Surface Chemistry of the Colloidal Two-Dimensional Cadmium Chalcogenide Nanoplatelets

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Semiconductor nanocrystals (NCs) have attracted widespread interest as building blocks for applications ranging from biomedical diagnostics to photovoltaics and opto-electronics. Especially bottom up colloidal synthesis methods allow for the formation of NCs with precisely controlled dimensions, composition and surface termination and therefore physical and chemical properties. The most popular nanocrystals are made of AIIBVI semiconductors such as CdS, CdSe, and CdTe because their absorption and photoluminescence (PL) bands lie in the visible range. These NCs could be synthesised in various forms such as dots, rods, branched particles, and platelets. The latter, nanoplatelets, also called 'solution processable quantum wells' have an atomically flat surface, and their thickness is quantized to an integer number of monolayers resulting in extremely narrow photoluminescence bands. There has been a tremendous increase in the research on the optical properties of these interesting nanoplatelets such as, study of electronic and phonon energy structure, exciton-phonon interaction, and dynamics of electronic transitions in platelets of varied thicknesses. At the same time, the role of surface ligands in controlling the stability of these ultrathin nanoplatelets in solution and effecting the optical properties gained less attention.

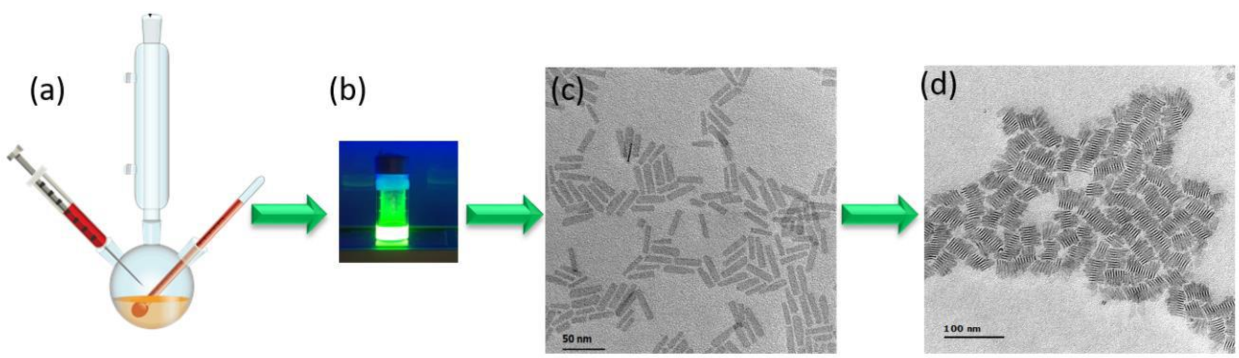

Figure 1: (a) Hot injection synthesis where precursors (e.g. Cd and Se) are injected to form nanoplatelets; (b) Nanoplatelets under UV light showing green emission for 5 monolayers of atomic units; (c,d) Transmission Electron Microscopy image of platelets capped with different ligands.

In this contribution, we present a full study of surface chemistry of colloidal cadmium chalcogenide nanoplatelets. The main emphasis is on using ligand engineering to control the colloidal stability, photoluminescence quantum yield, charge trapping and self-assembly. We demonstrate the role of different classes of ligands (X,Y and Z type ligands) on passivating the surface of nanoplatelets and identify the best capping agent in terms of enhancing optical properties (light emission efficiency) and long-term colloidal stability. The ligand-surface chemistry and their role in opto-electronic properties determination is well studied by using the solution-NMR toolbox along with absorption and photoluminescence (PL) spectroscopy and pump-probe transient absorption (TA) spectroscopy. Finally, we show that surface chemistry is the key in processing these 2-D emitters into optically smooth thin films which are free of light scattering and unwanted re-absorption for display applications or integrated lasers.