Photoluminescence in two-dimensional crystals

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Two-dimensional (2D) crystals derived from layered structures exhibit a unique set of properties as elegantly demonstrated for graphene. Semiconducting 2D structures such as MoS_2 sheets are attractive building blocks for novel electronic and optoelectronic devices. In this talk, I will report photoluminescence properties of group 6 transition metal dichalcogenide (TMD) 2D crystals and discuss how their spectral features provide insight into the evolution of chemical, structural, and electronic properties of these materials.

A single layer MoS_2 is a direct gap semiconductor in striking contrast to its indirect gap bulk counterpart [2]. As a result, single layer MoS_2 exhibits distinct band gap photoluminescence. We find that photoluminescence spectra of mono- to few-layer WS_2 and WSe_2 indicate that their band structure undergoes a similar indirect-to-direct gap transition when thinned to a single monolayer (Fig. 1) [3]. The transition is evidenced by distinctly enhanced PL peak centered at 630 and 750 nm in monolayer WS_2 and WSe_2, respectively. We demonstrate that indirect gap emission and direct gap hot electron emission is pronounced in few-layer WSe_2 due to small energy difference between the two transitions. At sufficiently high temperatures, short-range interlayer interactions in multilayer sheets weaken such that each layer behaves like an individual monolayer, giving rise to enhanced photoluminescence similar to the case of $MoSe_2$ [4].

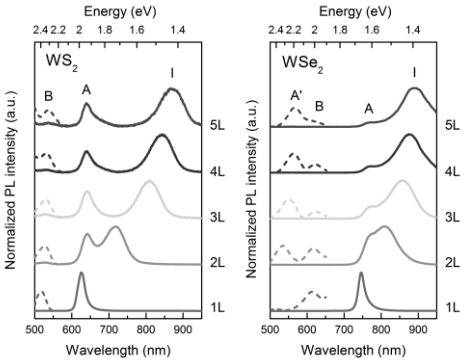

Fig.1 Photoluminescence spectra of 1 to 5 layer WS_2 (left) and WSe_2 (right).

[1] Wang et al. Nat. Nanotechnol. 7, 699 (2012).
[2] K. F. Mak et al. Phys. Rev. Lett. 105, 136805 (2010).
[3] Zhao et al. ACS nano. 7, 791 (2013).
[4] Tongay et al. Nano Lett. 12, 5576 (2012).