The Nano Research Young Innovators (NR45) Awards in two-dimensional materials

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Nano Research launched the *Nano Research* Young Innovator Awards (NR45) program in 2018 to feature young researchers under the age of 45 in various fields of nanoscience and nanotechnology, in recognition of their distinguished accomplishments and/or potential to make substantial contributions to their fields. The NR45 awardees were selected through a competitive process by an award committee from the journal's editorial board. The 2021 NR45 Awards focus on the topic area of two-dimensional (2D) materials, and highlight 35 innovators in cognitions of their extraordinary contributions to this rapidly expanding field. Congratulations to all the 35 outstanding young innovators!

The discovery of graphene has ignited intensive interest in 2D materials. In general, there is a large family of layered materials, in which the atomic layers are weakly bonded together by van der Waals interactions. The 2D materials can be readily prepared from the corresponding layered crystals through a micromechanical exfoliation approach, which has fueled the rapid expansion of 2D material research. However, such mechanical exfoliation approach is intrinsically unsuitable for practical technologies and it is imperative to develop more scalable synthetic strategies to 2D materials over large area or in large quantity. This special issue starts with a comprehensive review by Bilu Liu from Tsinghua University on the mass production of 2D materials beyond graphene, including “top-down” exfoliation and “bottom-up” synthetic approaches [1]. Next, Guangyu Zhang from Institute of Physics, Chinese Academy of Science highlights specifically on the large area epitaxial growth of high-quality continuous monolayer MoS₂ films [2]. Lei Fu from Wuhan University reviews a space-confined method for the growth of perovskite crystal film with controlled size, thickness, quality and structure [3]. Kai Xiao from Oak Ridge National Laboratory provides a focused review of controlled synthesis and processing of heterogeneities at multiple length scales and their impact on the macroscale properties and functionalities of 2D materials [4]. Litao Sun from Southeast University reviews the *in-situ* transmission electron microscopy (TEM) studies probing the nucleation and formation of 2D crystals [5]. Liying Jiao from Tsinghua University then presents a research article on fast growth of single crystalline WS₂ monolayer domains [6], and Shuyun Zhou from Tsinghua University reports a large-scale growth of PtTe, PtTe₂ and PSe₂ thin film via straightforward selenization or tellurization of deposited Pt films [7].

Modulation of the electronic and optical properties of 2D materials is an important frontier in 2D material research. Doping represents a common strategy to tailor the electronic properties of semiconductor materials. Goki Eda from National University of Singapore highlights the recent progress in substitutional doping 2D group VI transition metal dichalcogenides (TMDs) and their physical effects on optical and electronic properties [8]. With limited physical space in the atomically thin 2D crystals, it is often difficult to incorporate sufficient substitutional dopants without seriously disrupting the crystal structures. To this end, Wei Chen from National University of Singapore reviews an alternative surface charge transfer doping (SCTD) approach as a non-destructive doping technique for 2D materials [9]. Strain engineering offers another attractive strategy to tailor the physical properties of 2D materials. In an original research article, Andres Castellanos-Gomez from Consejo Superior de Investigaciones Científicas reports a systematic study on how uniaxial strain modifies the optical properties of single-, bi- and tri-layer TMDs [10]. Retaining the structural and electronic stability of 2D materials is essential for practical applications. Libo Gao from Nanjing University reports how elemental ratio, chalcogen vacancies or anti-site defects affect the environmental stability of 2D-TMDs [11]. Inelastic light scattering provides a powerful experimental tool to probe electron-phonon interactions and characterize 2D materials. Jun Zhang from Institute of Semiconductors, Chinese Academy of Science gives an overview of fundamental theory and experiment advances of Raman and Brillouin scattering studies in 2D materials [12]. Zheng Zhang from University of Science and Technology Beijing summarizes microscopy and optical spectroscopy techniques for probing the interfacial coupling effect and the structure-property relationship of van der Waals (vdW) heterostructures [13].

The atomically thin 2D semiconductors have attracted tremendous interest for diverse electronic applications. Peng Zhou from Fudan University provides an overview on the current status of 2D electronics and prospects possible pathways in exploring 2D materials for future electronics [14]. Yuan Liu from Hunan University highlights the recent progresses and opportunities in exploring 2D semiconductors for complementary-metal-oxide semiconductor (CMOS) logic circuits [15]. In an original research article, Yang Chai from the Hong Kong Polytechnic University reports a unique design of secured physical unclonable function (PUF) devices

exploiting physical randomness of 2D transistors [16]. 2D magnets have attracted enormous attention for fundamental investigation of 2D magnetism and the creation of a new generation of spintronic devices and magnetoelectronics. Yongji Gong from Beihang University summarizes the chemical vapor deposition growth of 2D magnetic materials and their characterizations and applications [17]. Bo Peng from University of Electronic Science and Technology of China highlights 2D ferromagnetic and ferroelectric vdW heterostructures for on-chip spintronic and nonvolatile memory devices [18]. Lei Liao from Hunan University reports a gate-tunable linear magnetoresistance in MoS₂ field-effect transistors with graphene insertion layer [19].

Many 2D materials typically feature strong light-matter interaction and display rich optoelectronics properties, making them interesting platforms for diverse optoelectronic devices including photodetectors and light-emitting devices. Xiangheng Xiao from Wuhan University summarizes the recent progress on high-performance photodetectors from metal dichalcogenides and various heterostructures [20]. Weida Hu from Shanghai Institute of Technical Physics, Chinese Academy of Sciences gives a comprehensive review on various advanced characterization technologies, including TEM, Raman, photoluminescence (PL) spectroscopy and Kelvin probe force microscope (KPFM), scanning photocurrent microscope (SPCM), and scattering scanning near-field optical microscope (s-SNOM) in studying 2D material based photodetectors [21]. Han Wang from University of Southern California specifically discussed mid-infrared (IR) detectors enabled by 2D materials [22]. Chuan Wang from Washington University in St. Louis highlights the opportunities in exploring 2D materials and their van der Waals heterostructures for emerging avalanche photodetectors [23]. Zhenhua Ni from Southeast University reviews the opportunities and challenges in exploring 2D materials for position-sensitive detectors (PSD) [24], and Wei-bo Gao from Nanyang Technological University reviews the optical valley physics in the 2D van der Waals heterostructure and their potential for a new generation of opto-valleytronics [25].

Two-dimensional materials provide tremendous opportunities for future on chip light sources. Yuerui Lu from the Australian National University summarizes the current achievement and future opportunities in exploring 2D materials for light emitting applications [26]. Qing Zhang from Peking University reviews the recent advances in the strong exciton-photon interaction and lasing of 2D-TMDs for ultra-small and low-energy consumption coherent light sources [27]. In five original research articles on 2D optoelectronics, Kai Zhang from Suzhou Institute of Nano-Tech and Nano-Bionics reports van der Waals epitaxy of ultrathin crystalline PbTe nanosheets with high near-infrared photoelectric response [28]; Mark C. Hersam from Northwestern University reports a Bi₂O₂Se based avalanche photodiode with an intrinsic carrier multiplication factors up to 400 [29]; Woo Jong Yu from Sungkyunkwan University reports a vertically stacked graphene/hexagonal boron nitride/silicon (Gr/h-BN/Si) vdW heterostructure with greatly enhanced detectivity near-zero external bias of photodetector by inserting thin layer of h-BN to suppress dark current [30]; Di Wu from Zhengzhou University reports a highly sensitive solar-blind deep ultraviolet photodetector based on graphene/PtSe₂/β-Ga₂O₃ Schottky junction [31]; and Dehui Li from Huazhong University of Science and Technology reports a giant enhancement of photoluminescence quantum yield of 2D perovskite by using graphene encapsulation to reduce quantum confined Stark effect and surface depletion field, and enhance radiative recombination efficiency [32].

The 2D materials have also shown considerable promises for catalysis and energy storage. Gongming Wang from University of Science and Technology of China summarizes recent progresses in the electronic structural modulation of MoS₂ for hydrogen evolution catalysis [33]. Dangyuan Lei from City University of Hong Kong discusses the dimensionality and interface engineering of TMD-based mixed-dimensional heterostructures for visible-light-driven photocatalysis [34]. Yuxi Xu from Westlake University gives a comprehensive review of the research progress in 2D polymer nanosheets, their structure-property relationships and applications in energy storage and conversion [35].

Together, this special issue provides an excellent collection of review articles and research papers, highlighting a diverse range of topics in 2D materials. We sincerely thank all the awardees for their contributions. We hope that you will enjoy this special issue, and encourage yourself and your colleagues to nominate outstanding young innovators in your field for the following years' NR45 awards.

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