Raman spectroscopy of two-dimensional materials and related heterostructures

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Two-dimensional materials (2DMs), such as graphene and transition metal dichalcogenides (TMDs), have been under intensive investigation. The rapid progress of research on graphene and TMDs is now stimulating the exploration of different types of 2DMs. The atoms within each layer in 2DMs are joined together by covalent bonds, while van der Waals interactions keep the layers together to form multilayer 2DMs, which makes the physical and chemical properties of 2DMs strongly dependent on their thickness (or layer numbers). These various 2DMs could be re-stacked/assembled horizontally or vertically in a chosen sequence to form van der Waals heterostructures (vdWHs), which can offer huge opportunities for designing the functionalities of such heterostructures. Two or more 2DMs with similar properties can be alloyed into a new type of 2DMs, namely, 2D alloy, which can offer tunable band gaps for promising applications in nanoelectronics and optoelectronics. Except the isotropic 2DMs such as graphene and 2H TMDs, anisotropic 2DMs such as black phosphorus (BP), SnSe, rhenium disulfide and rhenium diselenide (ReSe2) have one more degree of freedom to deliver various physical properties.

Raman spectroscopy is becoming increasingly important in the area of 2DMs. Raman spectroscopy can reveal information on the crystal structure, electronic structure, lattice vibrations and flake thickness of 2DMs, and can be used to probe the strain, stability, charger transfer, stoichiometry, and stacking orders of 2DMs. In particular, the unique interlayer vibrations have been widely used to develop a substrate-free layer-number identification of 2DMs, and to probe the strength of interlayer coupling in 2DMs and the interface coupling in artificial vdWHs. Here, we will review the recent advances on Raman spectroscopy in the characterization of different kinds of 2DMs and the corresponding 2D alloy and vdWHs. We will show that Raman spectroscopy is an ideal tool to probe the fundamental physics and potential applications of these various 2DMs, particularly when they are reduced down to monolayers or multilayers.

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