CH_2I_2 Improves Photocurrent and Suppress Ionic Motion in Photonically Cured $MAPbI_3$ Solar Cells

Weijie Xu

Robert T. Piper, Julia W. P. Hsu

University of Texas at Dallas

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Roll-to-Roll Processing of Perovskite Solar Cells (PSCs)

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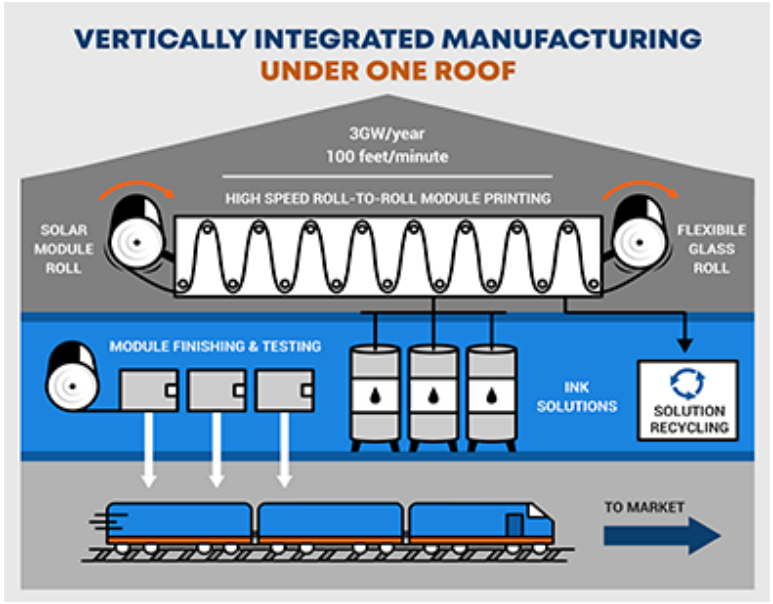
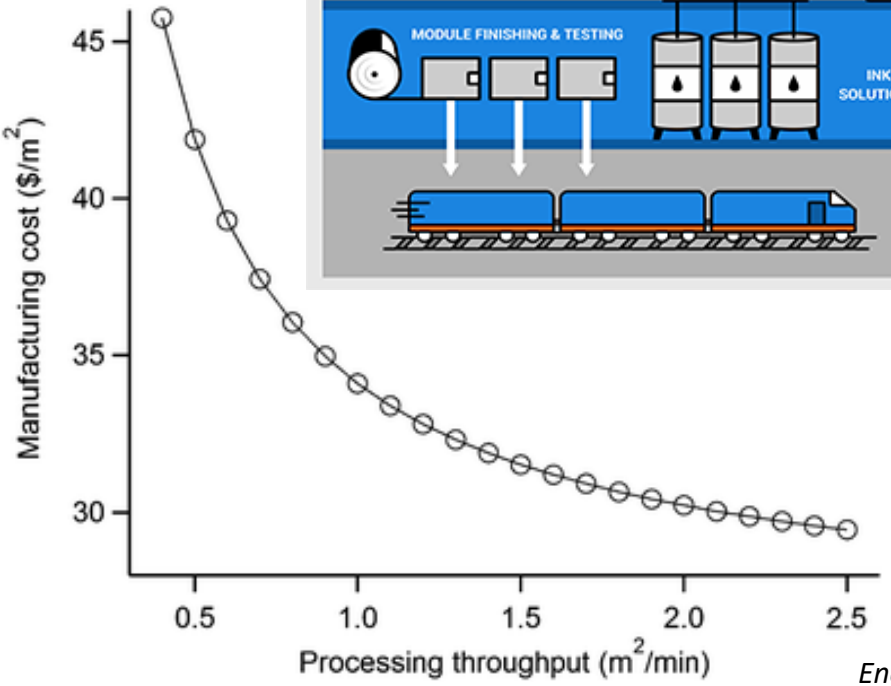
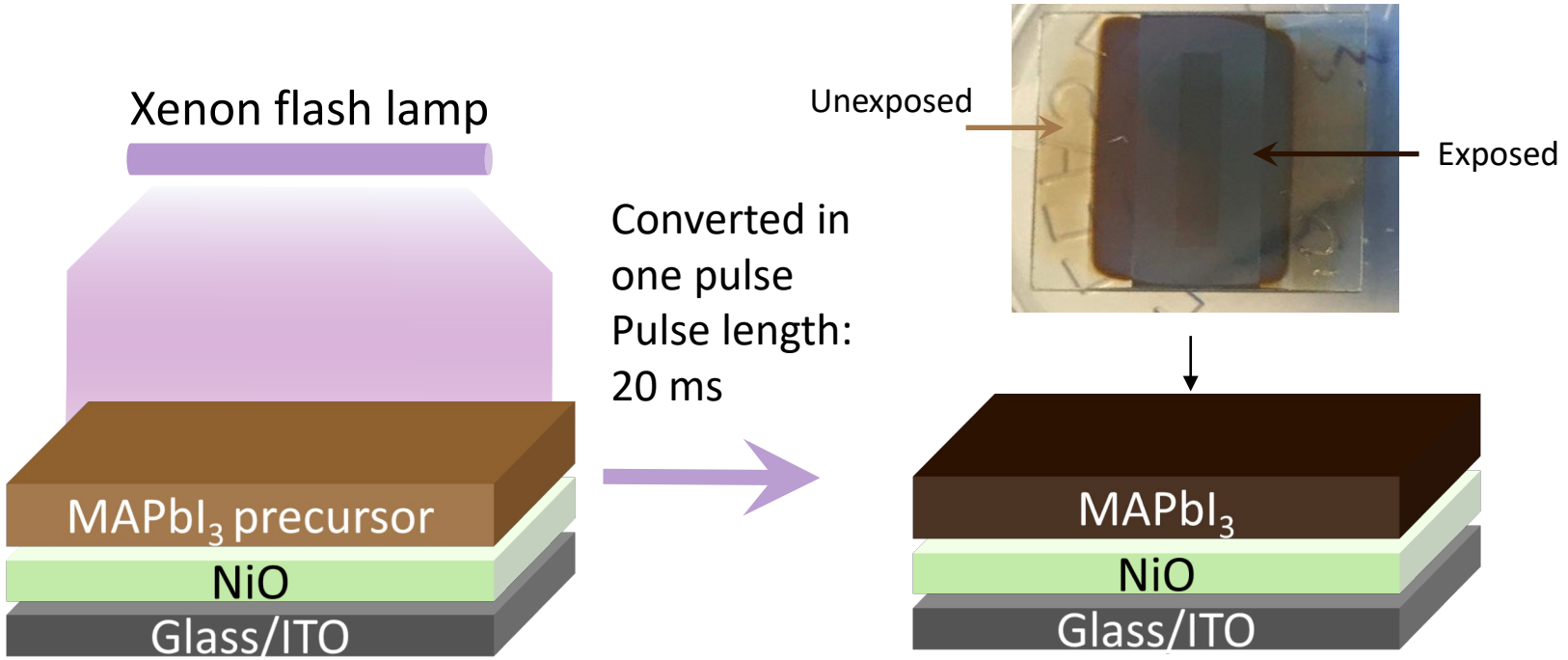




- 25.5% power conversion efficiency for lab device
- Higher the throughput, lower the cost.
- PSCs is compatible to roll-to-roll.
- Single manufacturing line may produce 3 GW of PSC solar panels per year @ $0.15/W.
  - Web speed = 30 m/min
- Thermal annealing on $MAPbI_3$ requires 10 min at 100 °C.
  - Making a 300-meter-long oven is impractical.
- *Requires high-speed and energy-efficient process!*

Energy Environ. Sci., 2017, **10**, 1297–1305.

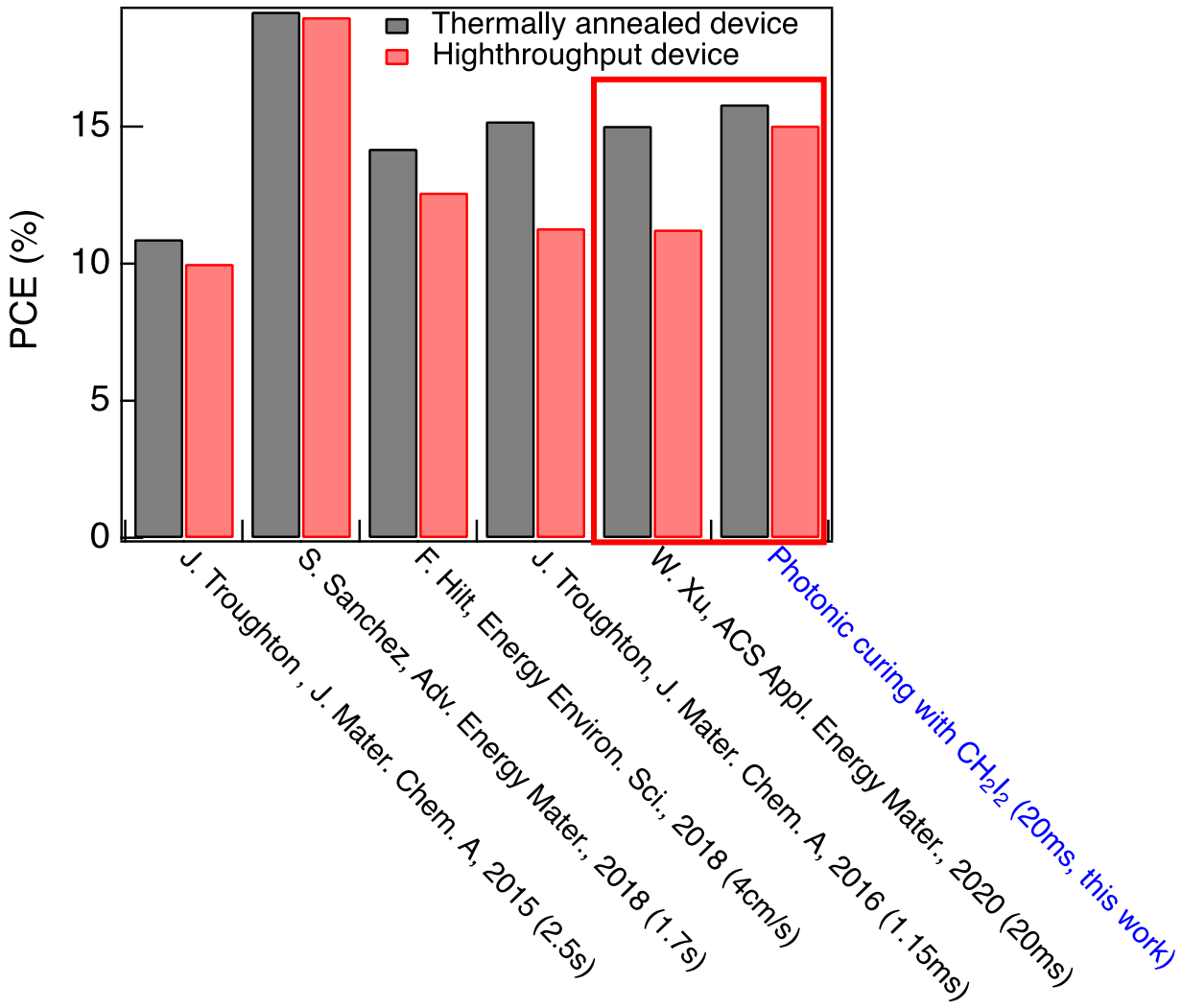
Photonic Curing to Make Perovskite Solar Cells



- Reported working photonic curing (PC) devices.
- Inferior PC device performance.

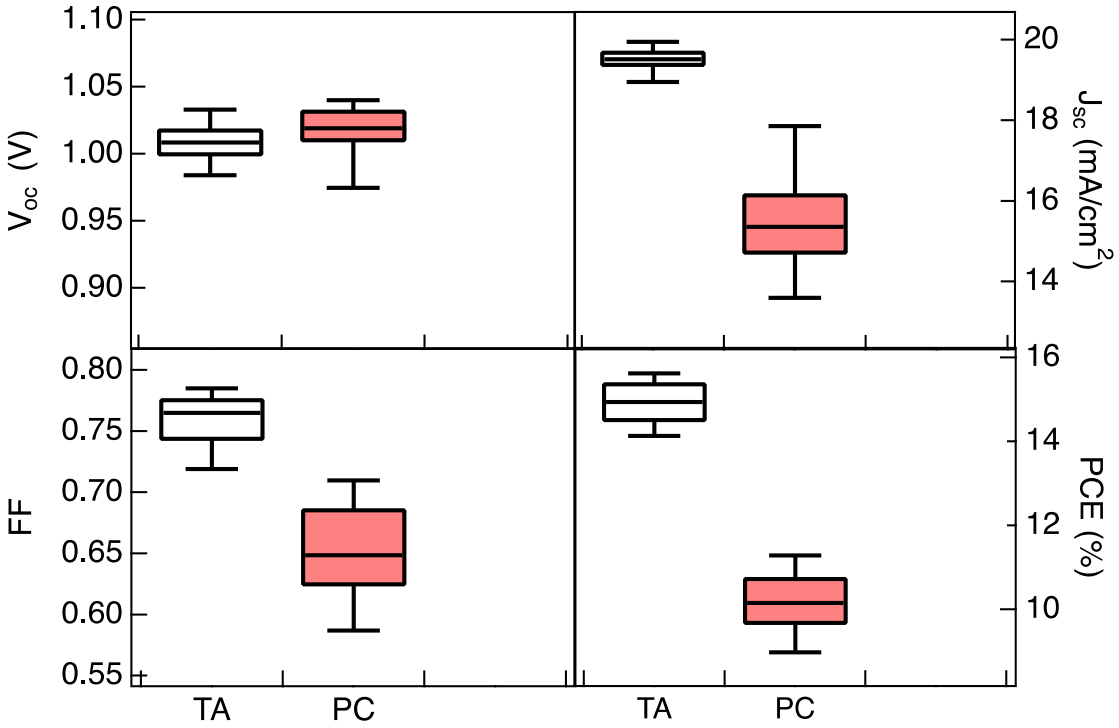
Xu, W et al. *ACS Appl. Energy Mater.* **2020**, *3* (9), 8636–8645.

Photonic Curing to Make Perovskite Solar Cells



- PCE will be compromised under high-throughput process
- CH_2I_2 has been reported to improve PC device performance (Ankireddy, JMCA 2018, 6, 9378), but the mechanism has not been studied.
- We also examine the cause of the inferior PC device performance

Photonically Cured Perovskite Solar Cell Performance



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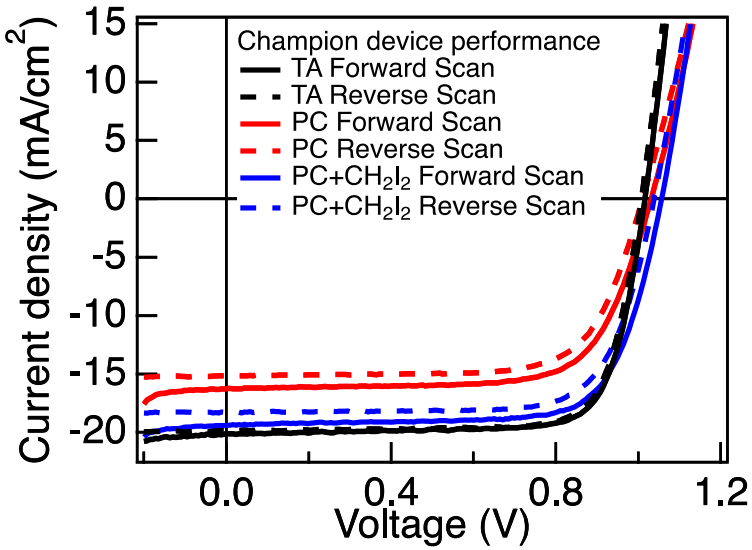
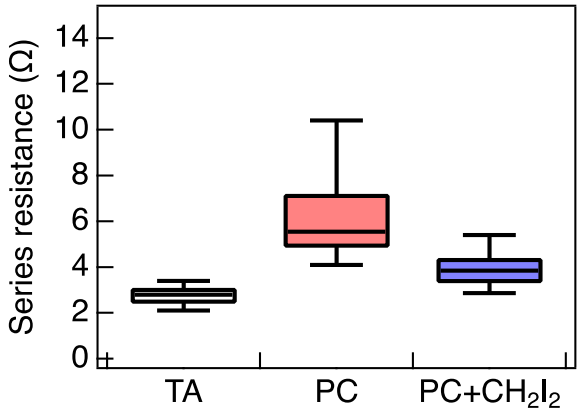
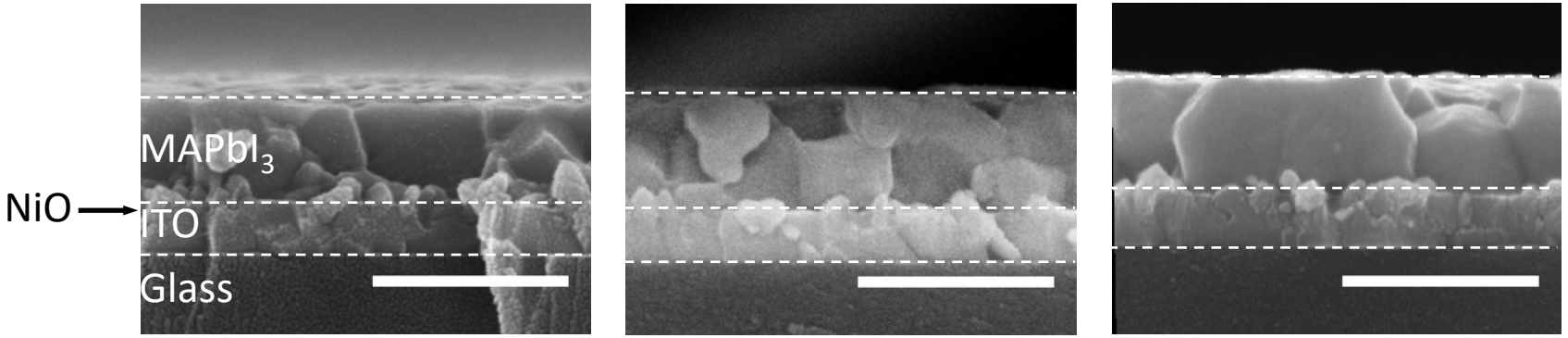


- PC device performance is lower than that of TA device mainly due to low J_{sc} and FF.
- Adding CH_2I_2 improves all parameters.
- Champion device performance:
  TA: 15.82%; PC: 11.86%; PC+CH_2I_2=15.04%

Device series resistance





TA PC $PC+CH_2I_2$

Scale bar = 500 nm

- Compared to TA device, PC devices has larger series resistance.
- After adding CH_2I_2, series resistance decrease.
- PC grain height is much smaller than PC + CH_2I_2 films, causing carrier transport through grain boundaries.

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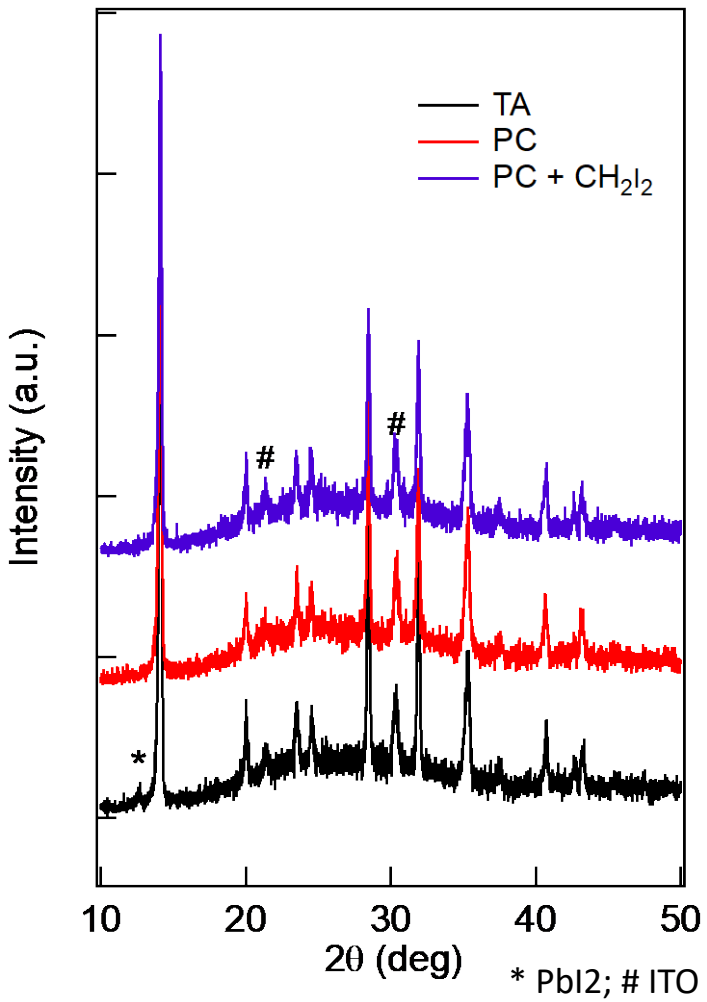
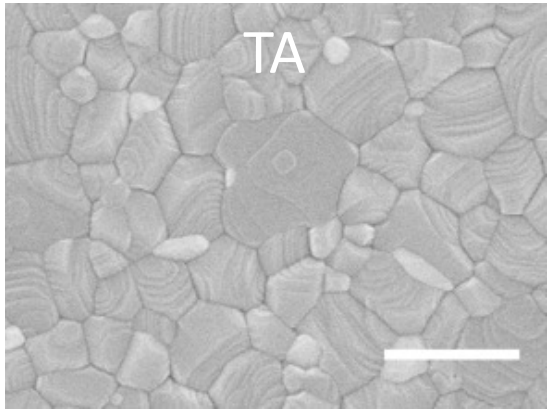
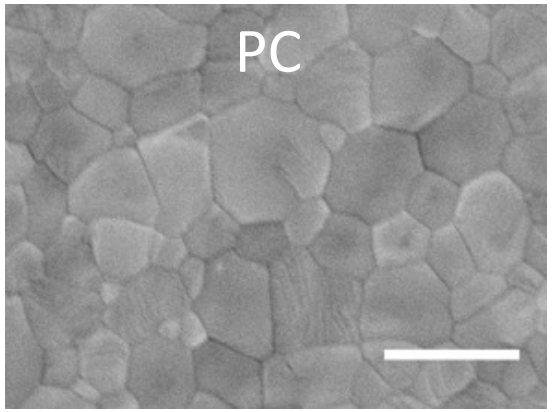
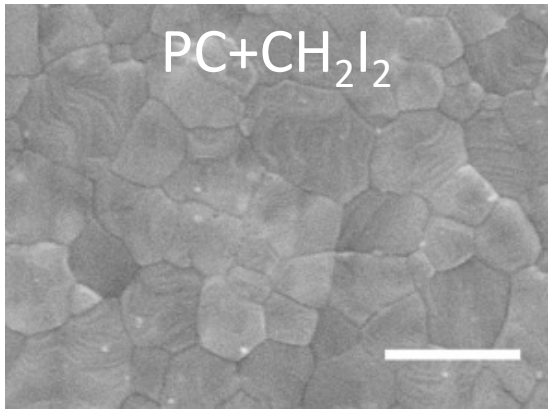
Crystallinity and Grain Size

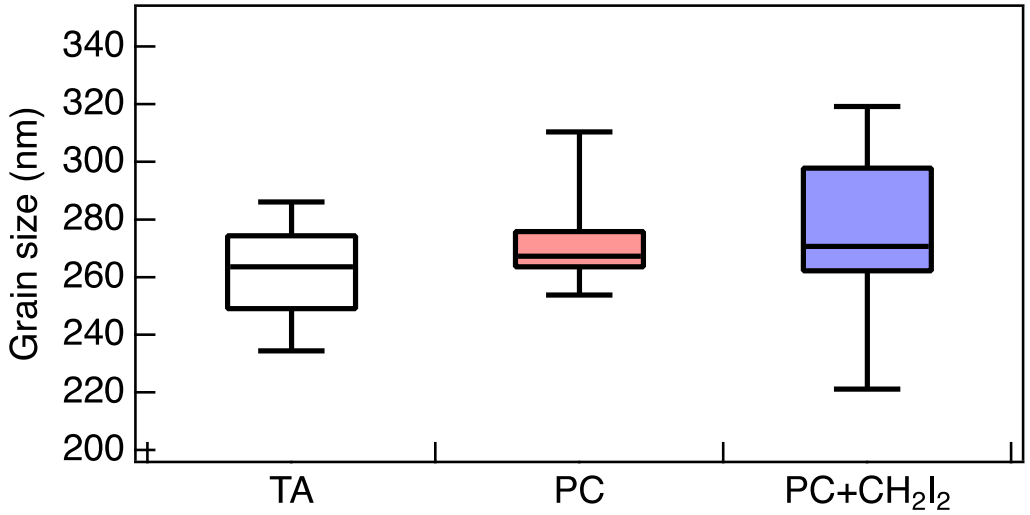






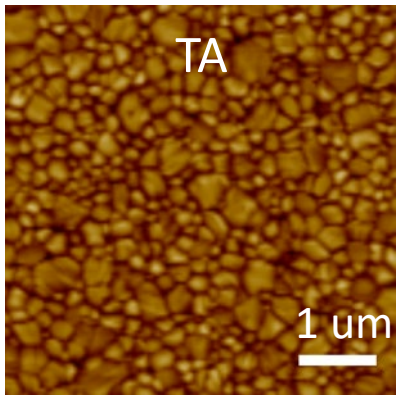


Scale bar = 500 nm



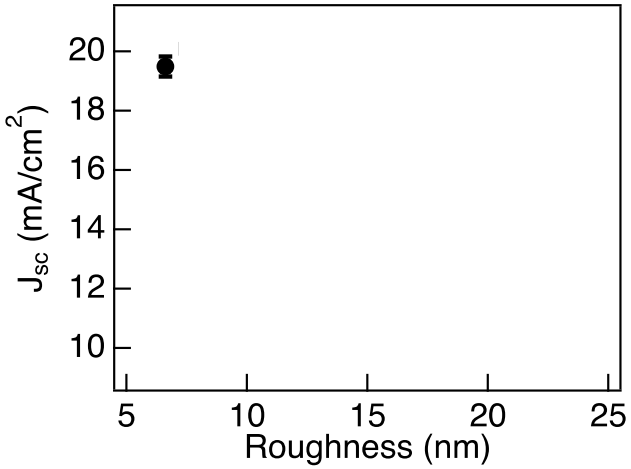
- Similar crystallinity.
- Similar grain size

Different Surface Morphology

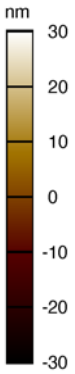


RMS=6.6 ± 0.1 nm

J_{sc}=19.5±0.3 mA/cm²



Legend:
TA
PC
PC + CH_2I_2
400 nm TA
400 nm PC



- Under AFM, photonically cured $MAPbI_3$ films have meso-scale, wave-like undulations.
- Adding CH_2I_2 reduce the amplitude of the undulations and improves J_{sc}
- Negative correlation between film roughness and PC device J_{sc}.

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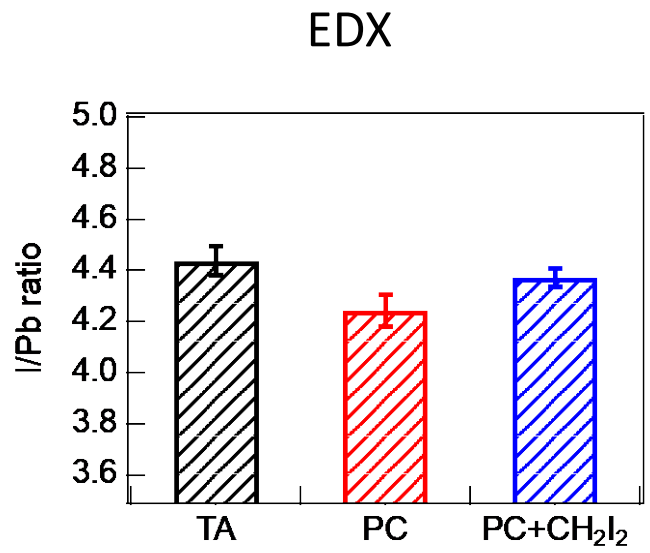
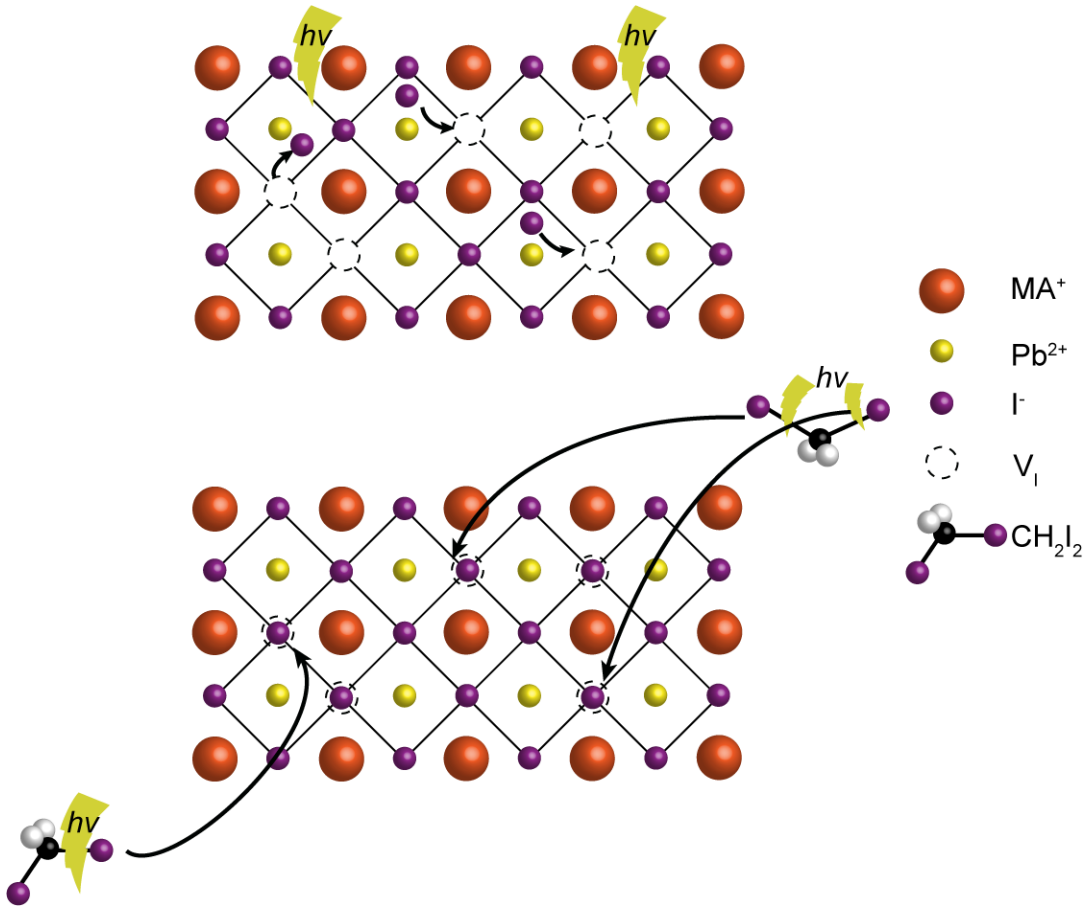
I/Pb Stoichiometry



- Compared to TA, PC film is I-deficient.
- I vacancies can facilitate iodine motion.
- Iodine from photo-dissociated CH_2I_2 fills I vacancies.



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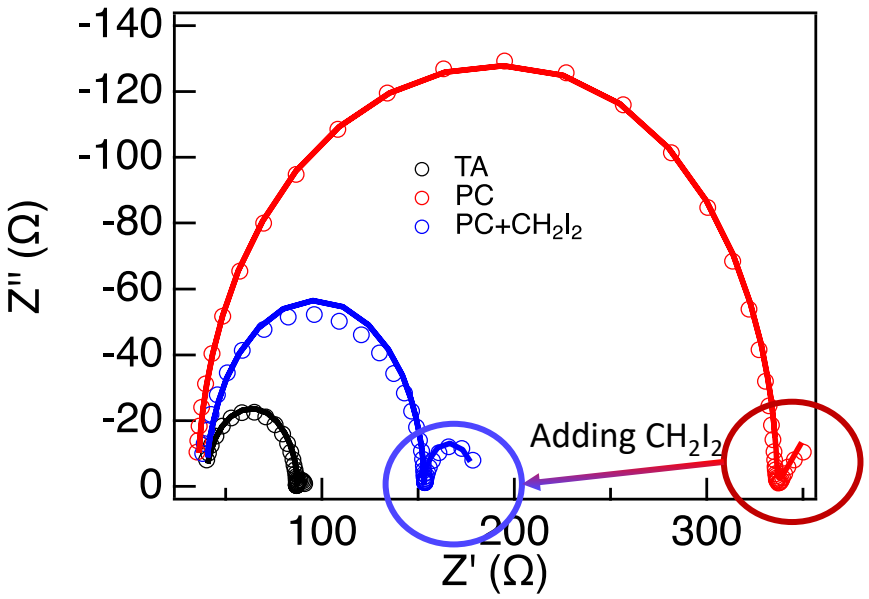
Frequency dependent device behavior



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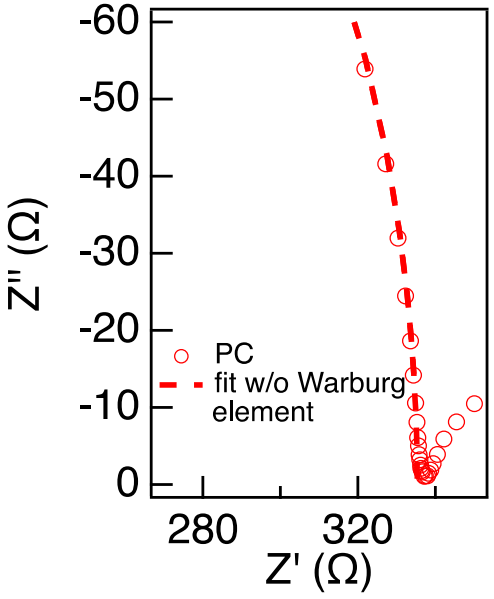
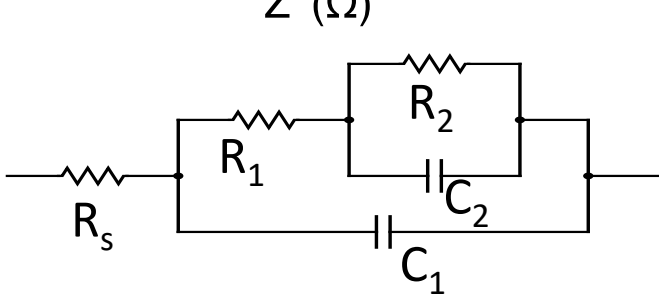
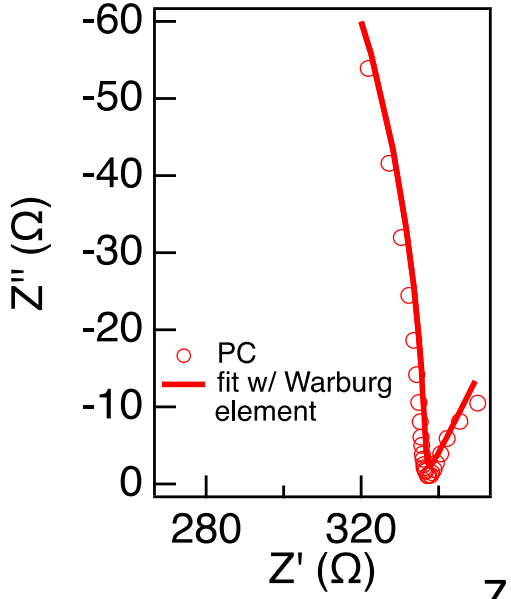
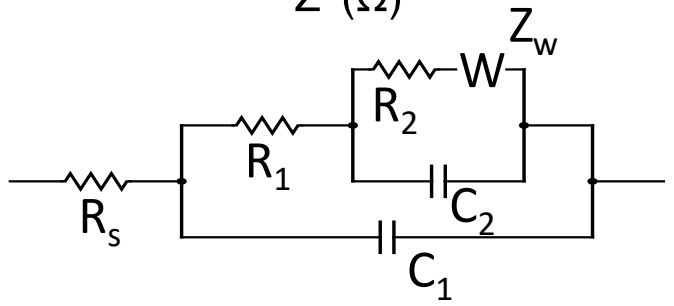




w/o Warburg element

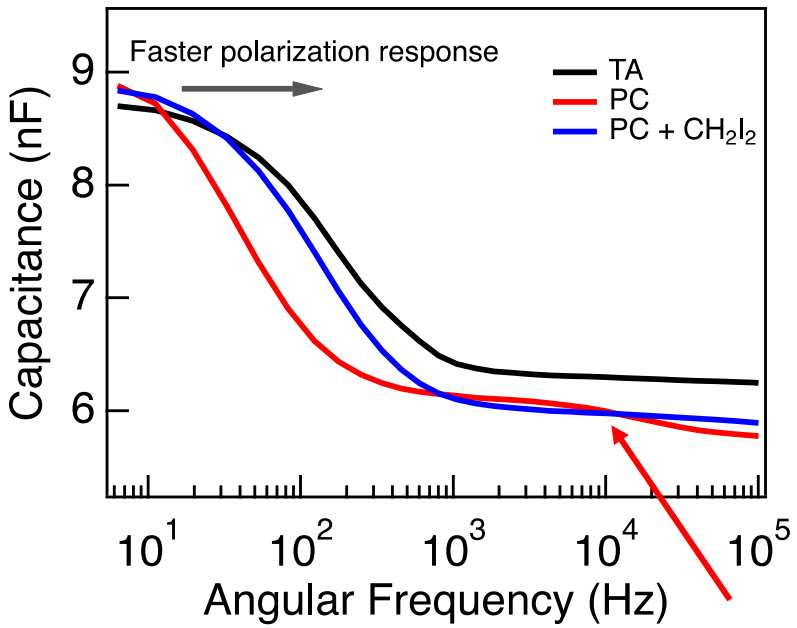


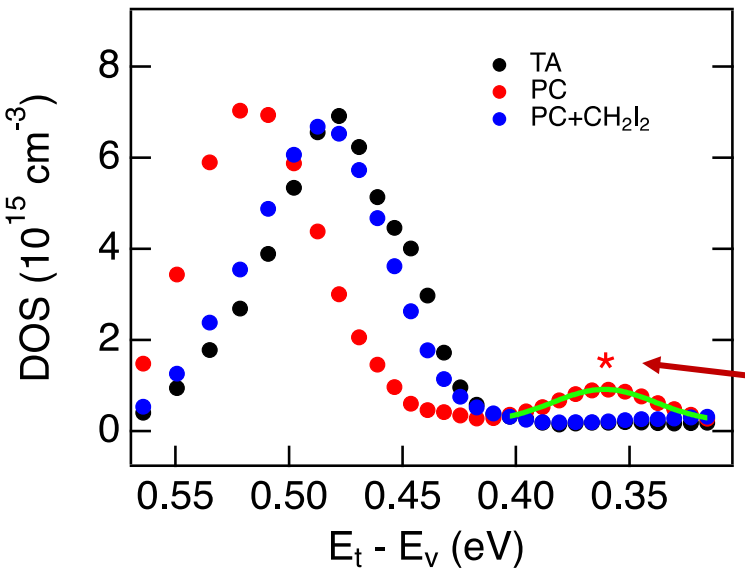


w/ Warburg element

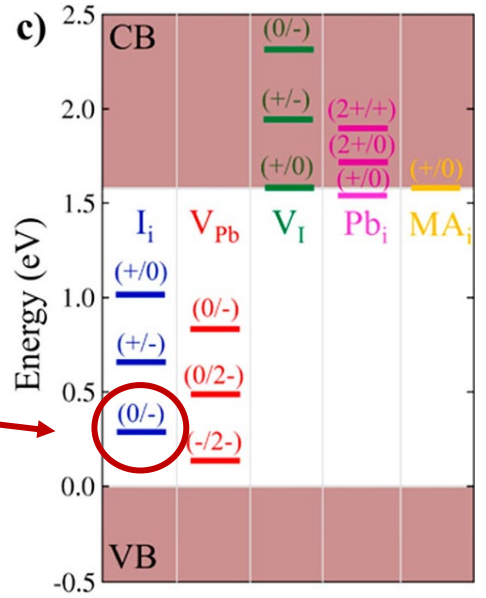
- Only the PC device has fingerprint 45° straight line, a signature of Warburg element, indicating ion diffusion at the interface.
- CH_2I_2 remove the iodine motion and the Nyquist plot is semicircle.

Defect state analysis





The second defects



ACS Energy Lett., 2018, **3**, 447–451.

- PC devices have slower polarization response compared to TA and PC + CH_2I_2 devices.
- PC shows a second defect state.
- Adding CH_2I_2 can remove the additional defects

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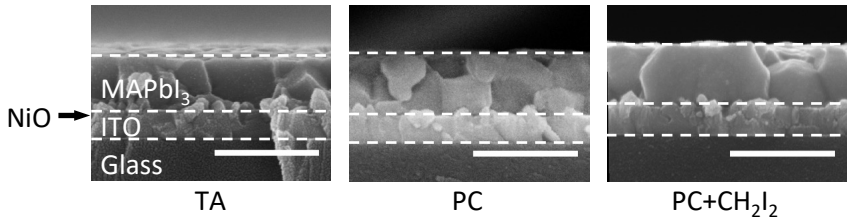
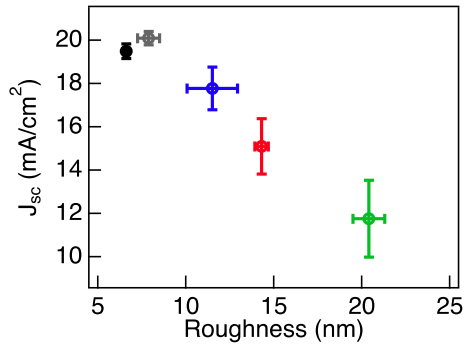
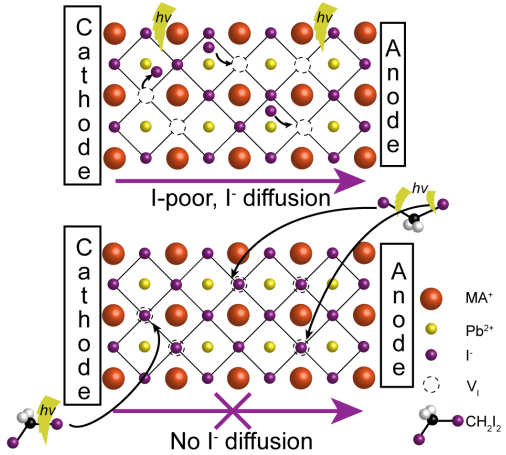
Summary

- CH_2I_2 promotes vertical grain growth, reduce series resistance and increase device fill factor.
- CH_2I_2 reduces film roughness by lowering the amplitude of the wave-like undulations, increasing J_{sc}.
- CH_2I_2 restore I stoichiometry and remove iodine motion in the films, contributing to higher J_{sc}
- Adding CH_2I_2 in PC devices improve PCE from 11.86% to 15.04%, comparable to TA device 15.86%.







Thank you