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Insights into 2D materials

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In 1959, American physicist Richard Feynman gave a lecture at the annual American Physical Society meeting, ''There's plenty of room at the bottom: An Invitation to Enter a New Field of Physics''. The recognition of the quantum confinement effect in solids inspired the discovery of zero-dimensional quantum dots and one-dimensional quantum wires and nanotubes. In this famous lecture, Feynman also asked, ''What could we do with layered structures with just the right layers?'' This question was partially answered in 2004 with discovery of graphene, which has exploded into a large research field with about 40 000 annual publications and was the topic of Nobel Prize in Physics, 2010.

The success of graphene has encouraged the exploration of other two-dimensional (2D) materials from layered structures. Since 2010, hundreds of other types of 2D materials have been studied, including elemental 2D materials, such as phosphorene, borophene, silicene and antimonene, as well as compound materials, such as transition metal chalcogenides and oxides, hexagonal boron nitride, MXenes, and organic–inorganic metal halide layered perovskites. These materials span the entire electronic phase space of solids, ranging from insulators, semiconductors, semimetals, conductors, and superconductors, as well as novel quantum matters. With thousands of layered materials that can be potentially thinned down to monolayers, it is believed that we are merely seeing the tip of the iceberg.

2D materials possess many intrinsic and unique features that make them attractive to both fundamental research and applications. In the few-layer regime, the electronic structure and lattice symmetry of these materials can vary significantly with thickness, resulting in thickness-tunable electronic, optical, and spin/valley properties. With a thickness comparable to or smaller than the characteristic Coulomb interaction lengths, the dielectric screening effect is significantly reduced, resulting in enhanced electron–electron interactions and the formation of stable excitons, trions, and biexcitons. The extended electric field beyond the material also provides opportunities to control the electronic and optical properties of 2D materials by manipulating their environment. The van der Waals nature of the interlayer coupling provides near-perfect surfaces that are free of dangling bonds, reducing carrier scattering and improving charge mobility and spin lifetime. The small thickness and the van der Waals coupling of 2D materials also enable their applications in flexible devices which can sustain large strain and, hence, can be used in flexible devices. In addition to their promising applications as individual materials, 2D materials provide a new route to fabricating van der Waals heterostructures. Without the constraint of lattice matching, which has been a significant roadblock when combining different 3D materials, a large number of materials can be assembled, producing many new functional materials.

This themed collection highlights the latest developments in this exciting field, emphasizing new insights into 2D materials from theoretical, computational, and experimental communities. In material discovery, the fabrication of several members of the 2D family is reported, such as Bi_2S_3 (**https://doi.org/10.1039/D1CP03815J**) and graphene fibers (**https://doi.org/10.1039/D1CP03238K**). New materials are also studied numerically based on first-principles simulations, including N_2P_6 (**https://doi.org/10.1039/D1CP03211A**) and germanium oxides (**https://doi.org/10.1039/D1CP02299G**). The physical properties of 2D materials are studied, focusing on the thickness-dependent carrier and phonon dynamics (**https://doi.org/10.1039/D1CP03202J**), gate-tunable superconductivity and charge density wave (**https://doi.org/10.1039/D1CP02214H**), temperature-dependent electrical/magneto transport

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(**https://doi.org/10.1039/D1CP03225A**), and magnetic-tuned valley polarization (**https://doi.org/10.1039/D1CP03490A**). The themed collection also features new progress in 2D heterostructures of graphene/Mo_2C (**https://doi.org/10.1039/D1CP03536C**), MoS_2/ferroelectric substrates (**https://doi.org/10.1039/D1CP02248B**), WS_2/GeS (**https://doi.org/10.1039/D1CP01892B**), and semiconducting polymer/franckeite (**https://doi.org/10.1039/D1CP01694F**), emphasizing their charge transfer and carrier properties. Several perspectives are included in this themed collection, highlighting the advanced characterization tools of polarized and angle-resolved Raman spectroscopy (**https://doi.org/10.1039/D1CP03626B**) as well as coherent anti-Stokes, stimulated, and tip-enhanced Raman spectroscopy (**https://doi.org/10.1039/D1CP03240B**). Various aspects of the applications of 2D materials are discussed in the themed collection, such as ferroelectric devices (**https://doi.org/10.1039/D1CP02788C**) and photodetectors (**https://doi.org/10.1039/D1CP03536C**).

2D materials are one of the most exciting and dynamic fields of materials science and technology. We hope that this themed collection offers a snapshot of some of the latest developments. There are many other topics in 2D materials that are equally exciting but were omitted due to space restrictions.

Finally, we would like to thank all the authors for their contributions, and the *PCCP* editorial staff for their guidance and support. We hope that researchers in physics, chemistry, engineering, and materials science will enjoy these papers and perspectives.