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EDITORIAL

Preface to Special Topic on Twisted van der Waals Heterostructures

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Twisted van der Waals heterostructures are becoming the building blocks for engineering new device structures, in which their electronic, optical and mechanical properties can be tuned by changing the “twist” angle between layers of 2D materials. Such twisted 2D heterostructures offer a unique opportunity to create a new field of “twistronics” by mechanically stacking different 2D van der Waals materials together. Together with the lattice mismatch of the adjacent 2D crystals, the twist gives rise to the moiré superlattice: a larger periodic unit than the original one, which has been used to engineer the optical properties and electronic structure of 2D materials and generate a series of novel phenomena. Although van der Waals interactions between 2D materials are quite weak, moiré superlattices can significantly modify the band structures of electrons and phonons. Unexpected distortions in band structure and topology lead to long-range correlations, charge-ordering, and several other fascinating quantum phenomena hidden within parent materials. At the most basic level, stacking, twisting, gate-modulating, and optically exciting these superlattices is a fundamentally new way to control these materials that just doesn’t exist in conventional semiconductor heterostructures. It therefore opens the door for seamlessly exploring physics from the weak to strong correlations limit within a many-body and topological framework. A whole new field of research in twistronic materials can be varied by simply twisting material layers. However, “twistronics” faces more challenges when compared to their untwisted counterparts, which requires more breakthroughs and research efforts on fabrication techniques, novel structure designs, and deep physical understandings. It is impossible to capture it all, and the aim of this focus topic is to highlight some of the important recent developments in synthesis, experiments, and potential applications of twisted van der Waals heterostructures.

This special topic assembles 6 review articles, 1 research article, 1 news & views and 1 comments & opinions providing a comprehensive summary of the latest development on twisted van der Waals heterostructures. Briefly, Huang *et al.* have comprehensively reviewed and discussed the recent progress on fabrication and flat-band physics in 2D transition metal dichalcogenides moiré superlattices[1]. In this review, they focus on the semiconducting transition metal dichalcogenides (TMDs) based moiré systems that host intriguing flat-band physics. They review the exfoliation methods of two-dimensional materials and the fabrication technique of their moiré structures, the progress on the optically excited moiré excitons, the formation mechanism of flat bands and their potential in the quantum simulation. Li *et al.* give an overview of phonons in 2D moiré superlattice[2]. They introduce the theory of the moiré phonon modes, electron-phonon coupling (EPC) modulated by moiré patterns, and the phonon-mediated unconventional superconductivity in 2D moiré superlattice. Gao *et al.* review recent advances in the coupling of moiré interlayer excitons to cavities, and comment on the current difficulties and possible future research directions in this field[3]. Compared with normal excitons, moiré excitons, especially interlayer or hybrid moiré excitons, have additional intriguing properties such as permanent out-of-plane dipoles, electrically tunable energies, long-range and strong interactions, and tunable spatial confinement by moiré potential. Li *et al.* review the interface engineering in two-dimensional heterostructures towards novel emitters[4]. They discuss the interface-engineered intralayer exciton emission and interlayer exciton emission, representative progresses on the exotic interfacial interactions including interfacial energy or carrier transfer, random fluctuations, localized excitonic states, moiré excitons and latest ones like moiré quantum emitters. Zhang *et al.* review the latest research on 2D twisted ferroelectrics, including bilayer stacked graphene, bilayer boron nitride, and transition metal dichalcogenides[5]. They also prospect the development of 2D twisted ferroelectrics and discuss the challenges and future of 2D ferroelectric materials. Zhao *et al.* report their recent research in gate tunable spatial accumulation of valley-spin in 40-degree-twisted bilayer WS_2[6]. They study the valley Hall effect (VHE) in 40-degree-twisted chemical vapor deposition (CVD) grown WS_2 moiré transistors, using optical Kerr rotation measurements at 20 K. A clear gate tunable spatial distribution of the valley carrier imbalance induced by the VHE is observed. Lu gives a scientific comment on single photon emitters originating from donor–acceptor pairs[7] published in Nano Letters[8]. The DAP transition is common among conventional semiconductors, such as silicon, diamond and GaN, and it describes a luminescence mechanism that involves the coulomb interaction between the ionized donors (D^+) and acceptors (A^-). Besides the charged sites, the light-induced electrons and holes can also be trapped by the neutral donor (D^0) and acceptor (A^0) before the radiative emission. Optical signature of DAP is generally characterized by a series of sharp emission lines at low temperatures. Chen *et al.*

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give comments on the recent progress of “magic” angles graphene moiré superlattice[9].

We sincerely hope this special issue could provide the meaningful and profound review and perspective on the field of “twistronics”. We would like to thank all the authors for their outstanding contributions to this special issue. We are also grateful to the editorial and production staff of the Journal of Semiconductors for their kind assistance.

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