Title: Colloidal semiconductor nanocrystals for efficiency: Synthesis, characterization and device applications

Abstract:

Colloidal semiconductor nanocrystals (for example, colloidal quantum dots (CQDs), colloidal nanoplatelets (NPLs)) are promising materials for myriad applications like color conversion in displays, lighting and biological imaging etc. They offer the advantages of tuning their optical and electronic properties with size, shape and controlling surface properties. The unique advantages lie in their scalability for displays and large area lighting. They can be either optically driven or electrically driven. Recently CQDs have been commercially applied as color converters for displays via optical excitation, due to their low cost and scalable synthesis and better energy efficiency. To effectively use these materials for efficient future lighting and other optoelectronic applications require the understanding of the material aspects which contribute to high efficiency of emission as light sources. NPLs which are recently introduced class of nanocrystals, offer exceptionally narrow PL spectral bandwidths. NPLs provide an opportunity to develop next generation of nano-emitters for optoelectronic applications by developing their quantum efficiency (QE) of emission while also developing our understanding of nanocrystal material aspects for efficiency. This work contributes to increasing the QE of NPLs by developing optimal surface passivation techniques with hetero-structure crown/shell growth and ligand passivation. It achieves the enhancement of QE in not only organic solvent systems but also pioneers their rendering into aqueous system with high QE which was hitherto unexplored in the research field. The development of aqueous solution of high QE NPLs opens up a possibility of myriad new applications in biological and optoelectronics fields, some of which are explored in this work. Along with an enhanced understanding of material aspects of efficiency there is a need to further understand the behaviour of the material during device operations. The development of quantum dot light emitting diodes (QLEDs) for lighting and displays has recently reached the levels of almost 100% internal QEs. Further research work is focussed on improving their stability and longevity maintaining the high efficiency during operation. This work in also explores the material aspects of efficiency under device operation by studying exciton decay dynamics of CQDs inside a QLED under operation. The results show the major efficiency quenching factors at play during device operation. This work adds to the valuable literature on not only providing synthesis techniques to develop efficient nanocrystals in organic and aqueous solutions as well as focusses on understanding the material behaviour in active device operating conditions which would contribute to future development of myriad applications in optoelectronic and other fields.