Resonance Raman spectroscopy in novel 2D structures

Marcos A. Pimenta
Departamento de Física, UFMG, Brazil

The discovery of graphene opened the new area of study about two-dimensional (2D) materials. It was observed that the physical properties were different in structures with more than one atomic layer, and also dependent on the twisting angle between two layers. New types of 2D structures emerged as very promising materials, such as the transition metal dichalgogenides (TMDs), which can exhibit a semiconductor or metallic behavior depending on the type of atoms. More recently, black phosphorus attracted the attention of many scientists, because it is also a mono-atomic 2D structure, such as graphene, but many of its properties are anisotropic in the 2D plane, and strongly dependent on the number of layers. Resonance Raman spectroscopy (RRS) has shown to be a very useful tool to provide information about the interaction of phonons with electrons or excitons in different 2D materials. We will present RRS results in different 2D structures, starting from the discussion of the effect on the Raman spectra of the twisting angle between two graphene layers, in a bilayer structure. We will show that new peaks appear in the Raman spectra of twisted bilayer graphene, and that they can have different physical origin. The anomalous enhancement of the G band is observed when the laser excitation energy is in resonance with the van Hove singularities, which are generated by the Moire superstructure [1]. We will then present a RRS study of different samples of 2D transition metal dichalcogenides (MoS_2, WS_2 and WSe_2) with one, two and three layers (1L, 2L, 3L) and bulk samples, using dozens of different laser excitation lines covering the visible range [2-4]. We observed that all Raman features are enhanced by resonances with excitonic transitions, and from the laser energy dependence of the Raman excitation profile (REP) we obtained the energies of the excitonic states and their dependence with the number of atomic layers. In the case of MoS_2, we observed that the electron-phonon coupling is symmetry-dependent, and our results provide experimental evidence of the C exciton recently predicted theoretically [4]. Finally, we will present a polarized Raman study about black phosphorus, by changing the polarization of the incident and scattered beam with respect to the crystalline axes. We observed an unusual angular dependence of the polarized spectra, which could only be explained by taking into account the complex values of the Raman tensor elements [5].

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