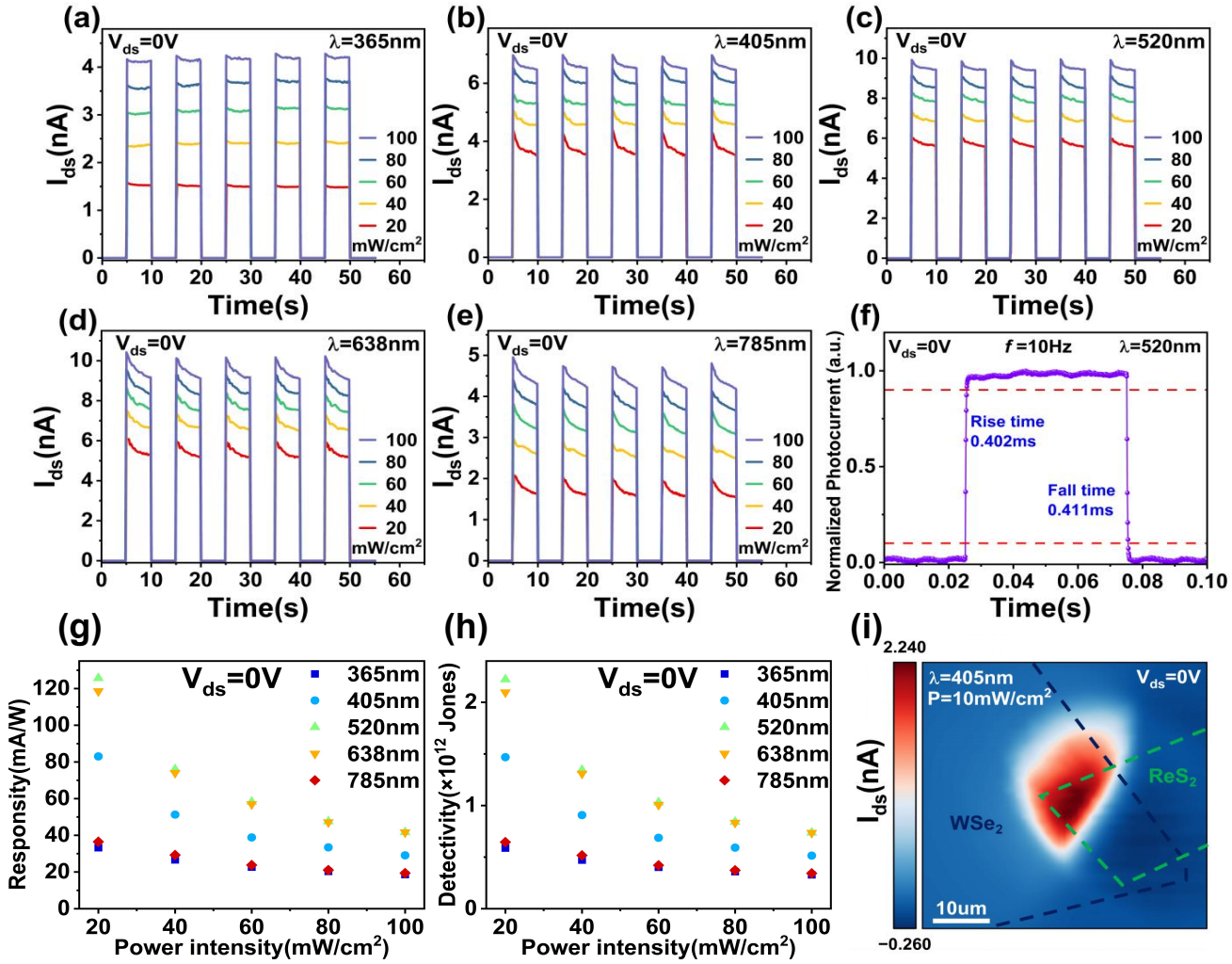


Fig.3.5 (a) Band structure diagram of ReS_2 and WSe_2 before heterojunction formation; (b) Schematic diagram of photovoltaic response

The transfer curves confirm that ReS_2 is n-type and WSe_2 is p-type. Based on material parameters, their electron affinities are 4.5 eV and 3.89 eV, with indirect bandgaps of 1.4 eV and 1.2 eV. A type- II band alignment is formed after contact, enabling spontaneous separation of photogenerated carriers.

3.5 Self-Powered Performance of the Device



At zero bias, the device exhibits stable self-powered photoresponse across multi-wavelength illumination (365, 405, 520, 638, 785 nm). The rise time is 0.602 ms and fall time is 0.411 ms. Responsivity and specific detectivity decrease with increasing optical power density. Photocurrent mapping confirms that photogeneration mainly occurs at the WSe_2 /ReS_2 overlapping heterojunction region.

Fig. 3.6 (a)–(e) Photoresponse time of the WSe_2/ReS_2 photodetector under different incident wavelengths; (f) Time-resolved photoresponse characteristics of the device; (g)–(h) Calculated R* and D* values of the WSe_2/ReS_2 photodetector at different wavelengths and light power densities; (i) Photocurrent mapping of the WSe_2/ReS_2 device under zero bias and 405 nm laser excitation

3.6Functional Investigation of the Device

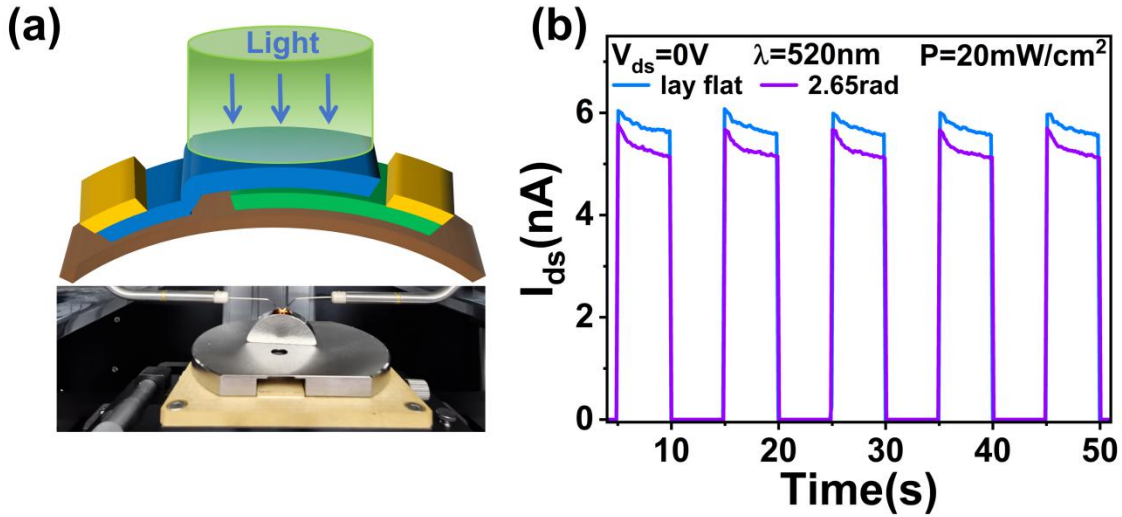


Fig. 3.7 (a) Schematic and photograph of the bent WSe_2 /ReS_2 flexible photodetector; (b) Photoresponse time of the heterojunction device under 520 nm laser illumination at flat and bent states.

The device maintains stable self-powered photoresponse under bending (2.65 rad). It exhibits obvious polarization-sensitive photodetection under 520 nm and 638 nm illumination, showing anisotropic photocurrent dependent on incident light polarization angle.

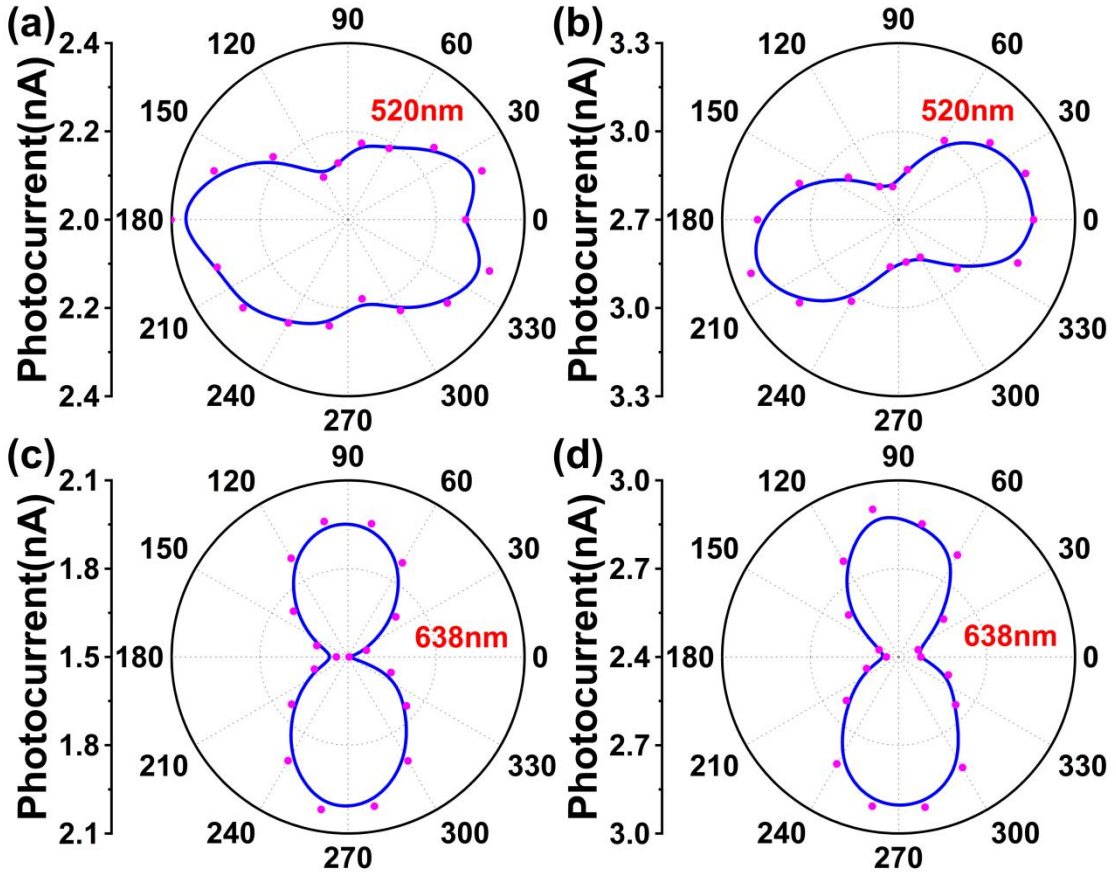
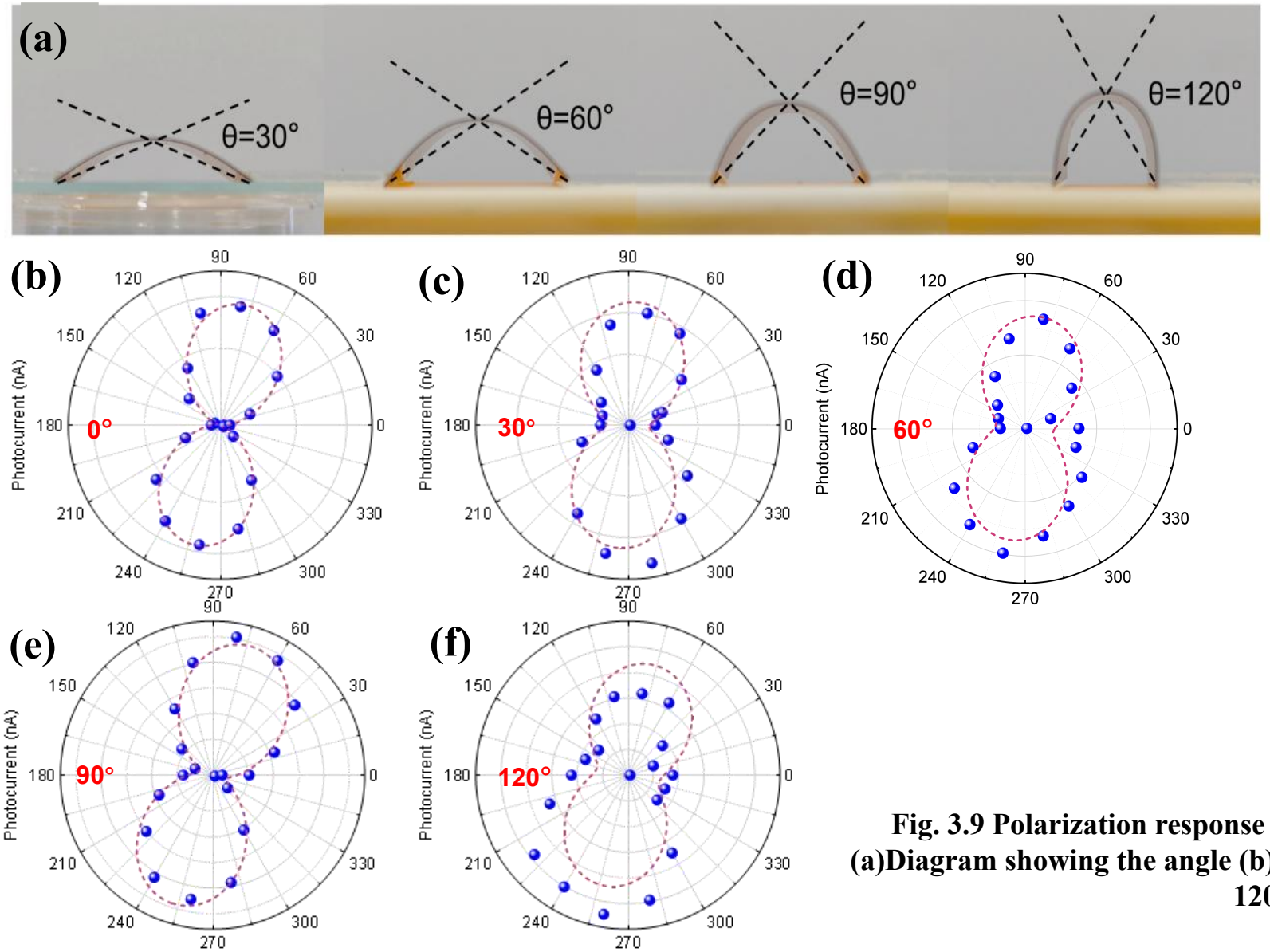


Fig. 3.8 Polar plots of polarization photocurrent under 520 nm illumination at Vds=0 V (a) and 2 V (b); under 638 nm illumination at Vds=0 V (c) and 2 V (d).

3.7 Functional Investigation of the Device



The device maintains obvious polarization-sensitive photoresponse at different bending angles (0°, 30°, 60°, 90°, 120°). The anisotropic photocurrent profile is well preserved upon bending, demonstrating stable polarization detection capability under mechanical deformation.

Fig. 3.9 Polarization response under varying bending angles (a)Diagram showing the angle (b) 0° (c) 30° (d) 60° (e) 90° (f) 120°

Research Summary

- The device shows broadband photoresponse (365–785 nm) with fast response (rise: 0.602 ms, fall: 0.411 ms). Photocurrent mapping verifies photoconversion at the heterojunction overlap.
- The constructed heterostructure features type- II band alignment, where the heterointerface built-in field facilitates photocarrier separation and realizes zero-bias self-powered photodetection.
- Originating from the intrinsic in-plane anisotropy of ReS_2 , the photodetector yields distinct polarization-dependent photoresponse.

CONTENT

01 Introduction

02 WSe_2 / ReS_2 Heterojunction

Flexible Photodetecto

03 Summary



廣西師範大學
GUANGXI NORMAL UNIVERSITY

Thank you for your attention!

Self-Powered Flexible Polarization Photodetector with Two-Dimensional TMC Heterojunction