Synthesis of Perovskite Quantum Dots for Phonon-Polariton Interaction with hexagonal Boron Nitride

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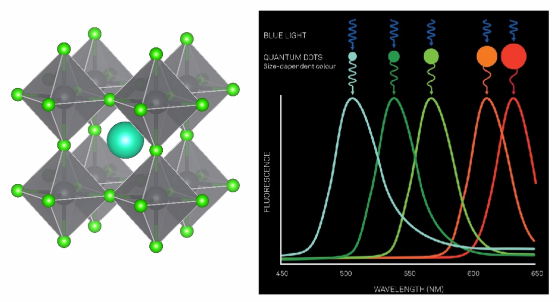
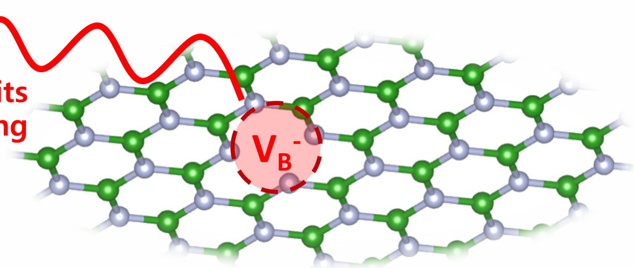
Perovskite / hexagonal Boron Nitride

Metal halide perovskite (MHP) quantum dots (QDs) exhibit **distinctive and tunable** optical properties:

- Near-unity photoluminescence quantum yield (PLQY)
- Narrow emission spectra
- Broad absorption spectra
- Facile bandgap tunability

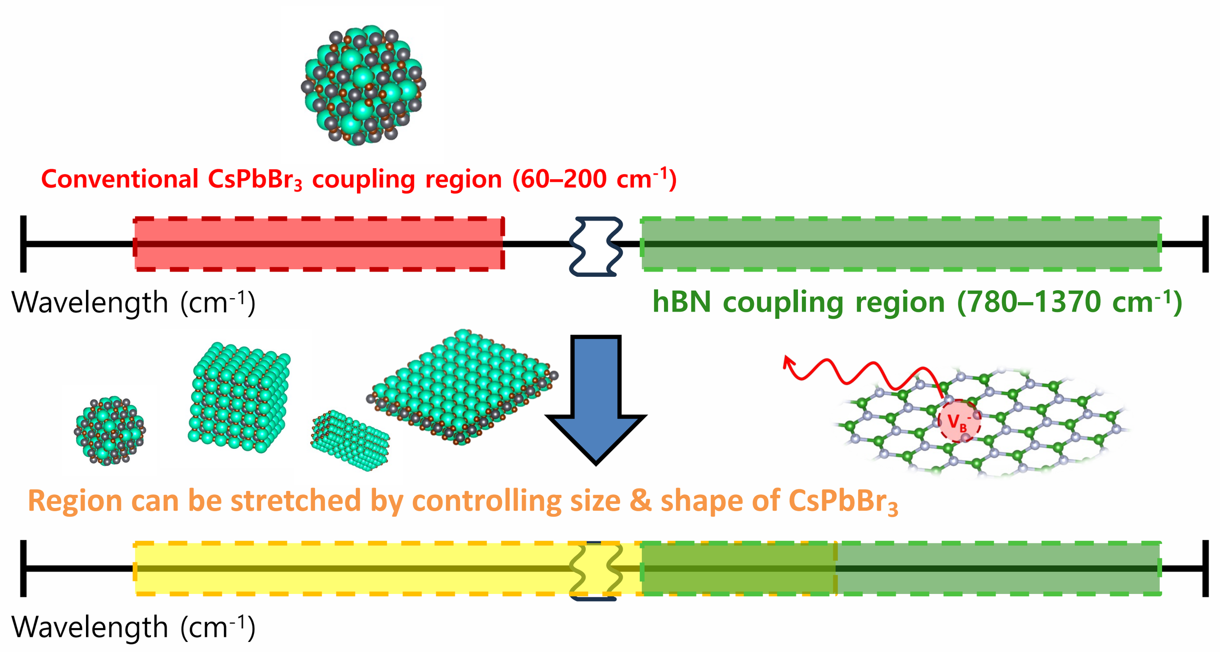


Hexagonal boron nitride (hBN), known for its wide bandgap and stable defect-based emission, has recently gained attention as a potential **single photon emitter (SPE)** due to its strong phonon-polariton confinement and hyperbolic dispersion. Defect centers in hBN can couple with specific optical phonon modes, enabling the efficient and isolated emission of individual photons.



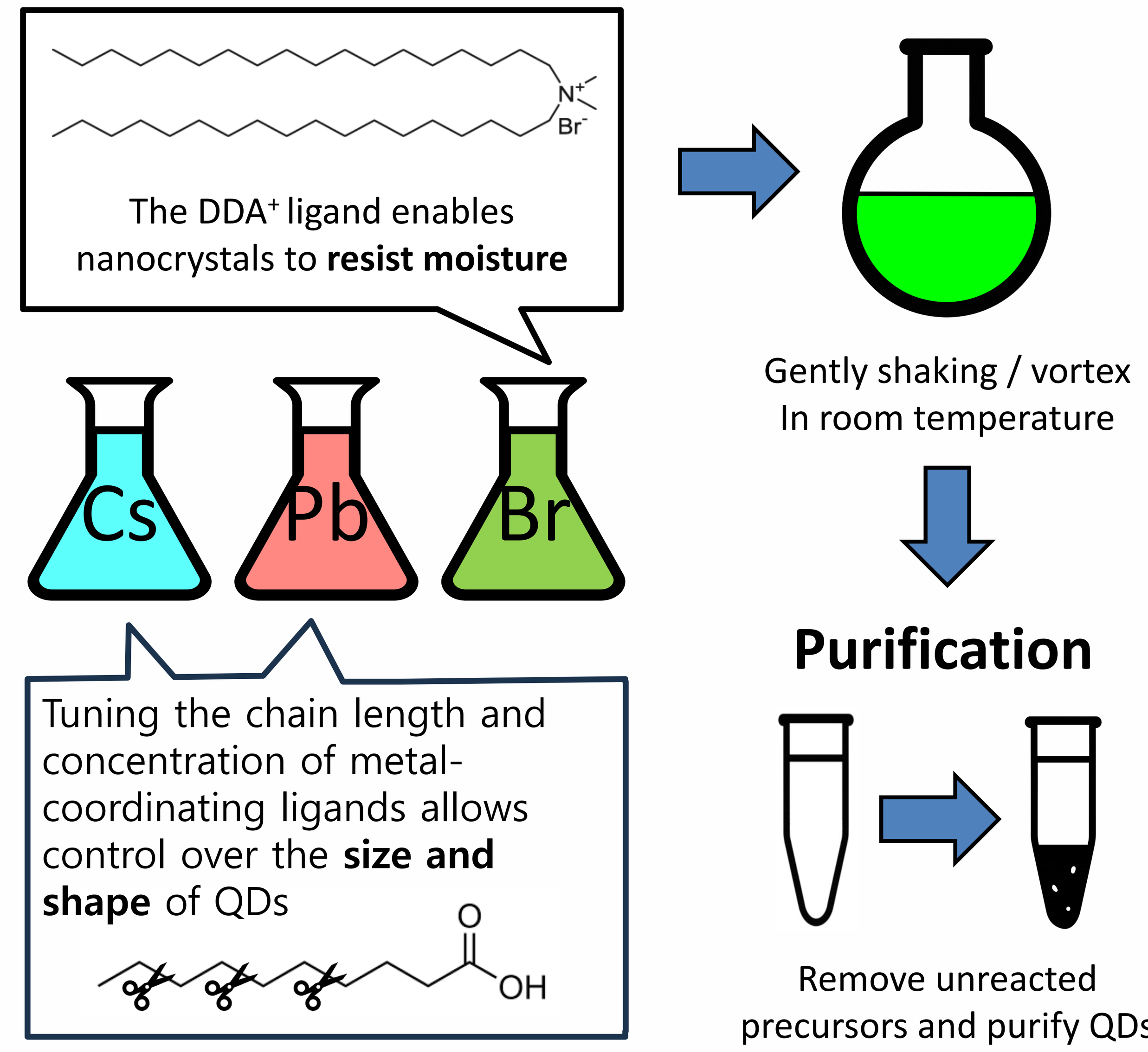
Phonon-Polariton interaction

Phonon-polaritons are quasipartlces resulting the strong coupling between infrared light and optical phonons in polar materials such as hBN. While CsPbBr3 nanocrystals typically lie outside this spectral regime, their vibrational response can be engineered – by tuning **size and shape** – to enable spectral overlap with hBN phonon-polaritons, offering new opportunities for nanoscale light-matter interaction.

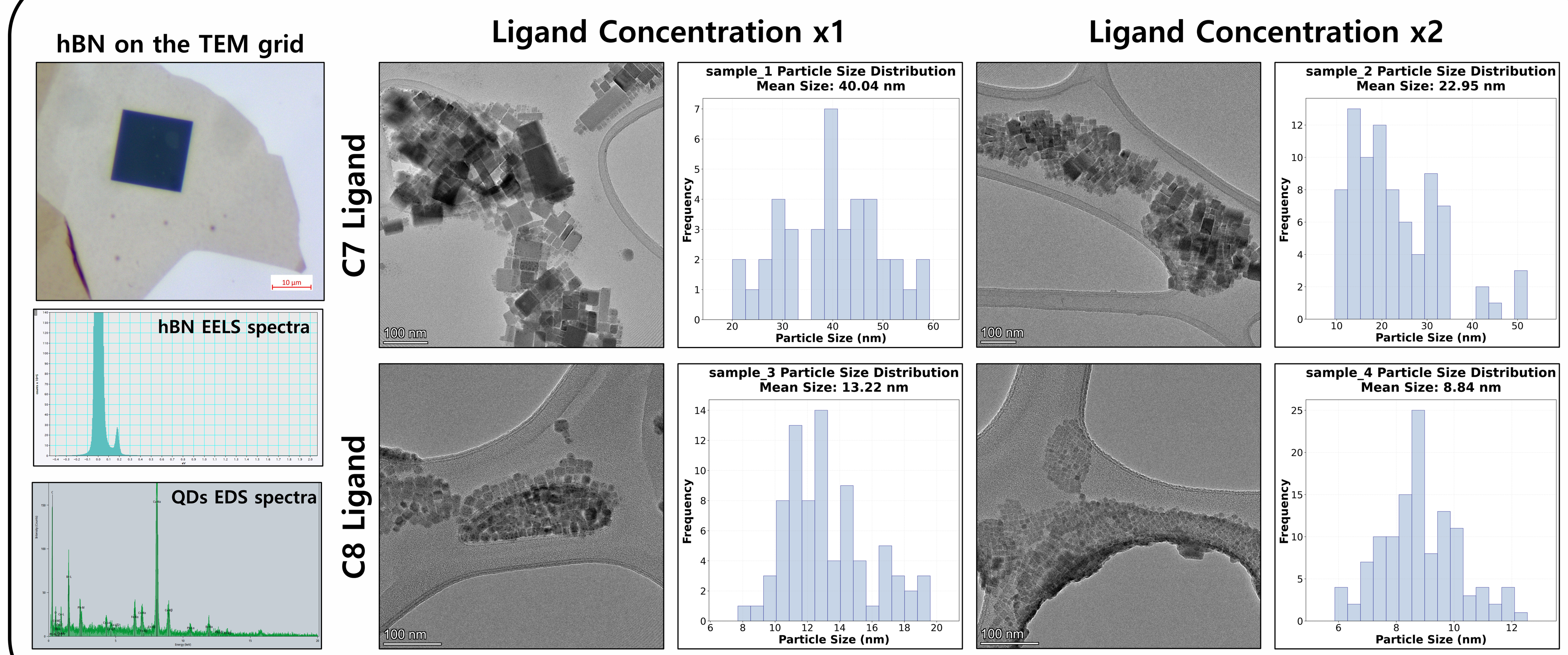


Synthesis Method

- Cesium and lead precursors were prepared by dissolving Cesium carbonate (Cs_2CO_3) and Lead acetate ($Pb(Ac)_2{\cdot}3H_2O$) in a coordinating acid mixture (e.g., oleic acid or octanoic acid), then diluted with xylene.
- Bromide source (DDAB) was dissolved in xylene separately.
- The precursor solutions were mixed under gentle vortexing at room temperature, enabling **ligand-assisted reprecipitation** (LARP) of $CsPbBr_3$ nanocrystals.
- Particle size and shape were controlled by adjusting ligand concentration and alkyl chain length.
- Resulting QDs were purified to remove unreacted species and byproducts.



Results



Conclusion / Future Work

Conclusion

- Ligand-assisted reprecipitation was successfully employed to synthesize morphology-controlled $CsPbBr_3$ quantum dots.
- By tuning the ligand concentration and chain length, we achieved control over QD size and shape, which in turn influences their vibrational response.
- This tunability suggests the feasibility of aligning QD vibrational modes with the mid-IR phonon-polariton regime of hBN (780–1370 cm^{-1}), offering a potential platform for engineered light–matter interaction at the nanoscale.

Future Work

- Create $CsPbBr_3$/hBN heterostructures by controlled dropcasting or spin-coating of QDs onto exfoliated or CVD-grown hBN.
- Explore capping or encapsulation methods (e.g., Al_2O_3, PMMA) to improve environmental stability and prevent $CsPbBr_3$ degradation.
- Will use scattering-type **scanning near-field optical microscopy** (s-SNOM) to spatially resolve polariton modes across both mid-IR (~1000 cm^{-1}, hBN) and THz (~100 cm^{-1}, $CsPbBr_3$) regimes. Also, **Electron Energy Loss Spectroscopy** (EELS) will be applied to observe interaction.
- Analyze whether **Fröhlich-type interactions** at the interface lead to measurable phonon hybridization, near-field energy transfer, or modified emission characteristics.

Reference / Funding Acknowledgment

- Room-temperature quaternary alkylammonium passivation toward morphology-controllable CsPbBr3 nanocrystals with excellent luminescence and stability for white LEDs. Chemical Engineering Journal.
- Efficient Up-Conversion in $CsPbBr_3$ via Phonon–Exciton Coupling, arXiv, 2023
- Phonon Polariton Behavior in 2D Materials, ALS feature.

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