Optical properties of van der Waals heterostructures

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Since the discovery of graphene in 2004, two dimensional (2D) materials attract lots of interest for their unique properties. In the wake of this discovery, another family of layered material with fascinating properties are the transition metal dichalcogenides (TMDCs); these materials, unlike the graphene, are finite bandgap semiconductors, so they could be suitable candidates to scale down the classical microelectronic devices to the nanometric limit. Looking beyond, these 2D materials can be used as building blocks to create some unique devices made by a vertical stack of a precise sequence of layers with the desired electronic properties. These layers are held together by weak van der Waals (vdW) forces, so this family of devices is called vdW heterostructures (Fig 1a).

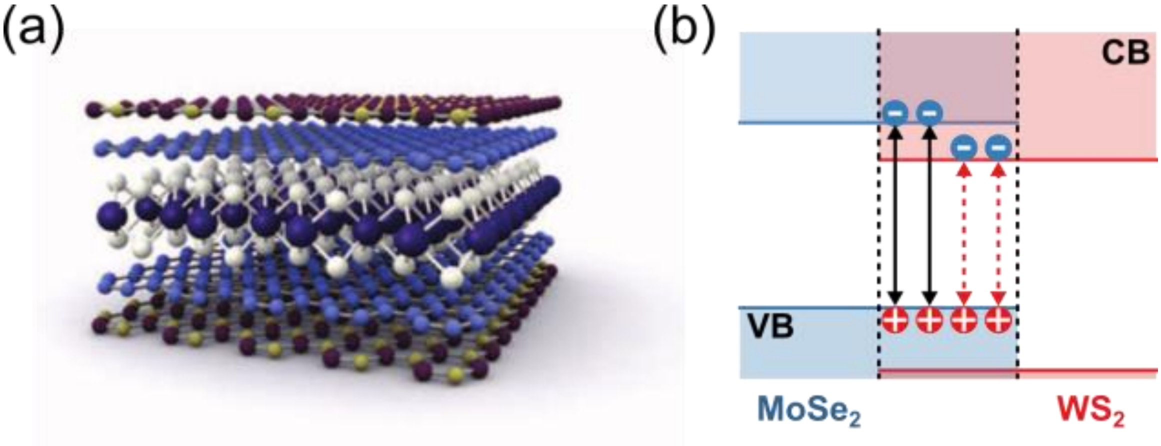

Figure 1: (a) Schematic illustration of a van der Waals heterostructure. (b) Band alignment of a $MoSe_2/WS_2$ heterobilayer with the intralayer transition (black solid arrows) and interlayer transition (red dashed arrows).

The mechanical stack of 2D material offers the possibility to finely tailor the optical properties of the final device. In fact, when two different TMDC are joined together it occurs a confinement of electrons and holes in the two different layers, according to their electronic structure (Fig 1b), and then these carriers, due to the Coulomb interaction form interlayer excitons (IX). The most intriguing aspect is the possibility to control the optical properties of this IX through an aimed choice of the 2D materials that form the heterostructure.

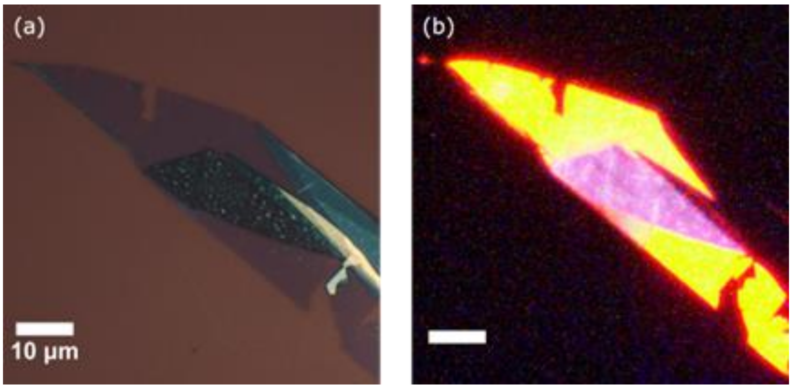

Figure 2: (a) Bright-field and (b) PL images of a $MoSe_2/WS_2$ heterostructure on a Si/SiO2 substrate.

The applications for this family of devices is really broad, their minimal thickness allow their use to create flexible displays and monitors, they can be integrated into existing technologies to add the function of energy harvesting, also they can be potentially employed for encoding and processing information, due to their valley properties.