

THESIS DEFENSE: Solution Processed Colloidal Quantum Dot-Based Short Wave Infrared Light Emitters

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10:00
ICFO Auditorium

Shortwave infrared (SWIR) light sources are highly significant due to their ability to interact with molecular bonds and penetrate materials with reduced scattering and absorption. These properties make SWIR light exceptionally valuable across diverse applications, including spectroscopic analysis, non-invasive biomedical imaging, food and agriculture, and environmental monitoring. However, traditional SWIR sources tend to be bulky, inefficient, and characterized by high bulb temperatures, prolonged warm-up times, limited dimming capabilities, relatively short lifespans, and high costs. This has resulted in an increasing demand for more efficient, compact, and cost-effective alternatives.
Solution-processed colloidal quantum dots (CQDs) are promising candidates for advanced SWIR light sources due to their wavelength tunability, high photoluminescence quantum

yield (PLQY), and cost-effective synthesis. While CQD-based light sources are well-established in the visible range, there is a need for further development of SWIR emitters. This thesis addresses this gap by utilizing CQDs to create efficient, flexible SWIR light emitters through a simplified and cost-effective fabrication method.

We developed SWIR light emitters with an emission wavelength of around 1350 nm using the down-conversion (DC) technique, where lead sulfide (PbS) quantum dots (QDs) absorb high-energy photons and emit lower-energy SWIR photons. Down-conversion using QDs addresses certain drawbacks of conventional phosphor-converted LEDs based on lanthanides or transition metal ions, such as the need for complex fabrication processes involving high-temperature sintering or annealing, limited emission band tunability, and challenges in supporting pulsed operations. We used binary blends of large-bandgap matrix QDs and small-bandgap emitter QDs, as they are reported to improve the PLQY.

Initially, flexible DC films were fabricated on PET substrates via solid-state ligand exchange (SSLE) and spin coating, with various ligands, including 3-Mercaptopropionic Acid (MPA), combinations of Zinc Iodide (ZnI_2) and MPA, and combinations of 1-Ethyl-3-methylimidazolium Iodide (EMII) and MPA, studied. The best performance was achieved using MPA as the ligand, and selectively exciting the emitter QDs proved more efficient than exciting both matrix and emitter QDs. The DC film treated with MPA, when excited by a 980 nm LED produced a SWIR power density of 0.19 mW mm?². Despite thes promising results, spin coating was found to be inefficient and labor-intensive, necessitatin a more scalable method

To address this, we developed an alternative fabrication method using ethyl cellulose (EC polymer, where oleic acid-capped QDs are mixed with EC to form flexible QD-EC composites This approach is industrially adaptable, reduces QD usage by a factor of 20, eliminate wastage, and requires less manual effort than the SSLE process. It also allows for scalabl fabrication of DC films in any size or shape. The maximum SWIR power density achieved for DC film with OA-capped PbS QDs, without ligand modification, was 0.18 mW mm?² . To further enhance efficiency, we applied solution-phase ligand exchange (SPLE) usi g 1-dodecanethiol (DDthiol) to improve surface passivation and reduce non-radiati e recombination. DC films made with DDthiol-treated PbS QDs demonstrated a three-fo d increase in SWIR power output and reduced efficiency roll-off by 37% at higher excitati n power, compared to films with oleic acid (OA)-capped QDs. The best-performing fil , composed of DDthiol-treated matrix QDs and OA-capped emitter QDs, achieved a maxim m SWIR power density of 0.54 mW mm?² . This methodology was further extended to deve op SWIR light sources emitting at 1470 nm. In summary, we developed efficient and flexi le SWIR light sources using solution-processed CQDs through a cost-effective and scala le fabrication method by overcoming the limitations of conventional sourc

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