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Investigating the Effect of Pyridine Vapor Treatment on Perovskite Solar Cells

Alison J. Ong

Office of Science, Science Undergraduate Laboratory Internship (SULI) Program

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Abstract

Perovskite photovoltaics have recently come to prominence as a viable alternative to crystalline silicon based solar cells. In an effort to create consistent and high-quality films, we studied the effect of various annealing conditions as well as the effect of pyridine vapor treatment on mixed halide methylammonium lead perovskite films. Of six conditions tested, we found that annealing at 100 degree Celsius for 90 minutes followed by 120 degree Celsius for 15 minutes resulted in the purest perovskite. Perovskite films made using that condition were treated with pyridine for various amounts of time, and the effects on perovskite microstructure were studied using x-ray diffraction, UV-Vis spectroscopy, and time-resolved photoluminescence lifetime analysis (TRPL). A previous study found that pyridine vapor caused perovskite films to have higher photoluminescence intensity and become more homogenous. In this study we found that the effects of pyridine are more complex: while films appeared to become more homogenous, a decrease in bulkphotoluminescence lifetime was observed. In addition, the perovskite bandgap appeared to decrease with increased pyridine treatment time. Finally, X-ray diffraction showed that pyridine vapor treatment increased the perovskite (110) peak intensity but also often gave rise to new unidentified peaks, suggesting the formation of a foreign species. It was observed that the intensity of this unknown species had an inverse correlation with the increase in perovskite peak intensity, and also seemed to be correlated with the decrease in TRPL lifetime.

Best Research-Cell Efficiencies

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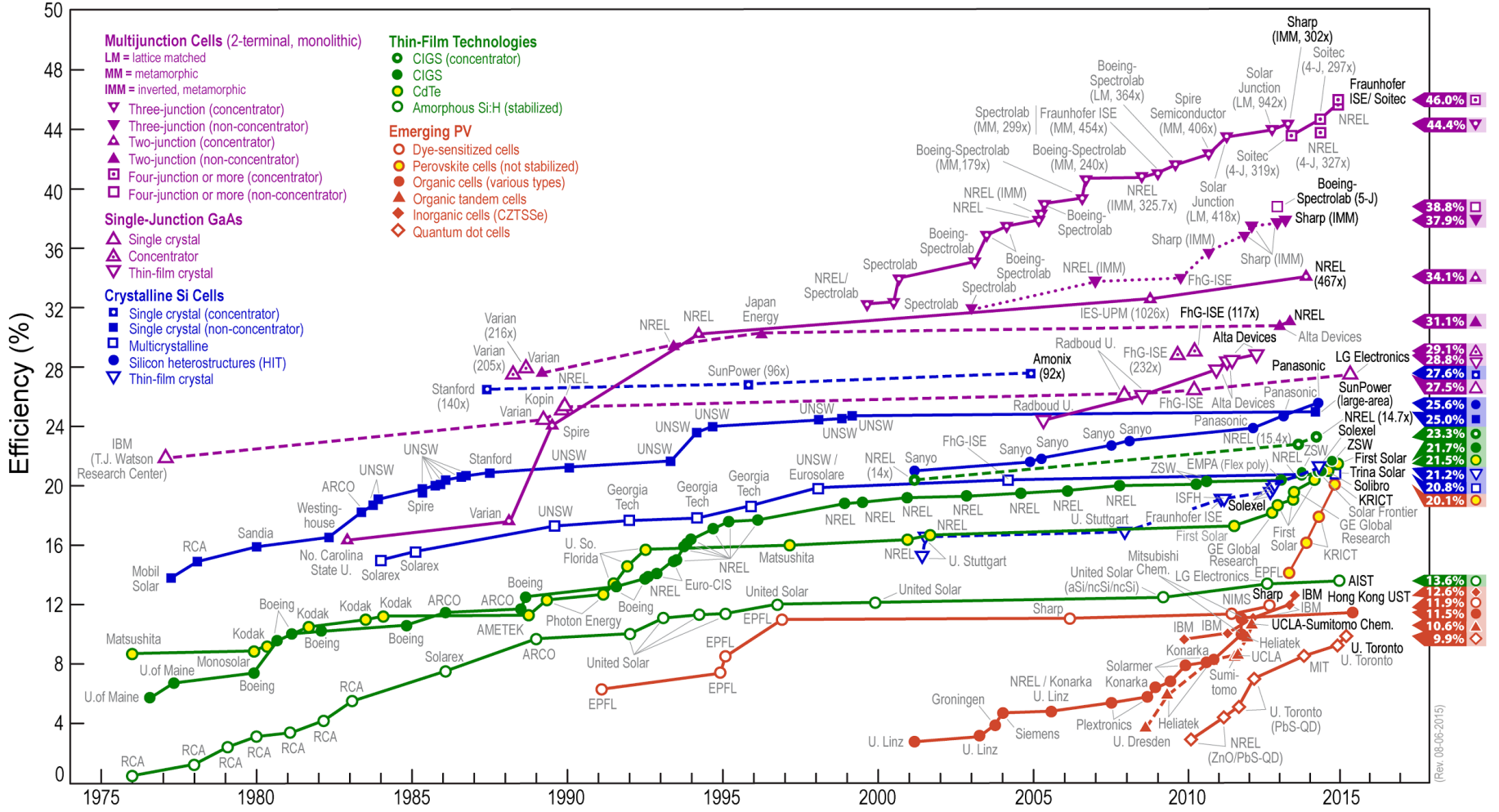
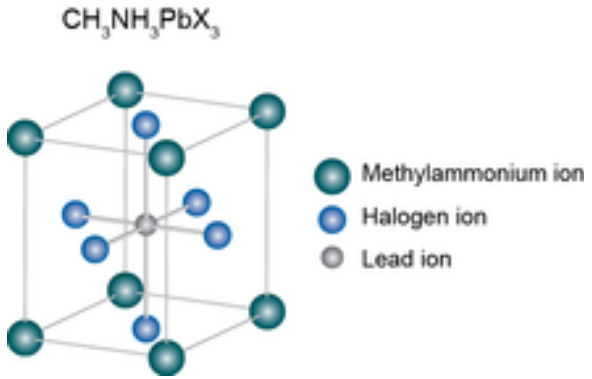


What is a perovskite?

"Perovskite...is a crystal structure with the formula ABX3 (X=halogen or oxygen)"

-Nam-Gyu Park, *Advanced Concepts in Photovoltaics*



$$CH_3NH_3I + PbCl_2 \rightarrow CH_3NH_3PbCl_xI_{3-x}$$

Methylammonium Iodide

Lead (II) Chloride

Perovskite

Research Goals

- Gain deeper understanding of perovskite structure and behavior
- Investigate enhancement of perovskite using post-production treatments

Prior Work

Sciencexpress

Impact of microstructure on local carrier lifetime in perovskite solar cells

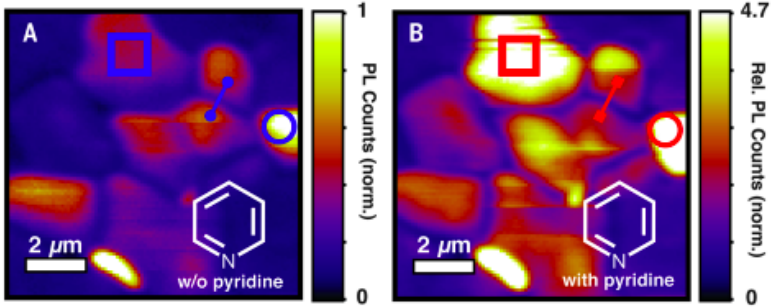
Dane W. deQuilettes,[1] Sarah M. Vorpahl,[1] Samuel D. Stranks,[2]* Hirokazu Nagaoka,[1] Giles E. Eperon,[2] Mark E. Ziffer,[1] Henry J. Snaith,[2] David S. Ginger[1]†

[1]Department of Chemistry, University of Washington, Box 351700, Seattle, WA 98195-1700, USA. [2]Clar
University of Oxford, Parks Road, Oxford OX1 3PU, UK.

*Present address: Research Laboratory of Electronics, Massachusetts Institute of Technology, Ca
02139, USA.

†Corresponding author. E-mail: ginger@chem.washington.edu

The remarkable performance of hybrid perovskite photovoltaics attributed to their long carrier lifetimes and high photolumines

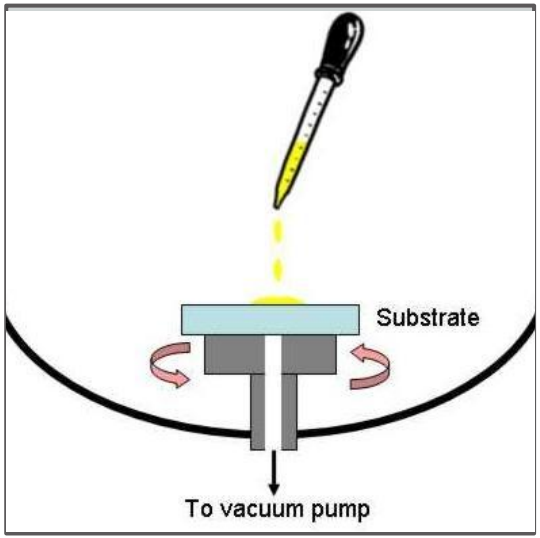


Research Goals

- Gain deeper understanding of perovskite structure and behavior
- Investigate enhancement of perovskite using post-production treatments
- Understand *why* pyridine treatment is effective and how it alters perovskite structure

Perovskite Synthesis

Solution Preparation



Spin Coating

Annealing

Optimization of Perovskite Annealing

- Annealing conditions are inconsistently reported, yet have large impact on film quality
- X-ray diffraction shows which substances are present

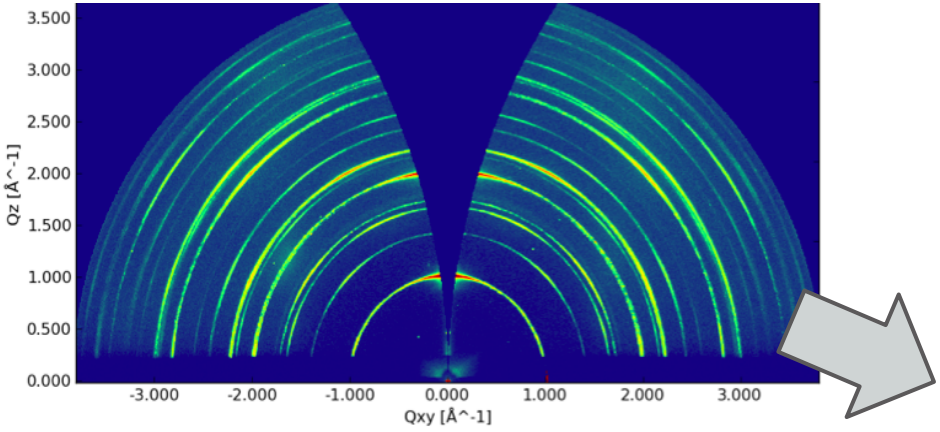
$$CH_3NH_3I + PbCl_2 \rightarrow CH_3NH_3PbCl_xI_{3-x}$$

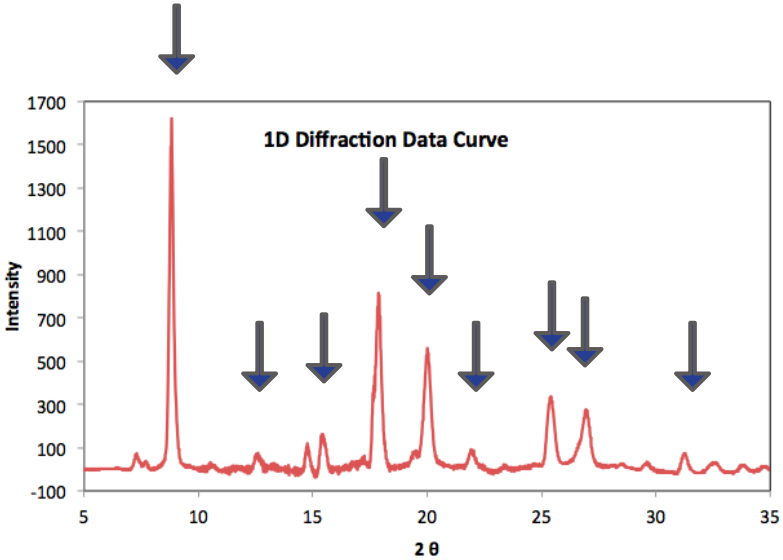
Methylammonium Iodide

Lead (II) Chloride

Perovskite

Optimization of Perovskite Annealing





Investigation of Pyridine Treatment

Time-Resolved Photoluminescence (TRPL)

- Carrier lifetime
- Indicator of efficiency

UV-Vis Spectroscopy

- Bandgap energy
- Number of trap states in film

X-Ray Diffraction

- Degree of perovskite crystallinity
- Amount and type of impurities

Time-Resolved Photoluminescence

- Pyridine vapor treati
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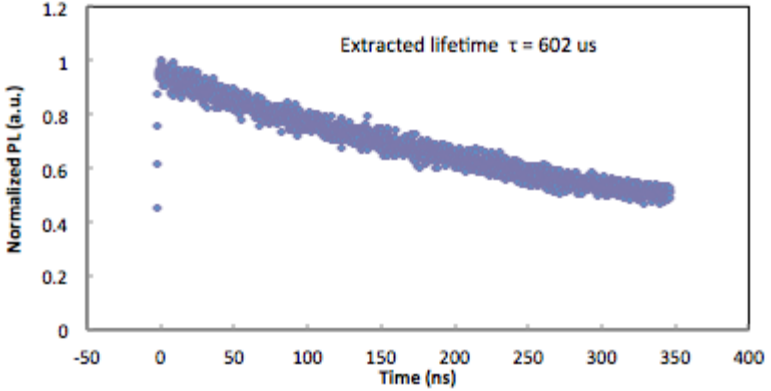
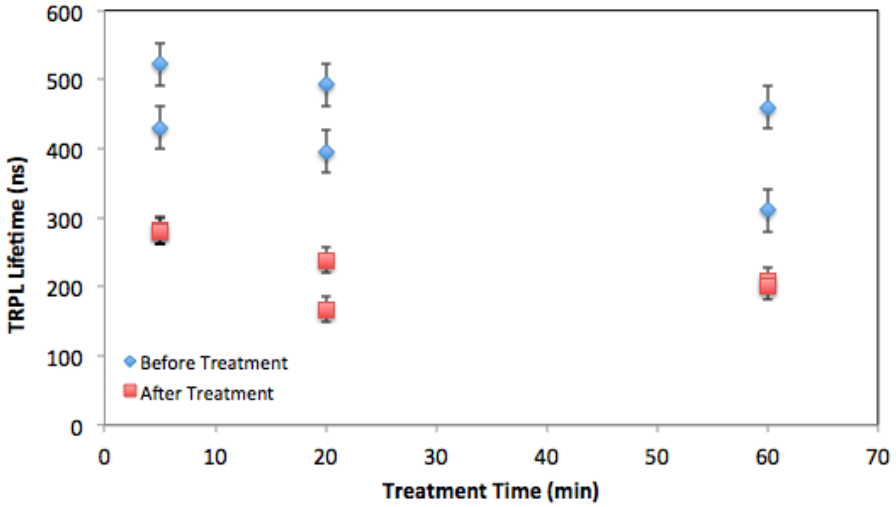
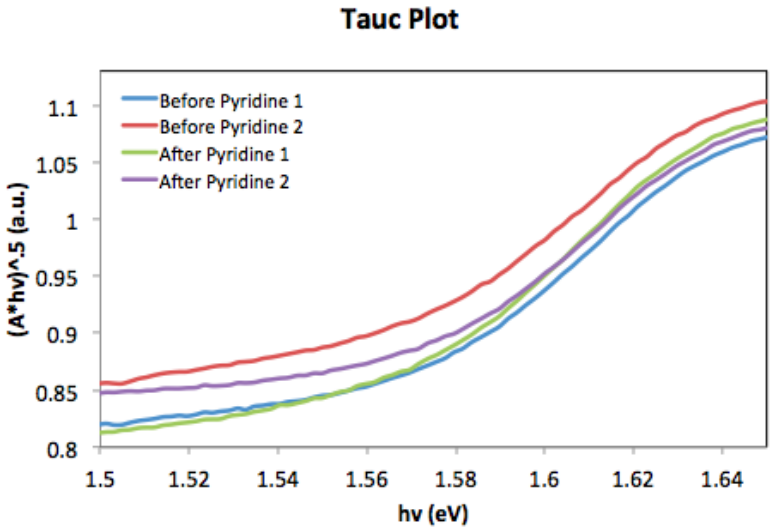
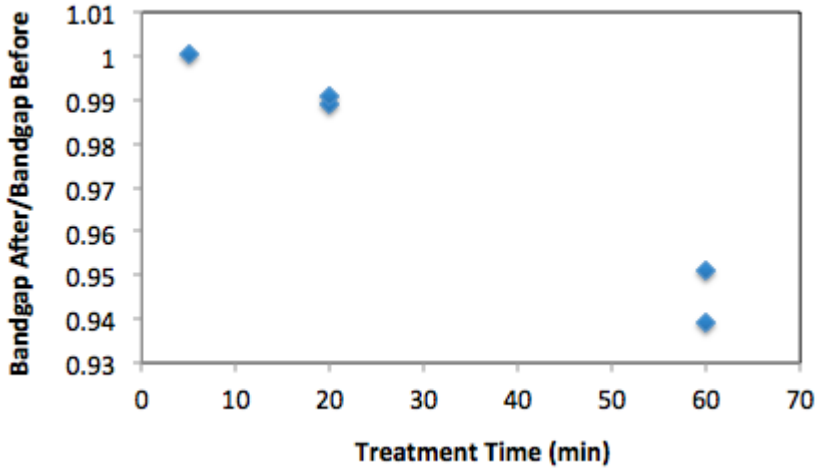




Time-Resolved Photoluminescence Lifetime

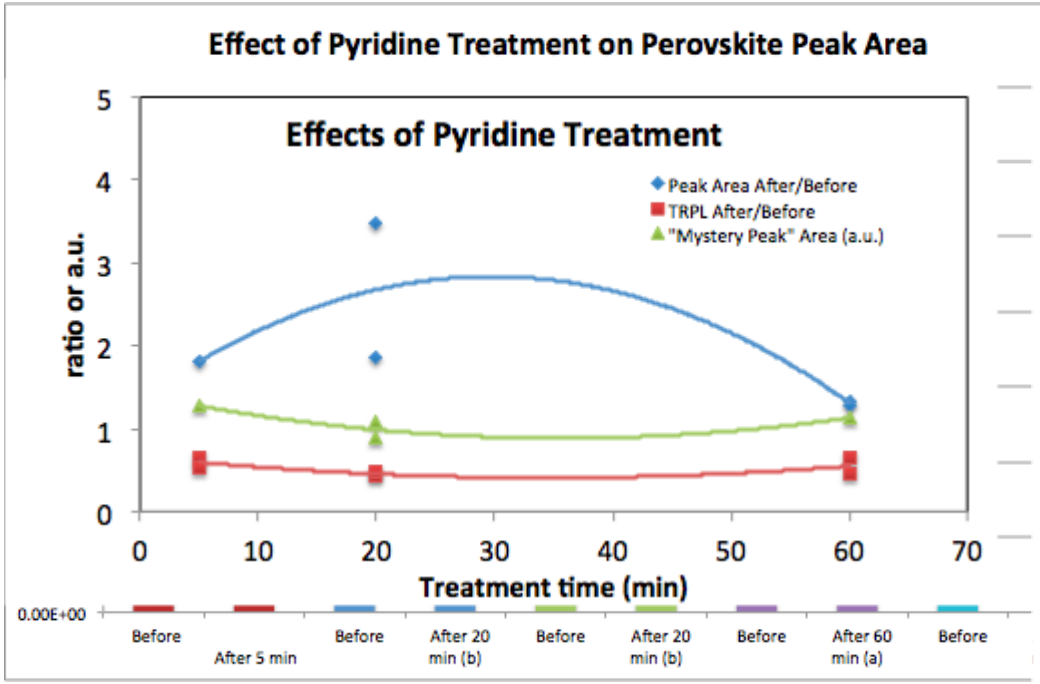
UV-Vis Data

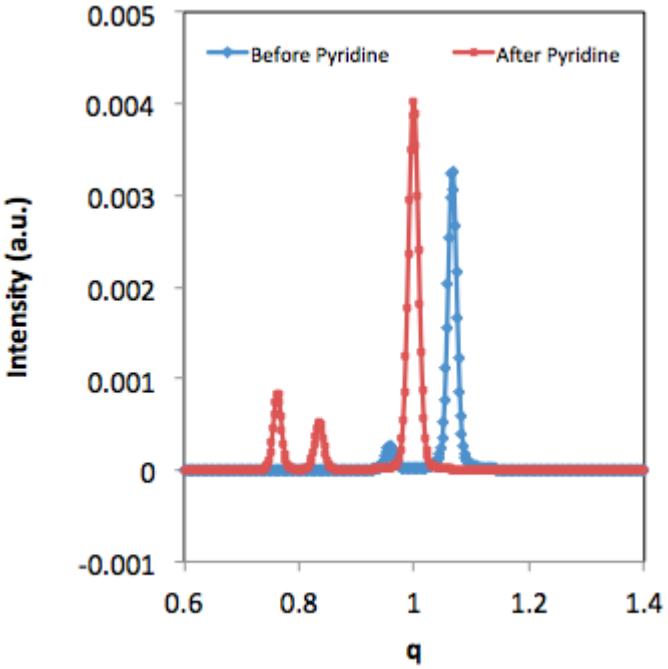




- Trend in bandgap agrees with TRPL data

X-Ray Diffraction





Pyridine treatment results in larger perovskite peak area

Conclusions

- Pyridine decreases PL lifetime and decreases the band gap
- Pyridine increases amount of perovskite but also causes change in crystal structure

Acknowledgements

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Thank you for your attention!