Layer number dependence of the optical properties and work function of single and few layers MoS_2: effect of substrate

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Two-dimensional materials such as graphene and transition metal dichalcogenides (TMDs) have focused the attention in recent years due to their exceptional optical and electrical properties. A typical example of TMDC is molybdenum disulfide (MoS_2). This material has an indirect bandgap of 1.27 eV in bulk, while as a single layer it has a direct bandgap of 1.75 eV, which makes it an excellent material for use in electronic and optoelectronic devices such as photodetectors or field-effect transistors (FETs). There have been many studies of 2D materials, so far they have focused mostly on the optical and mechanical properties of monolayers placed on different substrates. There are only a few studies performed on TMDs layers separated from the influence of the substrate and extremely few measurements concerned the electrical properties of MoS_2 monolayers.

In this work we have probed the influence of the substrate material on the optical and electrical properties of the one and few layers of MoS_2. The MoS_2 flakes of 1-5 atomic layers were deposited on specially designed SiO_2 substrate with microcavities and aluminum electrical contacts. From the photoluminescence and Raman scattering measurements performed in ambient we have determined the number of material layers and evaluated two dimensional electron gas concentration (2DEG). In the complementary Kelvin probe force microscope (KPFM) measurements we have determined the dependence of the work function on the number of material layers both in and without contact with the substrate. We have found that the value of the work function increases with increasing layer thickness and for all structures tend to the work function of bulk material (Fig.1 (a)). We have also found a clear correlation between the increasing value of work function determined for SiO_2/Si supported, suspended and Al supported MoS_2 monolayers, respectively, and the decreasing electron gas concentration determined by the decreasing T/X PL intensity ratio (Fig. 1(b)).

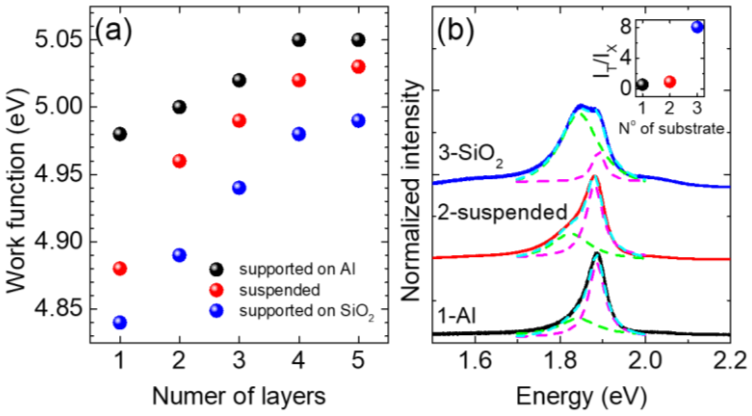

Fig. 1. (a) Dependence of work function on the number of layers of material for flakes placed on different substrates. (b) Normalized spectra collected from monolayer on Al (black), suspended over microcavities (red) and placed on SiO_2/Si (blue). Inset: Relative integrated intensity of trion and exciton lines at different substrates.

[1] M. Tamulewicz, J. Kutrowska-Girzycka, K. Gajewski, J. Serafińczuk, A. Sierakowski, J. Jadczak, L. Bryja, T. P. Gotszalk, *Nanotechnology*, accepted, doi: 10.1088/1361-6528/ab0caf.