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Stabilization of 2D Janus Layers Using Plasma-Assisted Atomic Layer Functionalization of Materials (PA-ALFM)

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Background

2D transition metal dichalcogenides (TMDs) are a class of 2D material systems with the general chemical formula MX2 where M is a transition metal atom (e.g., Mo, W, Ti) and X is a chalcogen atom (e.g., S, Se, Te). When the M atoms are selected from group-VIB elements Mo or W, they form MoS2 , WSe2 , or MoTe2 and these materials behave as direct gap semiconductors in the monolayer limit. Since the inversion symmetry is broken and the spin orbit coupling (SOC) is large, 2D group-VI TMDs have exotic band structures with individually controllable valleys in K-space. The combination of the spin and valley degrees of freedom means that optically generated electrons and holes are both valley and spin polarized (spin-valley locking). This quantum property is absent in other traditional semiconductors.

While classical TMD surfaces have the same type of chalcogen atoms, 2D Janus TMDs have different chalcogens on each side. Although Janus layers have been experimentally stabilized using chemical vapor deposition (CVD), this stabilization involves high processing temperatures which typically result in defects. The irreproducibility and lack of epitaxial quality has made it difficult to probe quantum effects in Janus layers.

Invention Description

Researchers at Arizona State University have developed a manufacturing method for highly crystalline epitaxial-grade Janus TMD materials that is capable of epitaxial chalcogen replacement for stabilization of Janus 2D layers. The described methodology is not specific to one particular system, and is applicable to others such as MoSSe, WSSe, and MoSTe. The plasma-assisted atomic layer functionalization of materials (PA-ALFM) is carried out at room temperature, thus enabling an energy conservative approach with fine control over the crystal structure that would otherwise be hindered by a higher thermal gradient. PA-ALFM can be easily adapted to current industrial standards and material systems. Room temperature synthesis permits effective quality control for synthesis of optical-grade materials as well as complex vertical and heterostructures of these materials. Additionally, fast in-situ processing limits foreign contamination.

Potential Applications

- 2D transition metal dichalcogenides (TMDs)
- Janus layer fabrication
- Electronic, optical, spintronic, and valleytronic devices

Benefits and Advantages

- Energy efficient due to room-temperature in-situ synthesis
- Highly precise and selective layer replacement
- Short operating times
- Efficient and effective use of materials
- Minimal probability of contamination
- Easily adapted to current industry standards

Laboratory Homepage of Professor Sefaattin Tongay