Excitons in $MoS_2/MoSe_2/MoS_2$ trilayer transition metal dichalcogenides

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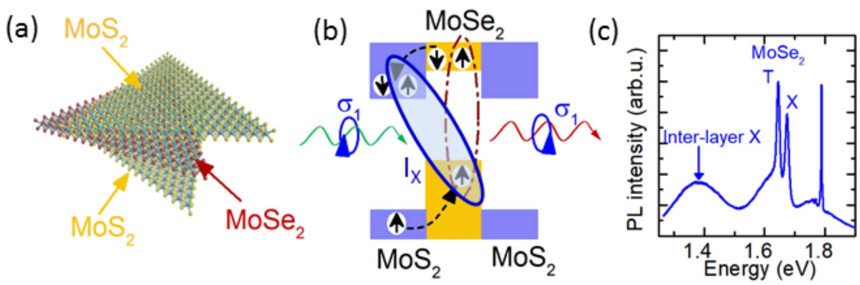
Monolayer transition metal dichalcogenides (TMDC) are rapidly emerging as potential building blocks for novel electronic and optoelectronic devices. In this talk I will discuss the optical properties of excitons in tri – layer transitions metal dichalcogenides (TMDC).

First, I will demonstrate a novel approach to neutralize the intrinsic defects of CVD-grown TMDCs, using flake transfer tools routinely employed in the fabrication of van-der-Waals heterostructures. We investigate the optical properties of trilayer stacks composed of external CVD-grown MoS_2 flakes as capping layers and an internal CVD-grown $MoSe_2$ flake which has a smaller band gap (Fig 1(a)). Remarkably, this fabrication approach strongly suppresses the localized exciton emission in $MoSe_2$ yielding a low temperature PL comparable to that observed in mechanically exfoliated samples (as shown in Fig 1(c)). This striking result can be understood from density functional theory, which suggests that the more reactive MoS_2 donates chalcogen atoms to heal vacancy defects in $MoSe_2$. Our results pave the way for the production of large area high quality TMDCs. Furthermore, the investigation of the charge transfer between the $MoS_2/MoSe_2$ layers allows us to demonstrate a novel way to introduce the valley polarization in $MoSe_2$. Tuning the excitation laser to the A-exciton resonance of the larger band gap MoS_2 leads to a considerable charge transfer towards lower band gap $MoSe_2$, as schematically presented in Fig 1(b). Our results show that spin of the hole is conserved during charge transfer leading to non-zero steady state valley polarization in $MoSe_2$, which has previously never been observed under non-resonant excitation [1-2]. The conservation of spin during the charge transfer opens new possibilities for spintronics and spin injection.

Furthermore, I will discuss optical properties of the long lived inter-layer exciton formed between the $MoSe_2$ and MoS_2 monolayers (schematically presented in Fig.1 (b)). Under circularly polarized excitation, the inter-layer exciton emission is intriguingly counter polarized. Such an effect has never been observed previously. Our results show that a careful choice of the TMDs forming the van der Waals heterostructure makes it possible to control the circular polarization of inter-layer exciton emission [3]. Finally, I will demonstrate the results of the magneto-photoluminescence spectroscopy, which give a deeper insight into the valley polarization and depolarization mechanisms of interlayer excitons [4].



[1] A. Surrente, PP et al *Nano Letters* **17**, 4130 (2017)
[2] M. Baranowski, PP et al *2D materials* **4**, 025016 (2017)
[3] M. Baranowski, PP et al *Nano Letters* **17**, 6360 (2017)
[4] A. Surrente, PP et al submitted