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

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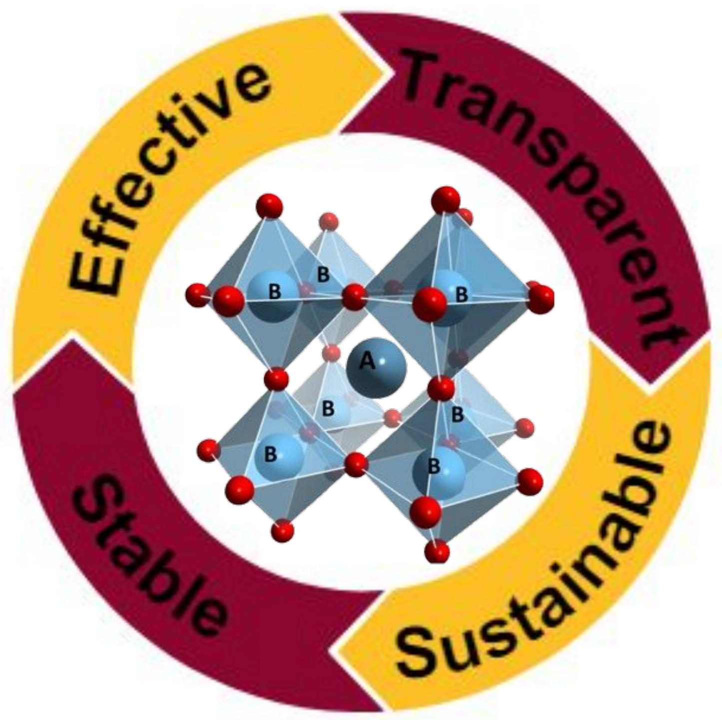
Introduction

The research endeavors to enhance the efficiency of perovskite films by utilizing tin (Sn) instead of toxic lead (Pb), aiming to reduce environmental transparent photovoltaic window absorber materials. This work uses fully inorganic precursor materials to create a more stable crystalline material, notably $CsSnBr_3$ (cesium tin bromide). However, current tin-based inks cannot carry the characteristics of efficiency and transparency together. The ability to find an ink that can simultaneously be efficient, transparent, and environmentally friendly has the potential to revolutionize how energy is gathered in the world, shifting from greenhouse gases to mainly solar energy.



A= Cs B=Sn X=Br

Materials & Methods

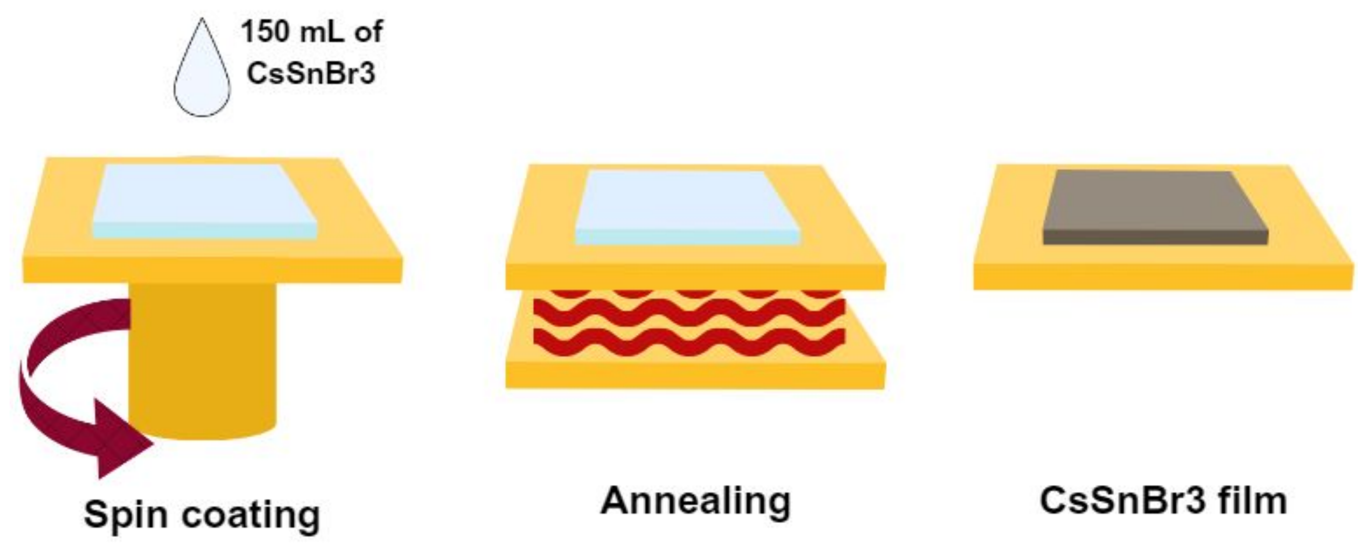
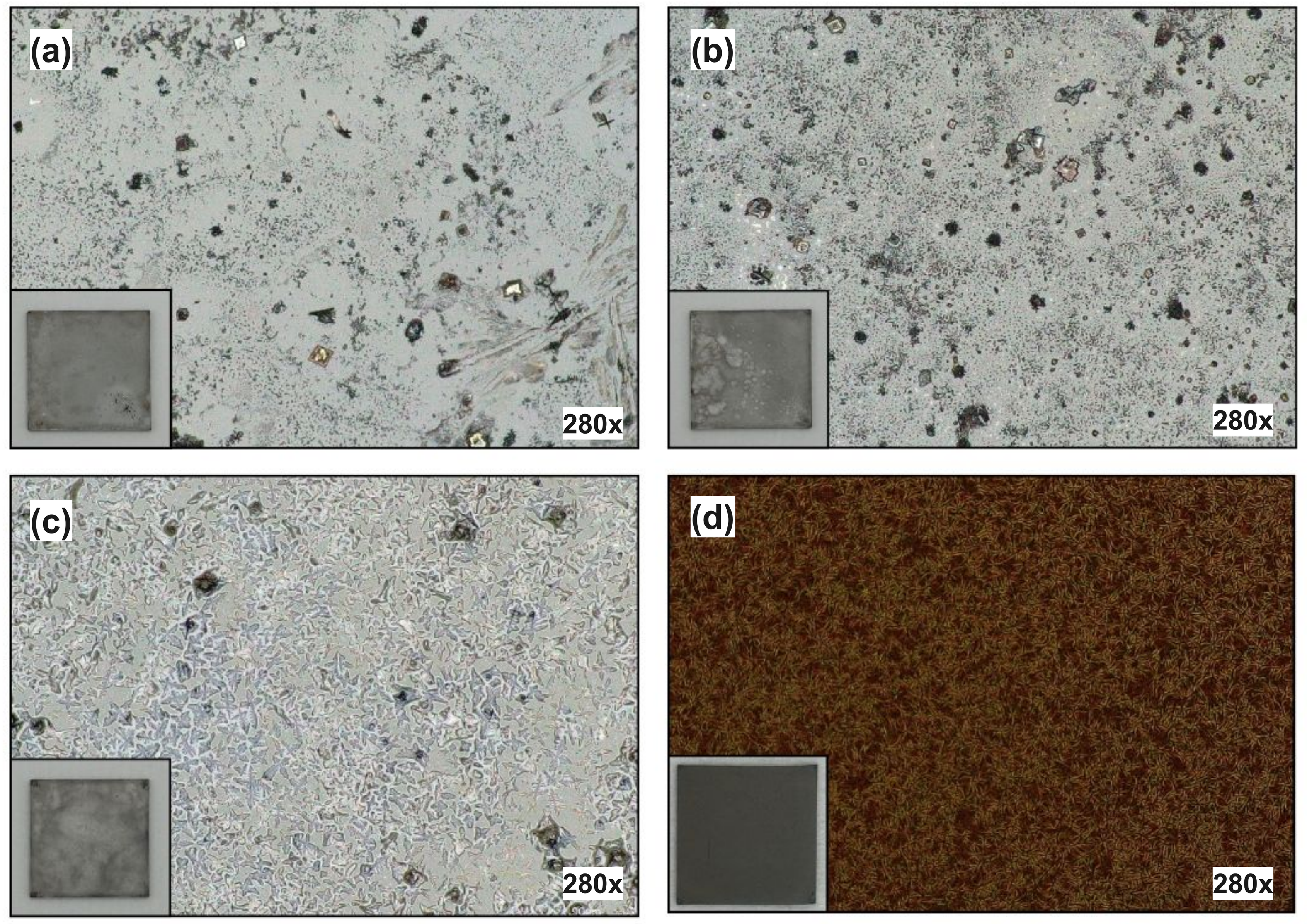


Fig. 1:
The schematic illustrates the process of spin coating and annealing $CsSnBr_3$ (cesium tin bromide) to create the film. Initially, 150 mL of the solution is added to a clean glass slide. The glass slide is then spin coated for 30 seconds at 2000 rpm and subsequently dried on a hot plate at 100°C for 10 minutes.

Results



(e)

$$t = \frac{r_A + r_X}{\sqrt{2(r_B + r_X)}}$$

(f)

PVK	Tolerance Factor
Ideal	0.9 - 1.0
$CsPbI_3$	0.81
$CsSnBr_3$	0.94

Challenges:

Although cesium tin bromide presents better results in stability, the biggest issue is that Sn (tin) oxidizes in air and/or moisture faster than Pb (lead).

Fig. 2:

(a-b) Microscope images of $CsSnBr_3$ solution with a concentration of 1 mole. Inks prepared using the same recipe but were made on different days.
(c) Microscope images of $CsSnBr_3$ solution with a concentration of 0.8 mole. The results revealed a more favorable structure.
(d) Microscope images of $CsPbI_3$.
(e) The tolerance factor is an indicator of stability by measuring the ionic radius of the cations (A and B) and the ionic radius of the ion.[3]
(f) Table illustrating the ideal tolerance factors for perovskites. The table indicates that $CsSnBr_3$ demonstrates greater stability by remaining within the range of 0.9 to 1.0.

Conclusions

Achieving uniform $CsSnBr_3$ films is challenging, primarily due to the inherent formation of Sn vacancies between the grains of $CsSnBr_3$. This arises from the self-oxidation process of Sn^{2+} to Sn^{4+}.[2] However, by adding SnF_2 (tin(II) fluoride) to the $CsSnBr_3$ solution, film performance can be enhanced. SnF_2 acts as a reducing agent, preventing the oxidation of the cesium tin bromide solution.

Future Work

- Test different concentrations of SnF_2 (0 mol %, 20%, and 40%).
- Make films with different solvents beyond dimethyl sulfoxide for stability characterization.
- Apply a polymethyl methacrylate (PMMA) coating on top of the perovskite to enable more moisture stability.
- Perform stability tests on $CsSnBr_3$ perovskites to compare the degradation of perovskites with different solvents and with the addition of PMMA.

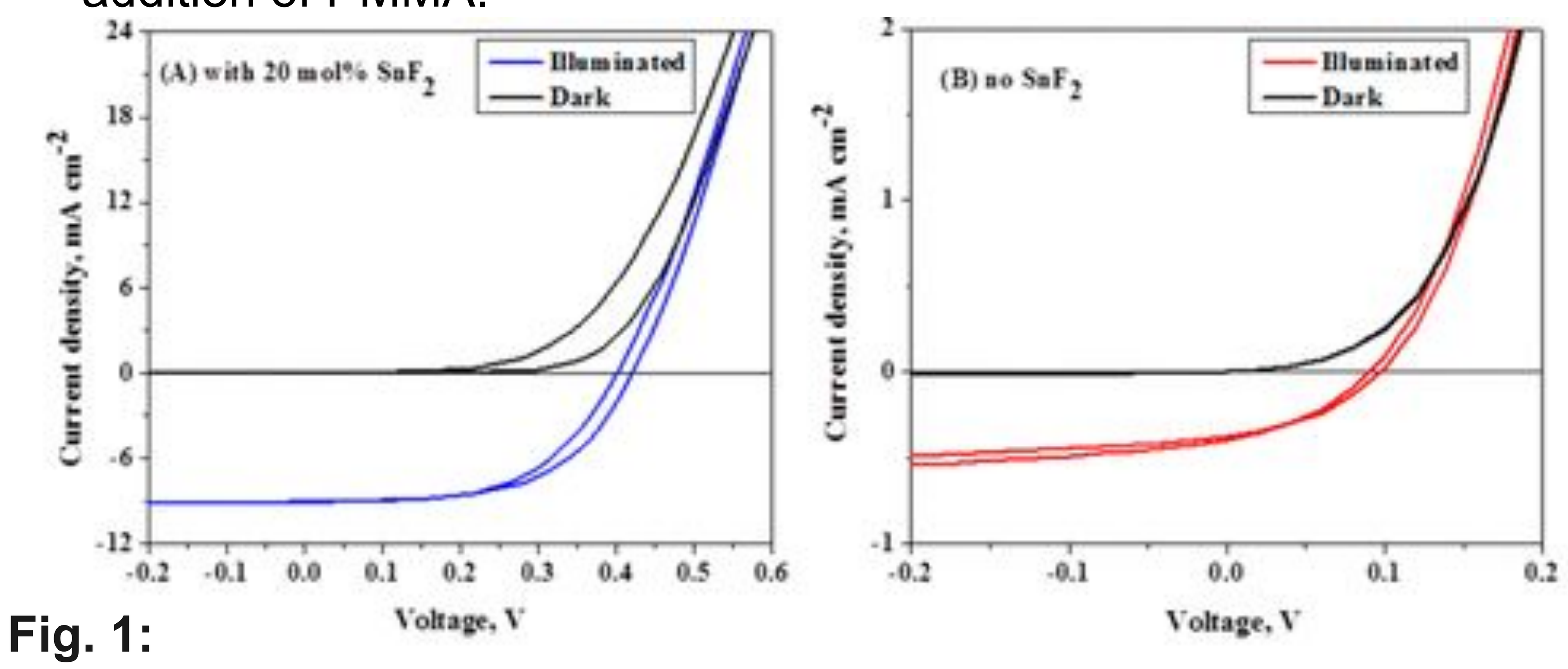


Fig. 1:
J–V characteristics of the best-performing $CsSnBr_3$ [(A) with and (B) without SnF_2] based cells in the dark and under illumination.[1]

References

1. *ACS Energy Lett.* 2016, 1, 5, 1028–1033
2. *ACS Energy Lett.* 2022, 7, 8, 2807–2815
3. *Chem. Sci.*, 2016, 7, 4548-4556

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