Nontoxic material design using tin-based perovskites for sustainable energy production

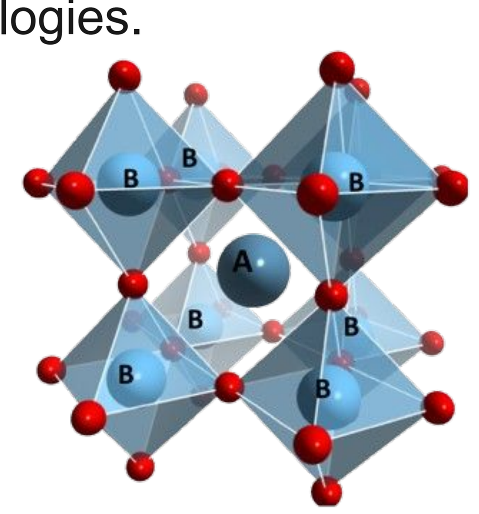
Clara Azevedo, Civil and Sustainable Engineering

Mentor: Dr. Nicholas Rolston, Assistant Professor | School of Electrical, Computer and Energy Engineering

Introduction

This research aims to enhance the stability and performance of lead-free perovskite films by utilizing tin (Sn) instead of toxic lead (Pb), addressing environmental and health concerns while developing semi-transparent photovoltaic windows. As global energy demand continues to rise, sustainable and nontoxic materials are essential to reduce dependence on fossil fuels and promote cleaner energy technologies.

Tin-based perovskites, such as $CsSnBr_3$ (cesium tin bromide), present a promising alternative to lead-based counterparts but remain highly sensitive to moisture and oxidation. These instabilities make it difficult to achieve uniform crystallization and consistent film quality. To address these challenges, starch is incorporated into the perovskite ink formulation as a viscosity modifier and stabilizing additive, enhancing film uniformity, conversion efficiency, and overall optical performance.



A= Cs B=Sn X=Br

Materials & Methods

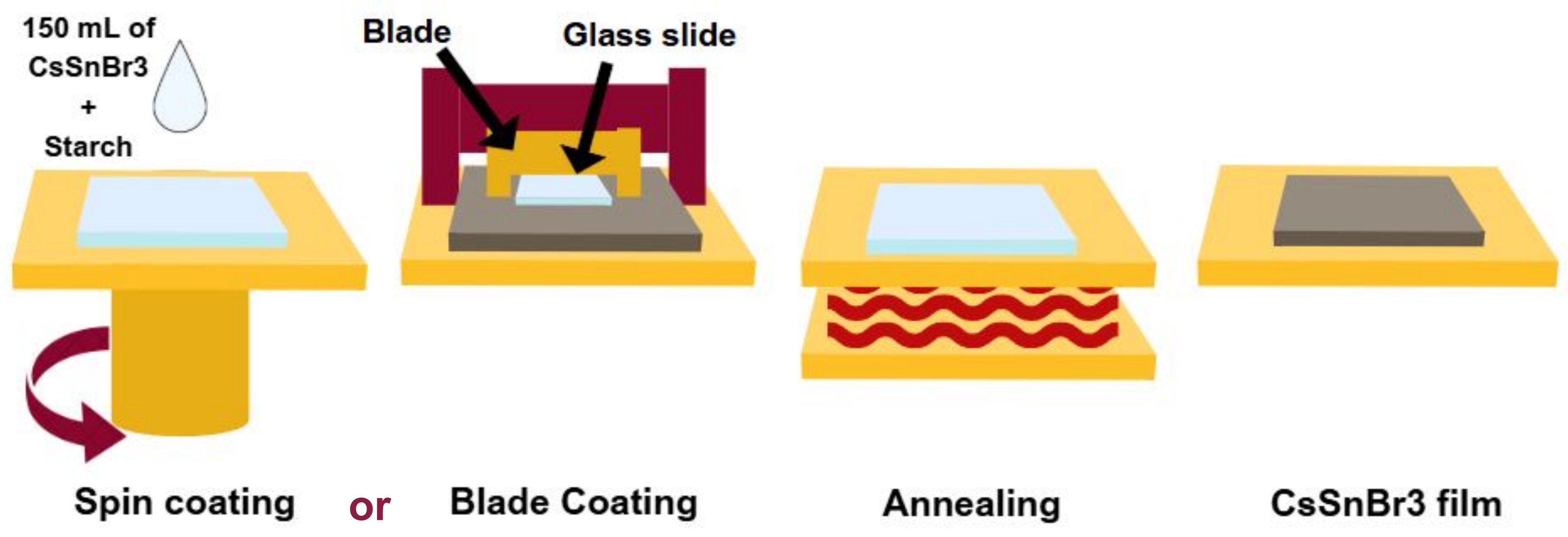
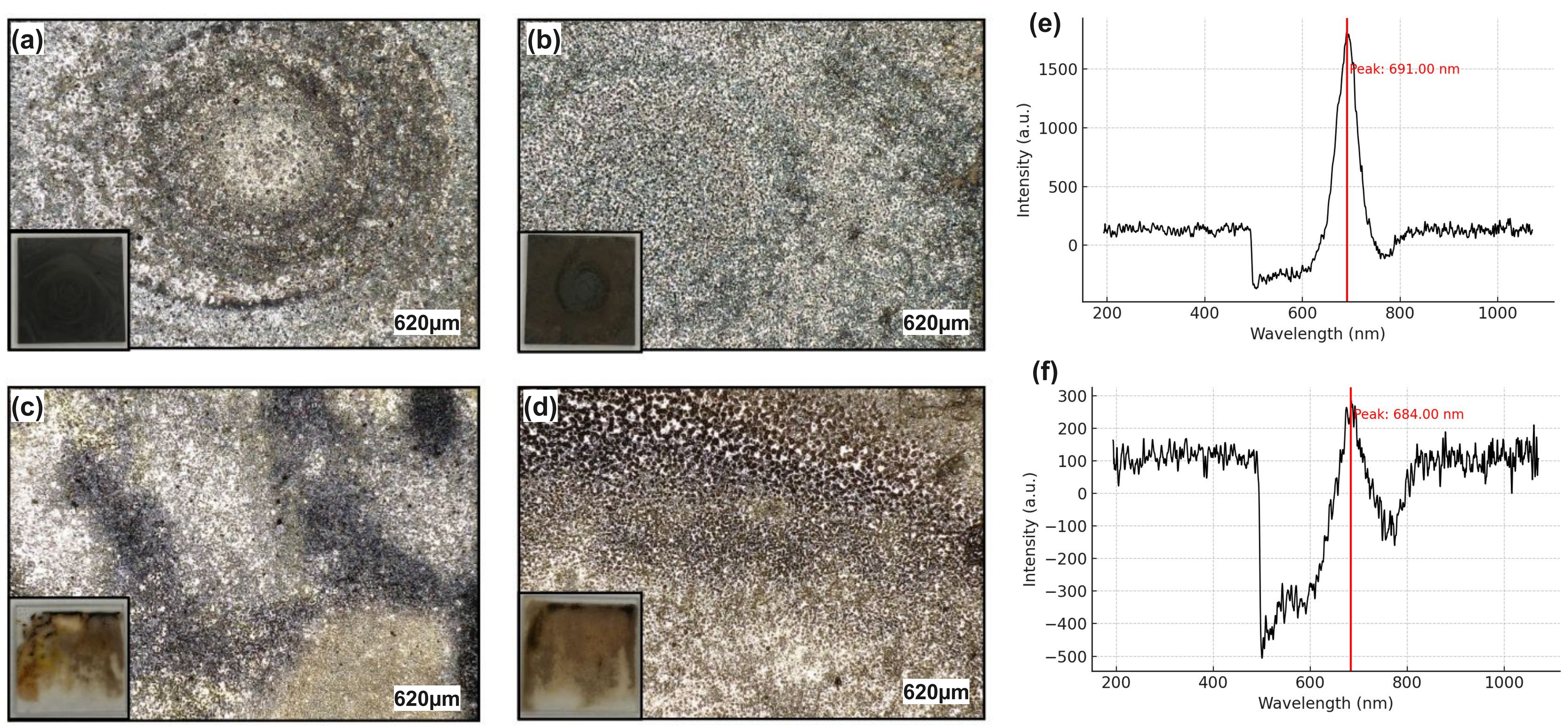


Fig. 1:
The schematic illustrates the fabrication process of $CsSnBr_3$ (cesium tin bromide) films using either blade coating (out of glovebox) or spin coating (inside glovebox), depending on the sample. A solution of 150 mL of $CsSnBr_3$ with starch additive was prepared and deposited onto a clean glass slide. The coated slides were then dried on a hot plate at 100 °C for 20 minutes to promote solvent evaporation and film formation.

Results



Challenges:
Even inside the glovebox, $CsSnBr_3$ ink was difficult to fully dissolve due to sensitivity to moisture and oxidation. Blade coating also showed poor film uniformity compared to spin coating.

Fig. 2:
(a) Sample prepared with 20% starch additive, spin coated.
(b) Sample prepared with 15% starch additive, spin coated.
(c) Sample prepared with 20% starch additive, blade coated.
(d) Sample prepared with 15% starch additive, blade coated.
(e) Photoluminescence test of sample showed in **a**, with a photon energy of 1.795 eV (1240/691)
(f) Photoluminescence test of sample showed in **d**, with a photon energy of 1.813 eV (1240/698.4)

Conclusions

The addition of starch to the $CsSnBr_3$ ink formulation notably enhanced the overall film quality, particularly for spin-coated samples. These films appeared darker and smoother, showing improved uniformity, full perovskite conversion, and a more compact morphology compared to films made without starch. The starch additive increased ink viscosity and stability, allowing better control over spreading and solvent evaporation during coating.

In contrast, blade coating performed poorly under the same conditions. The films exhibited incomplete conversion, visible surface irregularities, and patchy crystallization. These issues are likely related to the high sensitivity of $CsSnBr_3$ to humidity and the difficulty in maintaining a consistent film thickness during blade application.

Photoluminescence (PL) analysis further supported these findings. Spin-coated films showed intense, sharp emission peaks between 685–695 nm (≈1.8 eV), consistent with the theoretical band gap of $CsSnBr_3$, confirming successful perovskite phase formation. Blade-coated films, however, displayed weaker and broader PL signals, suggesting reduced crystallinity and poorer structural uniformity.

Future Work

- Experiment with different pre-heating and annealing temperatures to better control crystallization
- Incorporate EDTA to chelate Sn and prevent leaching during degradation.
- Characterize EDTA-treated films using imaging and photoluminescence.
- Evaluate degradation behavior of previously fabricated films.

Acknowledgements

I would like to express my gratitude to the GCSP Stipend for providing me with the opportunity to gain valuable experience and learning through this program. Additionally, I would like to extend my appreciation to Dr. Nicholas Rolston for his unwavering support.

ASU Ira A. Fulton Schools of Engineering
Arizona State University