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Colloidal Quantum Dots for Infrared Light: Emission and Detection

N Center #86120, Sungkyunkwan University, Suwon

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Abstract

Infrared light plays a central role in emerging sensing, imaging, and energy conversion technologies, driving demand for materials that efficiently emit, detect, and utilize low-energy photons. Quantum dots (QDs), with their size-tunable electronic structures and tunable surfaces and interfaces, offer a versatile platform for controlling infrared light–matter interactions. This presentation explores QD engineering for infrared emission and photodetection, extending to the enhanced utilization of photogenerated carriers.

The first part focuses on germanium (Ge) QDs as group-IV infrared emitters. A heat-up synthesis yields highly uniform, size-controlled Ge QDs that exhibit systematic size-dependent near-infrared emission. To address the limited radiative recombination associated with Ge's indirect band structure, shape engineering is employed to modify the electronic structure and enhance the photoluminescence quantum yield. These findings highlight the potential of morphological control to improve infrared emission from Ge QDs. The second part examines HgTe QDs as a narrow-band-gap platform for infrared photodetection. Their size-tunable band gaps and strong infrared absorption enable detection across a broad spectral range, while surface engineering improves their chemical and environmental stability. HgTe QD superlattices are also investigated as a means of strengthening interdot electronic coupling, facilitating charge transport, and improving detector response. Finally, spin-exchange carrier multiplication is explored in Mn-doped CdSe/HgSe inverted type-I core/shell QDs. Ultrafast spin-exchange interactions between photoexcited carriers and Mn ions enable excess photon energy to generate additional charge carriers before it is dissipated through phonon scattering. The resulting multicarrier generation is further investigated in photoelectrochemical processes, highlighting the potential of spin-dependent carrier dynamics to enhance photochemical energy conversion.

Together, these studies span infrared emission, photon detection, and enhanced carrier generation. They demonstrate how engineering QD size, shape, surface chemistry, electronic coupling, and spin interactions can advance infrared optoelectronics and photon-to-energy conversion.

Brief Bio



Jungchul Noh is an Assistant Professor in the Department of Chemical Engineering at Hongik University, South Korea. He received his B.S. and M.S. degrees in Chemical and Biological Engineering from Seoul National University in 2015 and 2017, respectively, and his Ph.D. from the University of Texas at Austin in 2022. He subsequently conducted postdoctoral research at Los Alamos National Laboratory from 2022 to 2025 before joining Hongik University in 2025. His research focuses on the synthesis and engineering of colloidal semiconductor nanocrystals for infrared optoelectronics and energy conversion. He investigates how the size, shape, composition, and surface chemistry of quantum dots influence their electronic structures and optical properties. His current interests include infrared-emitting quantum dots, narrow-band-gap quantum dots for photodetection, and spin-exchange interactions in doped nanocrystals. By integrating materials synthesis, spectroscopy, and device fabrication, he aims to develop efficient quantum-dot-based technologies for generating, detecting, and utilizing infrared light.

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