Testing the Thermal Stability of $FAPbI_3$-based Perovskite Solar Devices

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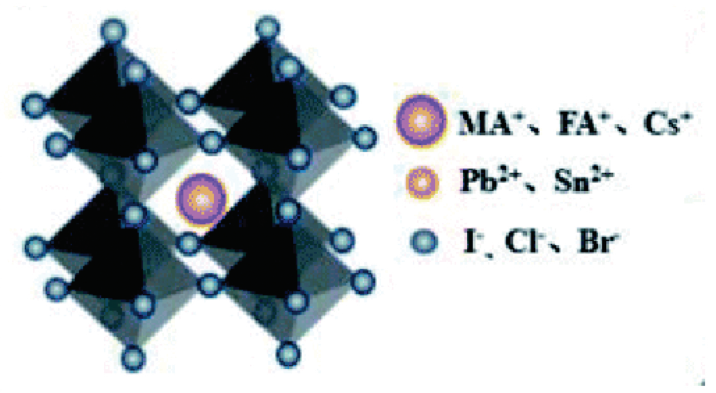
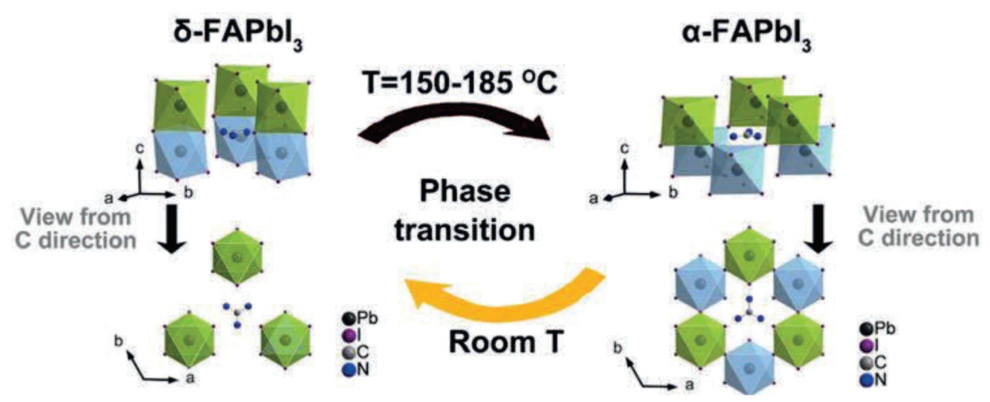
Background

There has been increasing focus in using the perovskite family of materials as opposed to silicon in solar panels due to their excellent photovoltaic properties, supply chain availability, and low-cost manufacturability. While the perovskite $MAPbI_3$ has been studied intensively over the years, the perovskite $FAPbI_3$ has recently gained popularity due to its narrower bandgap of 1.48 eV and increased operational stability. However, $FAPbI_3$ still faces thermodynamic stability problems – the ideal cubic a-$FAPbI_3$ only forms at about 160°C, and quickly degrades to a non-photoactive hexagonal d-$FAPbI_3$ yellow phase at room temperature. To prevent this degradation, adding MACl has been proposed to stabilize the $FAPbI_3$ crystal structure due to its smaller ionic radius [1].



[1] Perovskite Structure



[2] $FAPbI_3$ Phase Transition

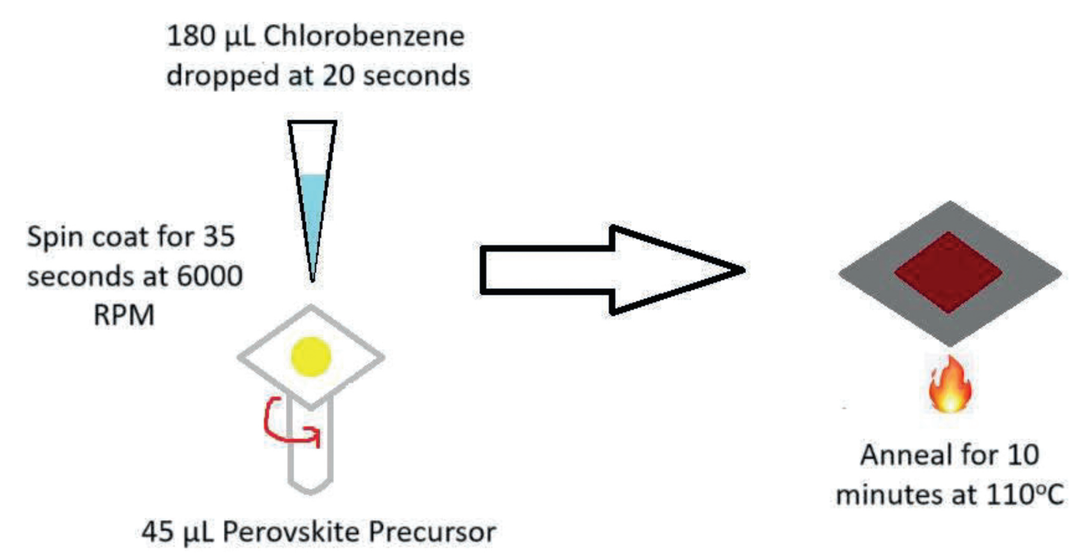
Research Question

The objective of this experiment is to determine how to improve the operational stability of $FAPbI_3$ by investigating the effects of molarity and the concentration of the additive MACl in producing stable, uniform films.

Materials and Processing

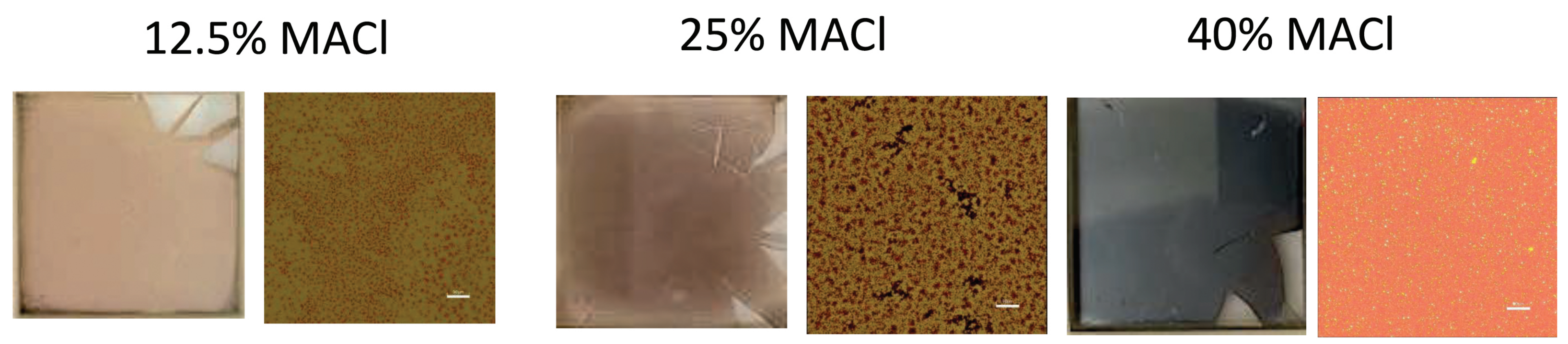
Precursor Recipe:

- 1M and 2M Formamidinium Lead Iodide ($FAPbI_3$)
- 12.5, 25, and 40% Methylammonium Chloride (MACl)
- 4:1 Dimethylformamide (DMF) to Dimethyl Sulfoxide (DMSO)



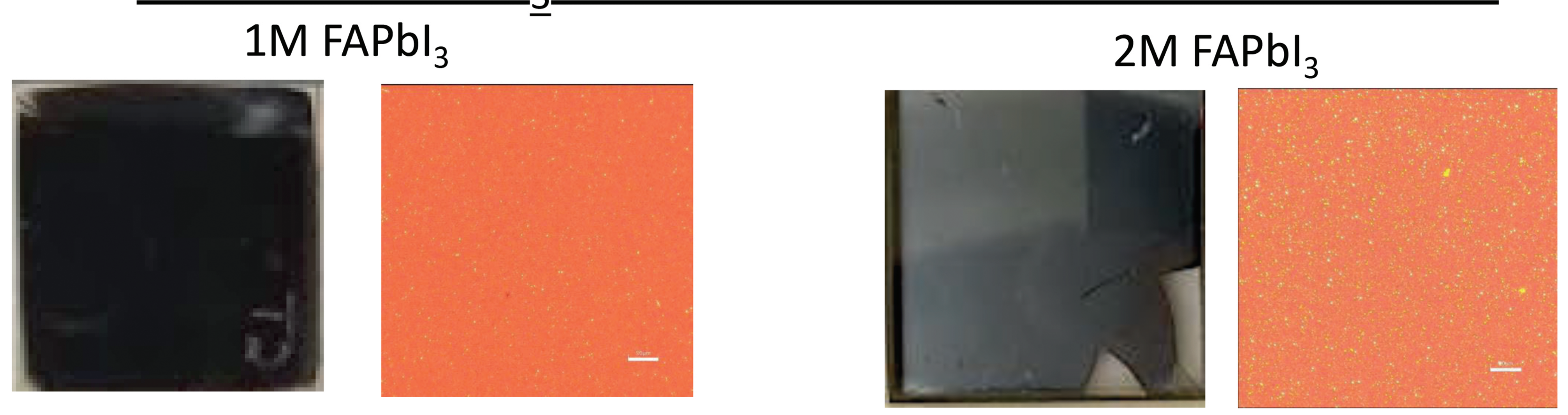
Results

Effects of MACl Concentration (2M Samples) after 30 minutes in open air



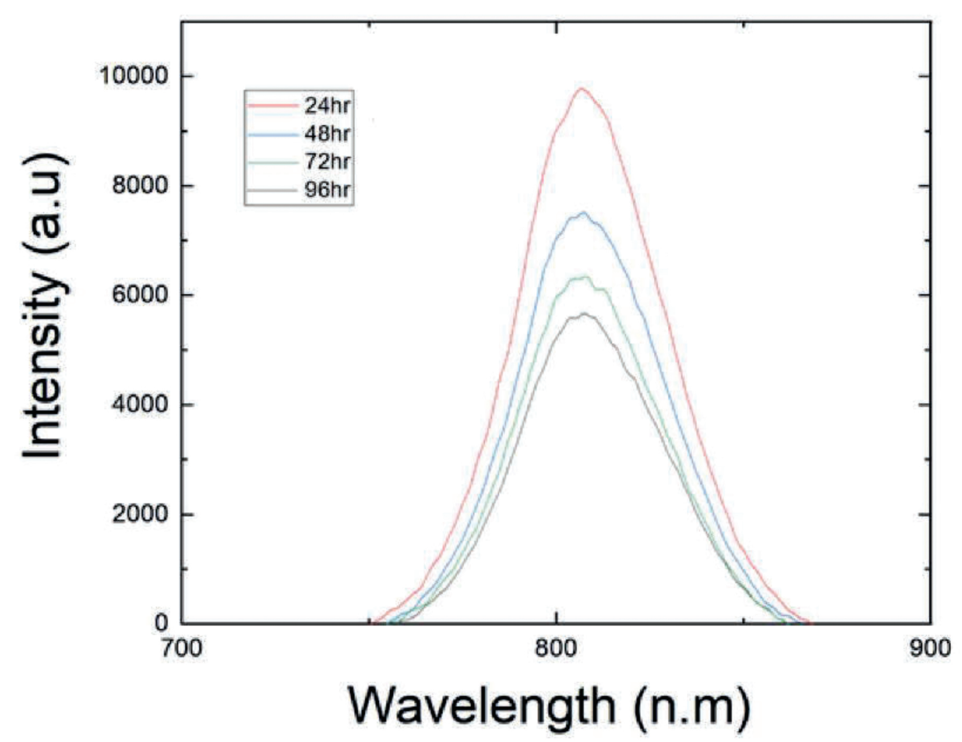
Increasing MACl content results in uniform crystallization that is much more stable. 12.5% MACl samples would degrade almost immediately, while 25% would follow suit after about 30 minutes.

Effects of $FAPbI_3$ Molar Concentration with 40% MACl



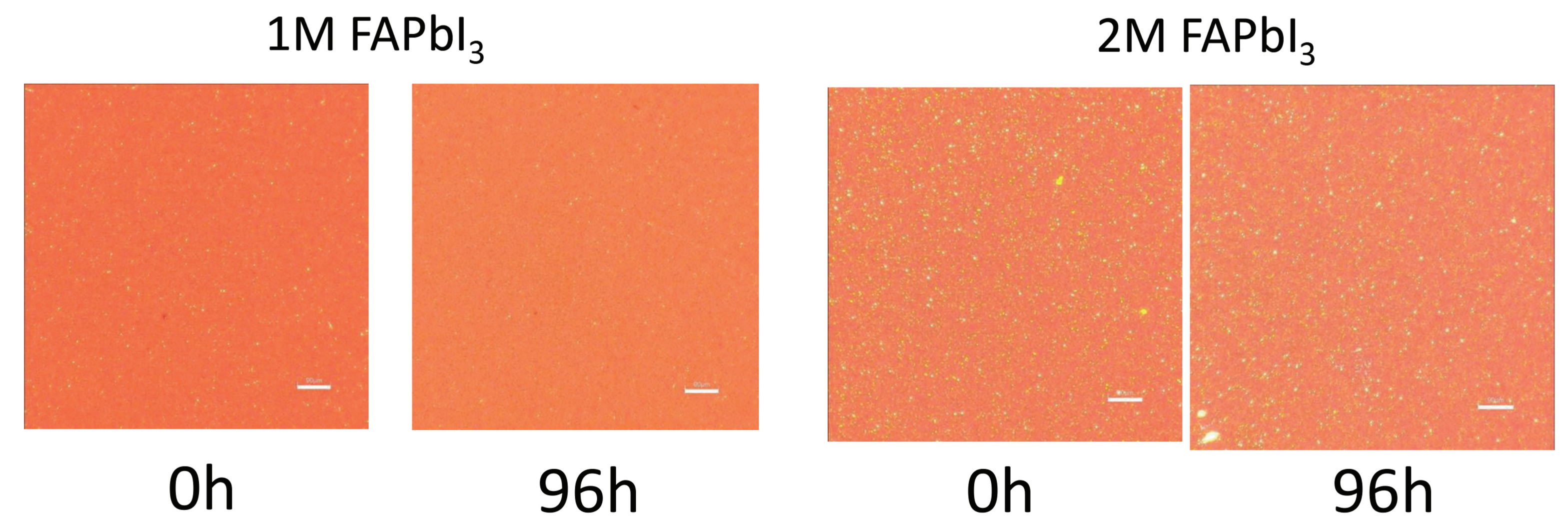
Decreasing Molar Concentration does not degrade crystallization of the films, but does result in a more even spread of the precursor solution. There are also fewer yellow spots present likely due to lower concentration of lead in the film.

Effects of Aging at 85°C

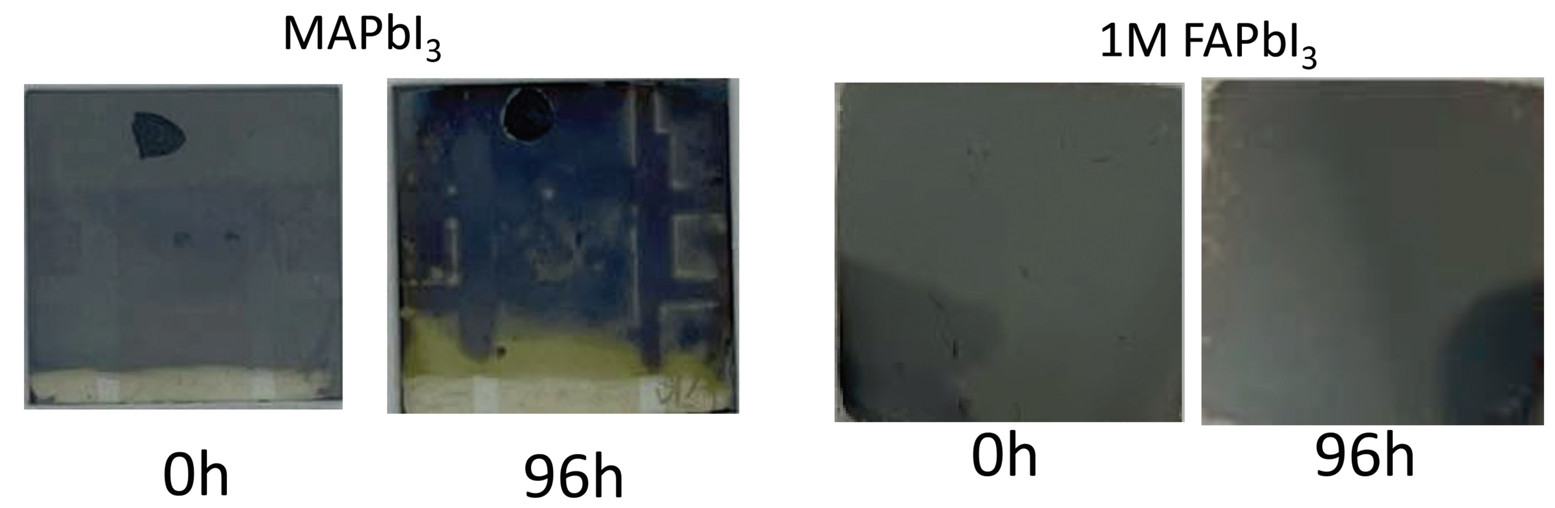


The wavelength of the films correspond to a bandgap of about 1.53eV, higher than the normal bandgap of $FAPbI_3$ due to the presence of MACl. While the wavelengths do not appreciably change during the aging process, the intensity of the films do.

Microscope Pictures during Aging Process



Macroscopic Comparison to $MAPbI_3$



The $FAPbI_3$ films undergo little change over the course of the heat treatment as opposed to the degradation seen in the $MAPbI_3$ films.

Conclusion

As the concentration of MACl increased, the $FAPbI_3$ films' stability increased as well, with 40% MACl demonstrating remarkable thermal stability. Heat treatment of 40% MACl films at 85C over a week demonstrated little degradation in the crystallization structure of the perovsite, and little to no shift in the bandgap of the films. However, the decreasing intensity of the films over time indicate a potential decrease in efficiency after undergoing heat treatment.

Future Work

- Study further how efficiency changes with MACl concentration
- Fabricate full $FAPbI_3$ devices to prove their viability
- Further study how addition of other additives such as Cesium and Rubidium will affect performance and stability of $FAPbI_3$ films.

FURI

References:

[1] Zheng, Z., Wang, S., Hu, Y., Rong, Y., Mei, A., & Han, H (2022), "Development of Formamidinium Lead Iodide-Based Perovskite Solar Cells: Efficiency and Stability", Royal Society of Chemistry, vol. 13, pp. 2167-2183.

[2] Leyu Bi, Qiang Fu, Zixin Zeng, Yunfan Wang, Francis R. Lin, Yuanhang Cheng, Hin-Lap Yip, Sai Wing Tsang, and Alex K.-Y. Jen *Journal of the American Chemical Society* **2023** *145* (10), 5920-5929 DOI: 10.1021/jacs.2c13566

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