Alloyed Heterostructures of Nanoplatelets for Highly Tunable Excitonic Properties

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Colloidal nanoplatelets (NPLs) have been an emerging class of semiconductor nanocrystals with their unique properties. [1] These NPLs, having magic-sized vertical thickness, are one dimensionally quantum confined structures in the vertical direction, enabling thickness-dependent optical properties. They have extremely narrow emission bandwidths (<10 nm) with suppressed inhomogeneous broadening. In addition to these, they feature ultrafast fluorescence, giant oscillator strength and large linear and non-linear absorption cross-sections. However, due to the pure vertical quantum confinement observed in these atomically-flat NPLs, they exhibit discrete emission and absorption features and suffered from the limited spectral tunability. Here, to achieve highly tunable excitonic properties, we proposed and demonstrated novel heterostructures of NPLs by precisely controlling their compositions.

First, we successfully synthesized homogenously alloyed $CdSe_xS_{1-x}$ core NPLs together with their core/crown and core/shell heterostructures. With changing the sulfur composition, these alloyed hetero-NPLs exhibit highly tunable emission behavior covering a broad spectral range from ~485 nm to ~650 nm. Also, thanks to their reduced reabsorption and tunable excitonic features, we achieved highly tunable and low-threshold optical gain performances (down to 50 μJ/cm^2) by using these alloyed hetero-NPLs. [2] In addition to NPLs having Type-I electronic structure, we designed and synthesized CdSe/$CdSe_{1-x}Te_x$ showing Type-II like electronic structure. By precisely tuning the composition of $CdSe_{1-x}Te_x$ crown region, we obtained again highly tunable excitonic features without changing the thicknesses of NPLs. [3]. With these hetero-NPLs possess highly stokes shifted emission with significantly improved quantum yield (up to ~94%), making them highly promising for the development of color converting LEDs.

[1] S. Ithurria *et al.*, *J. Am. Chem. Soc.*,2008, 130, 49.

[2] Y. Kelestemur, D. Dede *et al.*, *Chem. Mater.*, 2017,(doi. 10.1021/acs.chemmater.7b00829)

[3] Y. Kelestemur *et al.*, *J. Phys. Chem. C*, 2015, 119, 4.