Optical properties of van der Waals heterostructures

By Alessandro Catanzaro – PhD student at university of Sheffield, United Kingdom

Since the discovery of graphene in 2004, two dimensional (2D) materials have attracted lots of interest for their unique properties. In the wake of this discovery, another family of layered materials with fascinating properties, known as transition metal dichalcogenides (TMDCs), have been studied. These materials, unlike graphene, are direct bandgap semiconductors, so they could be suitable candidates to scale down classical microelectronic devices to the nanoscale. Looking beyond, these 2D materials can be used as building blocks to create unique devices consisting of vertical stacks of precise sequences of layers of the desired electronic properties. These layers are held together by weak van der Waals (vdW) forces, so this family of devices are called vdW heterostructures (Fig 1a).

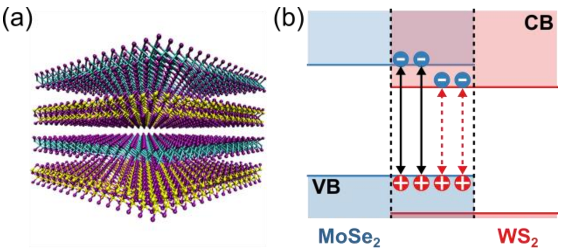

Figure 1: (a) Schematic illustration of a van der Waals heterostructure. (b) Band alignment of a $MoSe_2/WS_2$ heterobilayer with the intralayer transition (black solid arrows) and interlayer transition (red dashed arrows).

The mechanical stacking of 2D materials offers the possibility to finely tailor the optical properties of the final device. In fact, bringing two different TMDCs together allows the creation of spatially indirect excitons (IXs) (Fig 1b), which are formed by the Coulomb interaction between electrons and holes in the two different layers. The most intriguing prospect is the possibility to control the optical properties of these IXs by carefully choosing the 2D materials that form the heterostructure.

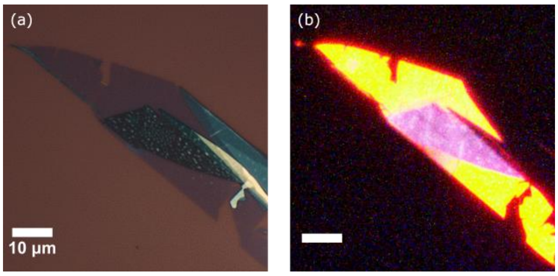

Figure 2: (a) Bright-field and (b) PL images of a $MoSe_2/WS_2$ heterostructure on a Si/SiO2 substrate.

The applications for this family of devices is really broad: their minimal thickness allows their use in creating flexible displays and monitors; they can be integrated into existing technology to add energy harvesting functionality; and also they may potentially be employed for encoding and processing information, due to their valley properties.