L.6: Synthesis of tunable and highly luminescent cesium lead halide perovskite collids

Recently, cesium lead halide ($CsPbX_3$, X = Cl, Br or I) perovskite quantum dots are emerging as promising materials for optoelectronic, photovoltaic and photodetector applications. The important features of these nanoparticles include high photoluminescence (PL) quantum yield in as prepared colloids, easy tunability of PL in the entire visible spectra and long term stability due to absence of organic groups as compared to organic-inorganic perovskite materials. In comparison to initially developed hot-injection method performed in inert atmosphere, room temperature synthesis at ambient conditions is more attractive due to its simple synthesis procedure and lower cost of production. However, in the room temperature synthesis conditions, particularly ratio of cesium and lead salts, solvent engineering and ion-exchange strategies play a vital role for obtaining stable and device grade nanoparticles.

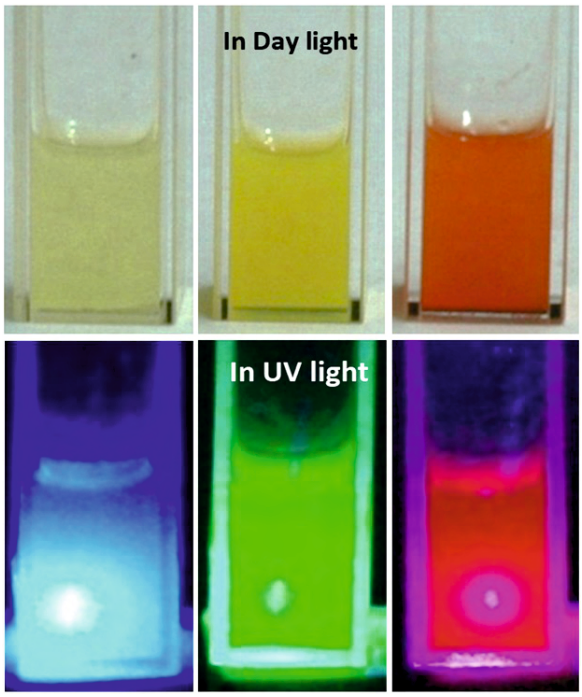

Fig. L.6.1: Photographic images of as prepared perovskite colloids of $CsPbCl_3$ (left), $CsPbBr_3$ (middle) and $CsPbI_3$ (right).

In this regard, different room temperature synthesis methods were studied for producing stable and highly luminescent all-inorganic i.e., $CsPbX_3$ perovskite quantum dots. The developed method is adaptable for producing wavelength-tunable colloids in the entire range of visible spectrum. Figure L.6.1 presents photographs of as-prepared colloidal perovskite nanoparticles, illuminated by day light (top row) and by UV light (bottom row), exhibiting three primary colours. The bandgap of these semiconductor nanoparticles can be altered by replacing halide ions via ion exchange strategies.

Role of different polar and non-polar solvents and different halide sources for ion exchange were studied towards preparation of tunable bandgap and emission wavelength. The synthesis with ion exchange was optimized in both aqueous and non-aqueous halide source. In these nanoparticles, gradual increase of anion size results in change in lattice parameters of the formed nanocrystals, which systematically red-shifts the absorption and PL wavelength spectrum. Figure L.6.2 presents the normalized PL spectra of as synthesized $CsPbCl_3$, $CsPbBr_3$ and $CsPbI_3$ perovskite colloids, when excited with UV light. The observed relatively narrow band emission, without overlapping peaks, shows that the implemented ion exchange method is effective in producing desired wavelength tunability and colour purity.

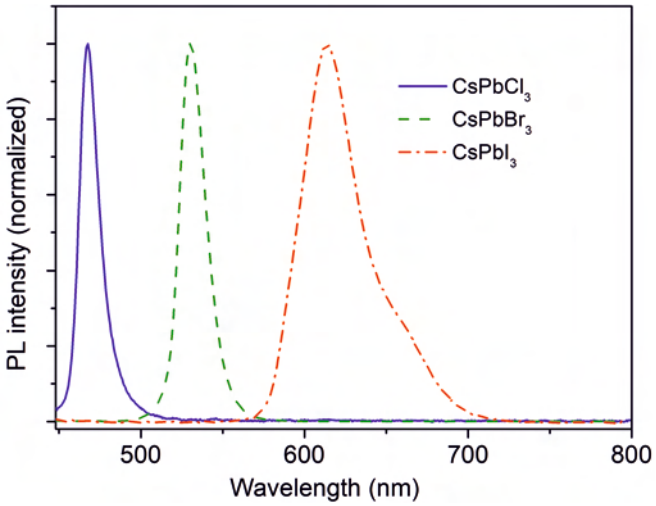

Fig. L.6.2: Photoluminescence spectra of perovskite colloids.

These $CsPbX_3$ perovskite nanoparticles are highly attractive for colour display units. The prepared nanoparticles were found to be stable up to one month of observation, which is significantly high as compared to the methyl ammonium lead halide perovskite quantum dots. Optimization studies on producing uniform films of these nanoparticles and fabrication of optoelectronic devices is in progress.

Notable features of the prepared nanoparticles include simplified room temperature synthesis method without the requirement of inert atmosphere, efficient luminescence without post processing with higher stability. The process is upgradable for large-scale production at significantly low cost. These colloids are attractive for photovoltaic and programmable light emitting diode applications.

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