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Editorial: Interface engineering in two-dimensional material based electronic and optoelectronic devices

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Editorial on the Research Topic
Interface engineering in two-dimensional material based electronic and optoelectronic devices

In nanotechnology and materials science, the transformative potential of two-dimensional (2D) layered materials has captured the attention and imagination of researchers worldwide. The true power of 2D materials lies in their unique properties and the seamless integration of these materials into multifunctional devices. At the core of this integration lies a burgeoning field known as *Interface Engineering*, which is pivotal in unlocking the full potential of 2D material-based next-generation electronic and optoelectronic device applications. Interface engineering is the intricate art of controlling and tailoring the properties of interfaces between different materials and environments, thereby influencing and modulating the performance of the device. From transistors and photodetectors to sensors and energy storage solutions, the impact of interface engineering reverberates across a wide spectrum of applications. Due to the inherent sensitivity of atomically thin 2D materials to their surrounding environment, high interface quality is crucial for realizing high-performance electronic and optoelectronic devices based on 2D materials. The properties of these materials can be drastically altered by factors such as substrate interactions, environmental conditions, and the presence of other materials in the device architecture. Interface engineering offers a solution by providing the tools and techniques to govern interactions between each material and environment, ultimately yielding the anticipated high-quality interfaces.

Furthermore, the cutting-edge nature of interface engineering in 2D materials is underscored by the ongoing development of interface engineering in 2D material devices, including passivating interface vacancy/trap states, interface doping, contact engineering, tunning the dielectric interface, and incorporating tunneling or charge transfer layers in 2D heterostructures. In this Research Topic, we emphasize the significance of interface engineering in 2D material-based electronic and optoelectronic devices. Four papers are published including three research articles and one mini review, covering a broad range of device applications such as transistors, photodetectors, photovoltaic devices and sensing devices.

Ion implantation is commonly employed for controlling semiconductor properties in the silicon industry. However, this technique is incompatible with 2D semiconductors due to the easily damaged lattice structure of atomically thin materials. To introduce a stable doping approach for 2D materials, Lee et al. investigated a facile n-doping method for 2D MoS_2 film with ferroelectric poly (vinylidene fluoride-co-trifluoroethylene) (P(VDF-TrFE)) polymer dopant. The polar phase formation of the dopant layer can modify the n-doping concentration in MoS_2. Field-effect transistors based on MoS_2 doped with P(VDF-TrFE) have shown largely enhanced electrical performance (carrier mobility of 34.4 $cm^2V^{-1}s^{-1}$ and on-current of 21 μA), and the doping exhibits remarkable thermal stability.

For the utilization of interfaces in the heterostructures constructed by stacking of 2D materials, Zhao et al. presented an investigation of 2D $MnSe/WSe_2$ heterojunction and studied its photoresponsive properties. The heterojunction device exhibits a current rectification on/off ratio of 6557 and a broad spectral range response (300–2,200 nm). The device achieves an ultra-high responsivity of 156 A/W, along with an excellent detectivity of 2.21×10^{12} Jones, and an outstanding external quantum efficiency of 36,400%. Meanwhile, the type-II band alignment and the built-in potential in the $MnSe/WSe_2$ heterojunction can facilitate the separation of photoexcited electron-hole pairs, which enables significant photovoltaic characteristics and self-powered photoswitching response. These results reveal the great potential of heterojunctions based on 2D non-layered MnSe in optoelectronic applications.

By modifying the device interface using the localized surface plasmon resonance (LSPR) technique, Li et al. demonstrated the improvement of the photoelectric conversion efficiency of dye-sensitized solar cells (DSSCs). The results show that DSSCs with LSPR display excellent current density and incident photon current efficiency performance compared to DSSCs without silver nanoparticles. This study suggests that the appropriate amount of silver nanoparticles plays a crucial role in improving the photon-electric conversion efficiency and the optimal proportion of metal nanoparticles represents a valuable and effective method for enhancing DSSC performance. This study provides new insights into the mechanisms and optimization methods of the LSPR effect in photovoltaic devices.

2D materials hold great promise as active substrates for surface-enhanced Raman spectroscopy (SERS) due to their tunable energy bands and interlayer coupling. Compared to noble metals, 2D materials have atomically smooth surfaces, greater chemical stability, and high interfacial tunability. To provide guidance for future tunable SERS studies based on 2D materials, Zhao et al. reviewed recent advances in tunable SERS on 2D materials based on interface engineering and provided perspectives. The various tunable modes of 2D materials offer great potential in tunable SERS active substrates, such as electrostatic tuning, surface doping, phase engineering, and so on. The study of tunable SERS on 2D materials through interface engineering is essential for the future development of multifunctional tunable photoelectric sensor devices.

We would like to express our gratitude to all the authors contributed to this Research Topic, as well as the *Frontiers* editorial staff and reviewers for their diligent reviewing and editing work. We firmly believe that the future of electronics and optoelectronics is intricately linked to the manipulation of interfaces, and interface engineering stands as the critical element that will unlock the limitless possibilities of 2D materials.

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LT: Conceptualization, Funding acquisition, Project administration, Writing–original draft, Writing–review and editing. YZ: Writing–review and editing, Writing–original draft. YD: Conceptualization, Writing–original draft.

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Conflict of interest

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