Resonance Raman studies of twisted bilayer graphene and 2D transition metal dichalcogenides

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Raman spectroscopy is a very useful tool to study graphene, since it furnishes information about the atomic structure, presence of disorder, number of layers, charge transfer and strain. However, important information about electrons can be also obtained in a resonance Raman spectroscopy (RRS) investigation, where the energy of the laser excitation can be tuned. An increasing number of studies have been dedicated twisted bilayer graphenes (TBG), since their optical and electronic properties are strongly dependent on the twisting angle. In particular, the Raman G-band can be significantly enhanced for TBG with specific twisting angles, and the enhancement occurs when the incident laser energy is in resonance with van Hove singularities that appear in the crossing region between the two Dirac cones of the top and bottom layers. Moreover, new and sharp extra peaks appear in the spectra both below and above the G-band position, and are ascribed to phonon modes within the interior of the graphene Brillouin zone that become Raman active through an umklapp double resonance (U-DR) Raman process, where momentum conservation involves reciprocal lattice vectors of the Moire patterns. [1]. In this work, we performed a Raman spectroscopy study of 150 samples of TBG with many different twisting angles, using several different laser lines in the visible range. The intensities and FWHM of all Raman features, mainly the G and 2D bands, were analyzed as function of the twisting angle and laser energy. A huge increase in the G band intensity could be observed for samples with intermediate twisting angles (between 9 and 14 degrees) and the results could be explained in terms of resonances with van Hove singularities of TBG. We will also present resonance Raman results of the sharp and extra peaks ascribed to the umklapp double resonance process. The Raman excitation profile of both the G-band and the new extra peaks was obtained experimentally [2], and our results are compared to the theoretically simulated spectra of TBG considering both resonances with van Hove singularities and the umklapp double resonance processes. Finally, we will present resonance Raman studies of the 2D transition metal dichalcogenides MoS_2, WSe_2 and WS_2 with one and few layers. We will show that the Raman spectra is strongly dependent on the laser energy, and we will present the Raman excitation profile of the first and second-order Raman features, which provide information about the electronic transitions and the electron-phonon interaction in these compounds.

References

[1] A. Righi et al, Physical Review B **84**.(2011) 241409
[2] A. Righi, et al, Solid State Communications **175** (2013) 176