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Felicidades a la nueva graduada de doctorado del ICFO

La Dra. Stephy Vincent se ha doctorado con una tesis titulada ï¿½Solution Processed Colloidal Quantum Dot-Based Short Wa e Infrared Light Emittersï¿½

January 23, 2025

Felicitamos a la Dra. Stephy Vincent que ha defendido su tesis esta manana en el Auditorio del ICFO.
La Dra. Vincent obtuvo su Master en Fisica por la Mahatma Gandhi University en India y se unio al equipo de investigacion de Functional Optoelectronic Nanomaterials dirigido por el profesor ICREA Dr. Gerasimos Konstantatos. Su tesis titulada ï¿½Solution Processed Colloidal Quantum Dot-Based Short Wave Infrared Light Emittersï¿½ fue supervisada por el profesor ICREA Dr. Gerasimos Konstantatos.

RESUMEN:
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 (ZnI2) 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, eliminates wastage, and requires less manual effort than the SSLE process. It also allows for scalable fabrication of DC films in any size or shape. The maximum SWIR power density achieved for a 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) using 1-dodecanethiol (DDthiol) to improve surface passivation and reduce non-radiative recombination. DC films made with DDthiol-treated PbS QDs demonstrated a three-fold increase in SWIR power output and reduced efficiency roll-off by 37% at higher excitation power, compared to films with oleic acid (OA)-capped QDs. The best-performing film, composed of DDthiol-treated matrix QDs and OA-capped emitter QDs, achieved a maximum SWIR power density of 0.54 mW mm?^{2} . This methodology was further extended to develo SWIR light sources emitting at 1470 nm. In summary, we developed efficient and flexibl SWIR light sources using solution-processed CQDs through a cost-effective and scalabl fabrication method by overcoming the limitations of conventional sources.

Comite de Tesis:

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