Template-Guided Growth of Lead Halide Perovskites for Scalable Neuromorphic Computing

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Introduction

- All-inorganic lead halide perovskites (LHPs) offer exceptional excitonic transitions and tunable optical properties.
- This makes them promising materials for nanophotonic applications, including solar cells, light emitters, and photodetectors.
- In this project, we explore their potential for neuromorphic computing (NC) by developing a monolithic photonic platform integrating wide-bandgap $CsPb_2Br_5$ and semiconducting $CsPbBr_3$.

Scheme for Neuromorphic Computing

- LHPs can support room-temperature exciton-polariton quasiparticles with strong optical nonlinearity.

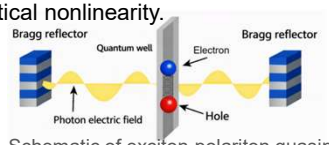

Fig. 1. Schematic of exciton-polariton quasiparticles.

- These nonlinearities allow perovskite microstructures to function as a physical neuron whose activation resembles a rectified linear unit (ReLU).
- Our patterned structures provide a scalable material platform for such neuromorphic devices.

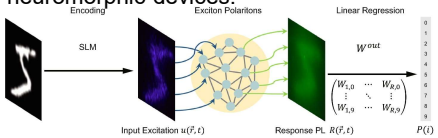

Fig. 2. The operating process of polariton neuromorphic computing on image recognition. (Gan et al., 2025)

Patterned Synthesis of LHPs

Stoichiometric Phase Control

- A 2mL precursor solution of CsBr + $PbBr_2$ is dissolved in dimethyl sulfoxide (DMSO) with controlled molar ratios.

Surface Modification

- Polydimethylsiloxane (PDMS) is exposed to fluoroalkyl silane (FAS) vapor to create a lyophobic surface.
- PDMS is stamped onto Si template at 50 °C.

Template-Guided Growth

- The precursor is drop-cast onto the modified microstructured template.
- The precursor is then sandwiched between the template and a glass slide
- The solvent is evaporated at 60 °C, and the confined nucleation and growth occur.

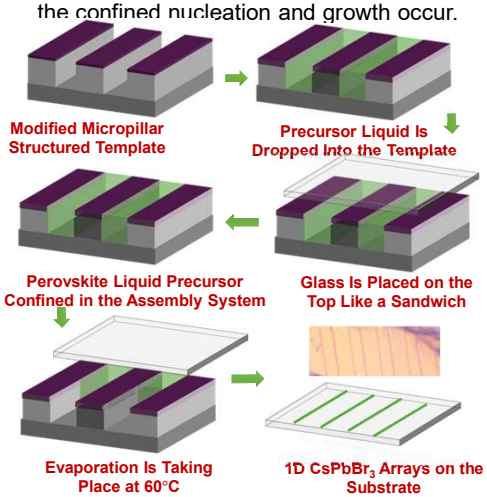

Fig. 3. Patterned synthesis and self-assembly of LHP crystals.

Phase Control During Synthesis

- $CsPbBr_3$ is the semiconducting phase, which exhibits excitonic emission.
- $CsPb_2Br_5$ is the wide-bandgap phase, which can serve as the photonic cavity to reach the light confinement required by the exciton-polariton condensation.

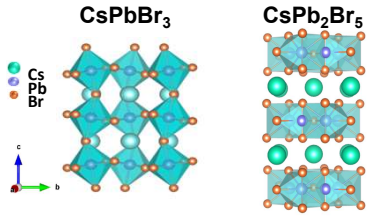

Fig. 4. Crystalline structures of $CsPbBr_3$ and $CsPb_2Br_5$.

- We successfully produced patterned $CsPbBr_3$ and $CsPb_2Br_5$ microstructures, via stoichiometric control.
- The phases have been confirmed using optical spectroscopic measurements.

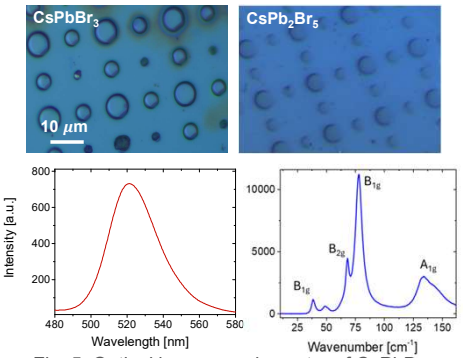

Fig. 5. Optical images and spectra of $CsPbBr_3$ excitonic emission and $CsPb_2Br_5$ Raman peaks.

Phase Conversion via Irradiation

- Controllable and localized $CsPb_2Br_5$ to $CsPbBr_3$ phase conversion has also been demonstrated under laser irradiation.

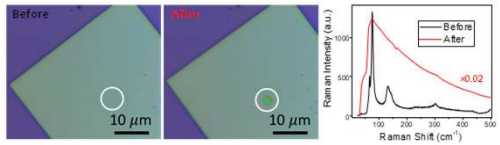

Fig. 6. Optical images and spectra of a $CsPb_2Br_5$ crystal before and after laser irradiation.

Conclusions and Future Work

- By integrating stoichiometric phase control, surface modification, and templated substrates, we demonstrate a soft-lithographic route for the patterned growth of $CsPbBr_3$ and $CsPb_2Br_5$.
- The ability to convert $CsPb_2Br_5$ into $CsPbBr_3$ enables scalable fabrication of perovskite-based cavity-emitter coupled systems suitable for neuromorphic photonic hardware.
- These results highlight a materials-level pathway toward room-temperature polariton devices and integrated photonics.

Acknowledgements

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