2023「中技社科技獎學金」
2023 CTCI Foundation Science and Technology Scholarship
境外生研究獎學金
Research Scholarship for Overseas Students

Photophysics and Optoelectronic Applications of Colloidal Nanocrystals

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Background

Semiconducting colloidal nanocrystals (NCs) have recently gained attention as a family of materials having immense potential for efficient optoelectronics owing to their tunable and direct bandgaps, engineerable optical and electronic characteristics, and near-unity photoluminescent quantum yield (PL QY) in solution phase. Zero-dimensional (0D) colloidal quantum dots (CQDs) and two-dimensional (2D) colloidal quantum wells (CQWs) are two of the most studied classes of nanocrystal family.

PL QY of NCs is extremely high in colloids but drops drastically when these are deposited as a thin film. Moreover, stability of these materials is known to be vulnerable against high pump powers and extended excitation durations. These are two of the most critical concerns regarding these materials from the application perspective. Our research aims to resolve the above-mentioned discrepancies and enable maximum exploitation of the benefits promised by NCs for optoelectronics.

Research Summary

It is known that PL QY of excitonic materials can be tuned through modifying their doping levels (*Science 364, 468-471 (2019)*). We are attempting see the effect of molecular dopants (*e.g.,* Benzyl Viologen or BV) on PL QY of colloidal NCs. Concurrently, mechanisms behind photo-degradation of these materials are also under investigation. The corresponding results are shown in **Figure 1a-c**.

On application side, microspheres of colloidal NCs (both CQDs and CQWs) are being prepared utilizing a chemical process known as solvent emulsion. These microspheres have the potential to exhibit whispering gallery mode (WGM) lasing. Preliminary results on this topic are shown in **Figure 1d-f**.

Acknowledgements

This project is supported by the National Science and Technology Council, Taiwan, under grant no. NSTC 110-2112-M-009-010-MY3. D.H.L. acknowledges the Yushan Scholar Program supported by the Ministry of Education, Taiwan.

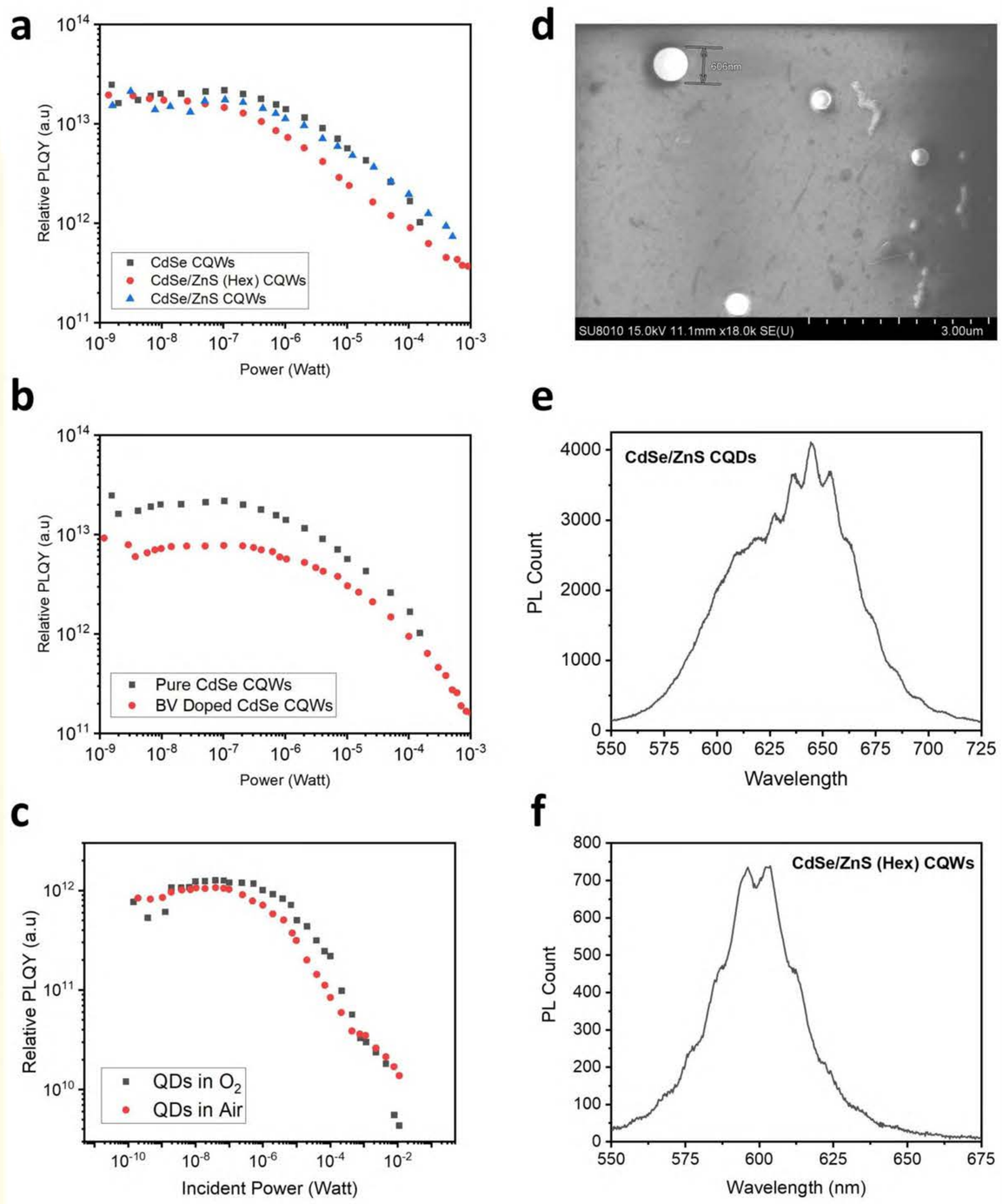

Figure 1. Summary of results on physics and applications of CQDs and QWs. a) Relative PL QY of various CQWs as a function of incident power indicating irreversible degradation of the material at high pump powers. b) Relative PL QY of pure and BV-doped CdSe CQWs. c) Relative PL QY of CdSe/ZnS CQDs as a function of excitation power in air and O_2 environment. d) SEM micrographs of CdSe/ZnS microspheres created using solvent emulsion. e, f) Emission spectra associated with microspheres of CdSe/ZnS CQDs and CdSe/ZnS (Hex) CQWs, excited with a 532 nm continuous-wave (CW) laser.