Excitons and exciton-phonon interactions in 2D MoS_2, WS_2 and WSe_2 studied by resonance Raman spectroscopy

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The discovery of graphene opened the new area of study of two-dimensionals materials, and the transition metal dichalgogenides (TMD) emerged as very promising materials since they are semiconductors and a single layer of TMD shows a very strong photoluminescence signal. The 2D materials exhibit a very strong exciton binding energy, and the electron-phonon coupling plays an important role in their optical properties. Resonance Raman spectroscopy (RRS) is a very useful tool to provide information about excitons and their couplings with phonons. We will present in this work 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 more than 30 different laser excitation lines covering the visible range. We have observed that all Raman features are enhanced by resonances with excitonic transitions [1]. 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. The first and second-order Raman features exhibit different resonance behavior, supporting the double resonance mechanism for the second-order Raman features. In the case of MoS_2, we observed that the electron-phonon coupling is symmetry dependent, and our results provide the first experimental evidence of the C exciton recently predicted theoretically [2]. The RRS results WSe_2 show that the Raman modes are enhanced by the excited excitonic states (A' and B') and we will present the dependence of the excited states energies on the number of layers [3]

[1] M. A. Pimenta et al, Accounts of Chemical Research **48** (2014) 41
[2] B R Carvalho et al, Phys Rev. Letters **114** (2015) 136403
[3] E. del Corro et al, ACS Nano **8** (2014) 9629