Two-Dimensional Materials for Advanced Optoelectronics: From Material Design to Device Integration

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Abstract

Two-dimensional (2D) tungsten disulphide (2D WS_2) has attracted significant attention for next-generation optoelectronic applications due to its tunable bandgap, strong light–matter interaction, and excellent electrical properties [1,2]. The present study elucidates the synthesis of 2D WS_2 via a solid-state reaction route followed by liquid-phase exfoliation to obtain few-layer nanosheets. Structural and optical characterisation validate the effective synthesis of high-quality two-dimensional layers. The prominent (002) hkl planes identified from XRD are the characteristic peaks of layered 2D WS_2, signifying the inherent periodicity along the c-axis [3,4]. The FESEM images show a nanosheet-like morphology. The bandgap estimated from UV-Vis spectroscopy is 1.7 eV. 2D WS_2-based prototype devices for photodetectors and thin-film transistors are designed. Photodetector devices were fabricated on an Au/SiO_2/Si substrate configuration and operated under a low bias voltage of 1 V. A low-cost spin coating strategy was adopted for coating the 2D material over the Si/SiO_2 substrate. The device will work in a broad spectrum range from visible to IR. The fabricated device can operate in the nanoampere to microampere current range. This product can be used in different applications, such as CMOS/CCD image sensors, medical imaging, light sensors for automatic headlights, environmental monitoring, and security systems [5]. The material is also used to fabricate a 2D thin-film transistor. The output characteristics and transfer characteristics of the thin-film transistor were investigated. The device has a high on-off ratio (10^4 to 10^8) and low leakage current (10^{-9} A). This can be used for wearable electronics, memory devices, logic gates, and neuromorphic computing [3,5]. Their unique electrical and spin-valley features provide advantages over typical silicon-based transistors.

References

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Figures

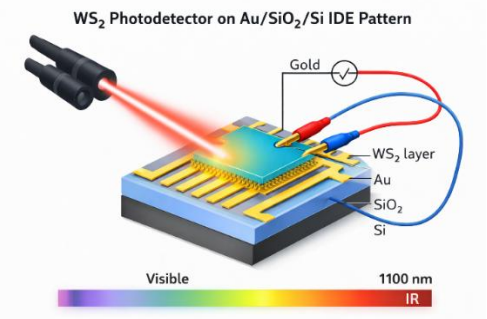

Figure Schematic of WS_2 photodetector device.