cross sectional and topological analysis of perovskite *photovoltaics cell using scanning electron microscope*

H. Setiawan[1], P. Zhang [1], C. Boehlert [2], P. Askeland[2]

The daily input of solar energy to the earth's surface is more than enough to supply human's electricity needs for a long time. However, the traditional crystalline Silicon photovoltaics (solar) cell technology has a rather complicated fabrication process and thus expensive cost. Recently, much attention has been focused on the hybrid organic/inorganic perovskite solar cell as the possible next-generation solar cell technology due to its rapidly growing efficiency and its lower fabrication cost.

MICHIGAN STATE UNIVERSITY
HANANIEL SETIAWAN
setiawah@msu.edu

photovoltaics effect

- When **photons hit PV cells**, electrons become excited. Photons with enough energy to overcome the band gap energy of the material, **electrons will be stripped from the outer orbita**l.
- This creates a **flow of current** which eventually produces potential and power when external current path are provided (i.e. when connected to an external circuit).

sample preparation

- **Spin-coat** PbI_2 dissolved in DMF (Dimethylformamide) and CH_3NH_3I dissolved in Isopropyl separately for 40 seconds at 4000 rpm to deposit solution uniformly.
- After stacking the two layers, heat 100 ^{0}C to get $CH_3NH_3PbI_3$ perovskite layer.

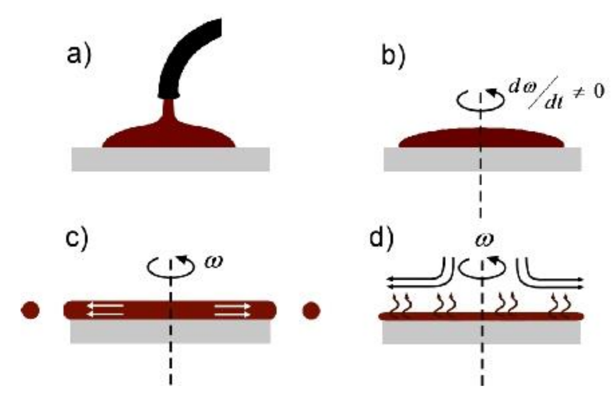
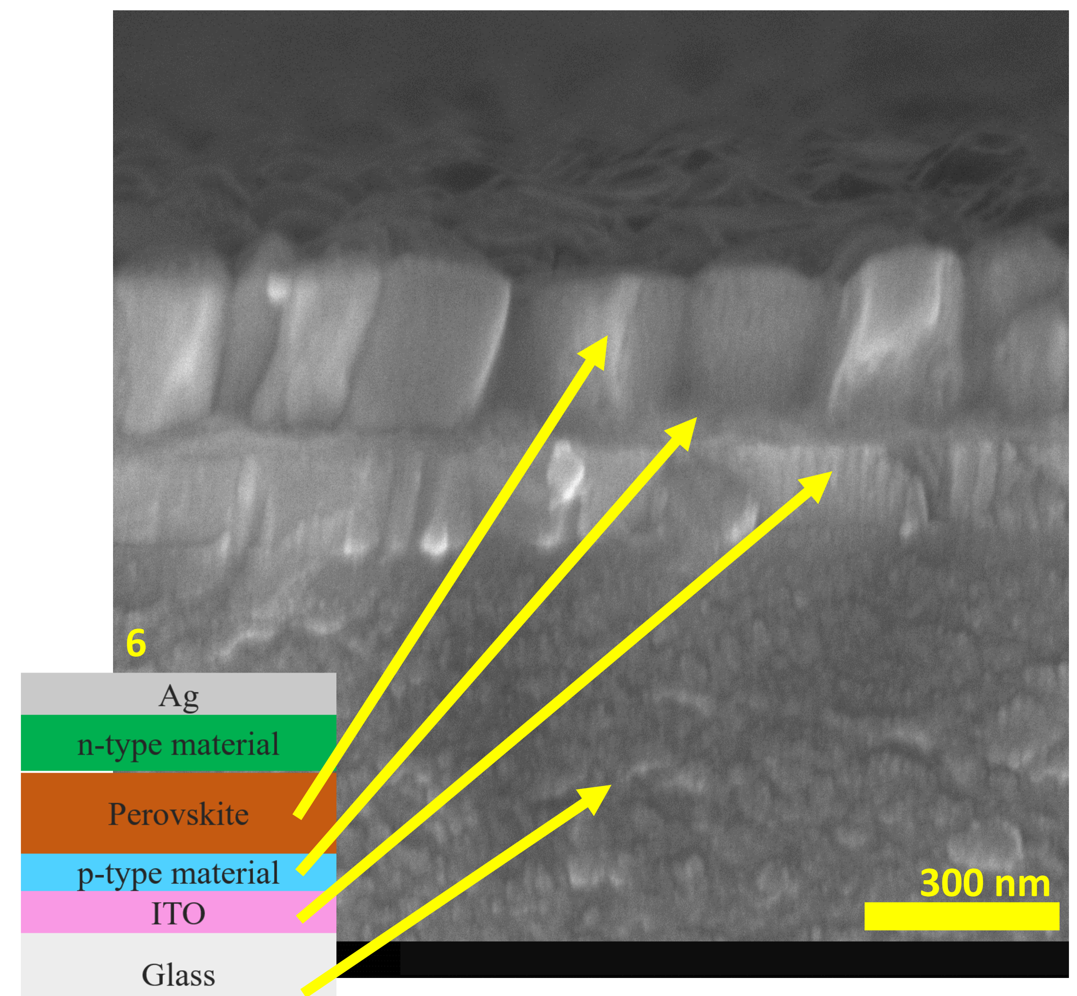


Fig. 3 Steps of spin coating. a) Dispensation. b) Acceleration. c) Flow dominated. d) Evaporation dominated.(source: S.L Hellstrom, Stanford University)



cross-sectional view

why perovskite cell?

- **Hybrid organic/inorganic semiconductor** materials (crystal) with general chemical formula ABX_3.

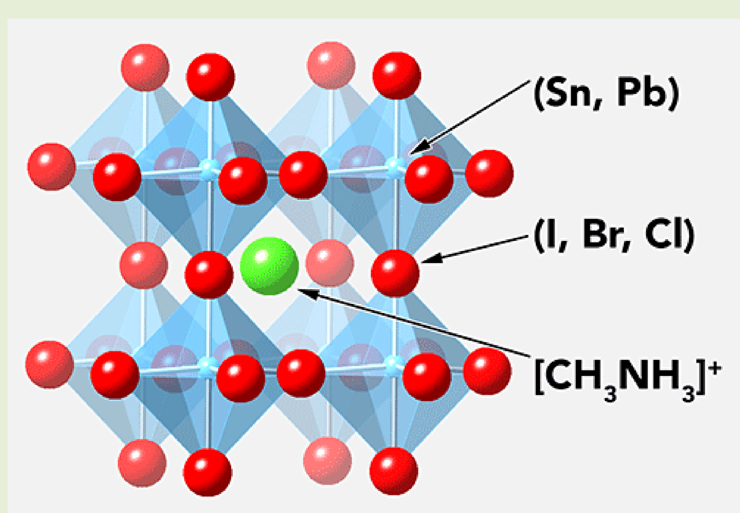


Fig. 1 A: organic cation, B: inorganic cation, and X: halogen atom (source: Zhaoyang Fan Group)

- Traditionally, **crystalline Silicon** material requires **complicated fabrication** process and **costly**.
- Silicon PV cell also suffers from slow-growing efficiency growth (~10-15% growth in 40 years) while perovskite **solar cell efficiency grew from 3.8% to 20.1%** between **2009 and 2015** [1,2]
- Perovskite solar cell has: high luminescence efficiency, excellent carrier transport, appropriate bandgaps, and apparent tolerant of defects [3,4,5]
- However, it is **moisture-sensitive** property and its **lifetime** as solar cells is **not well understood.**

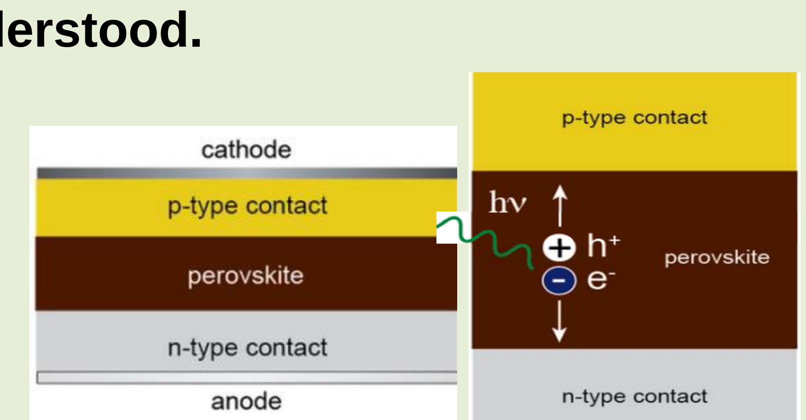
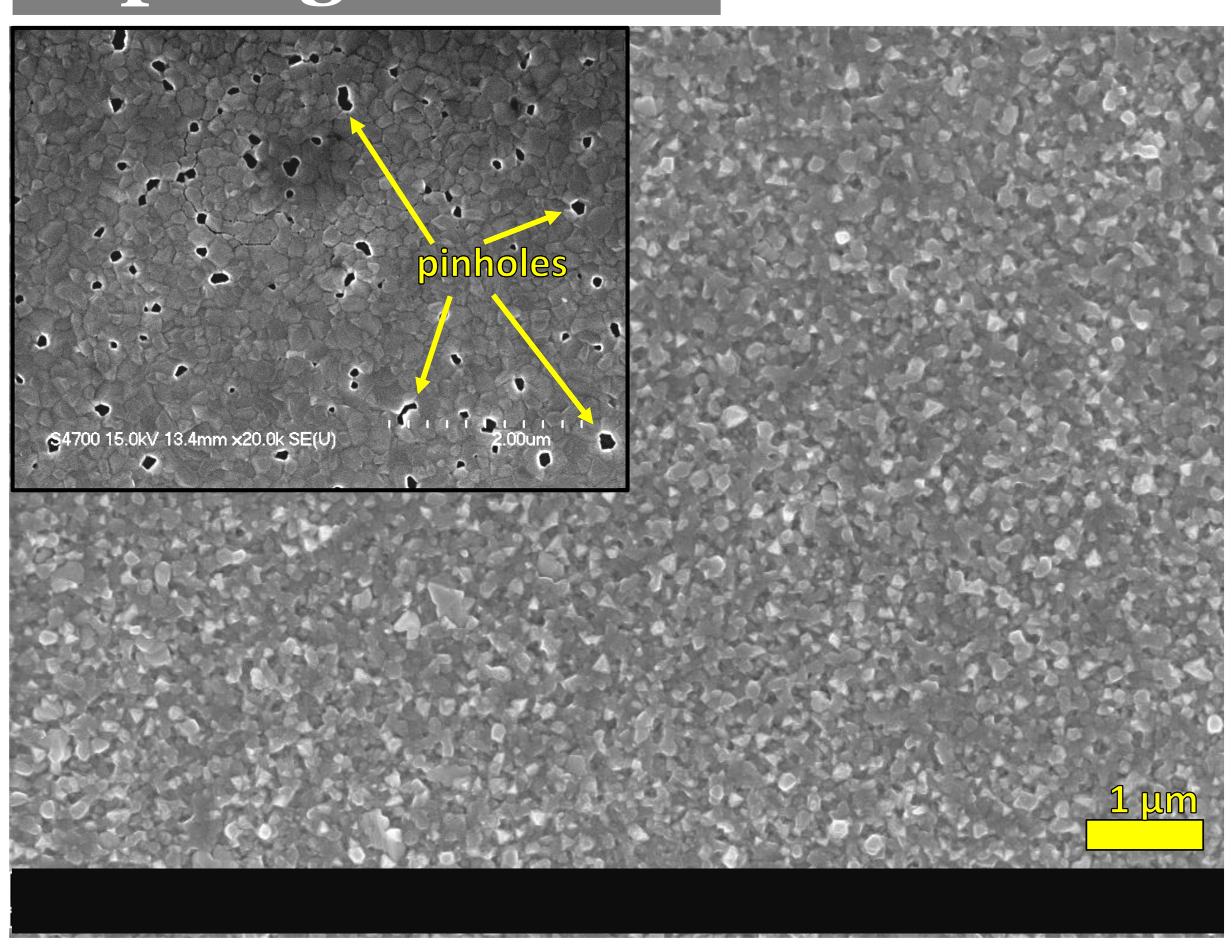
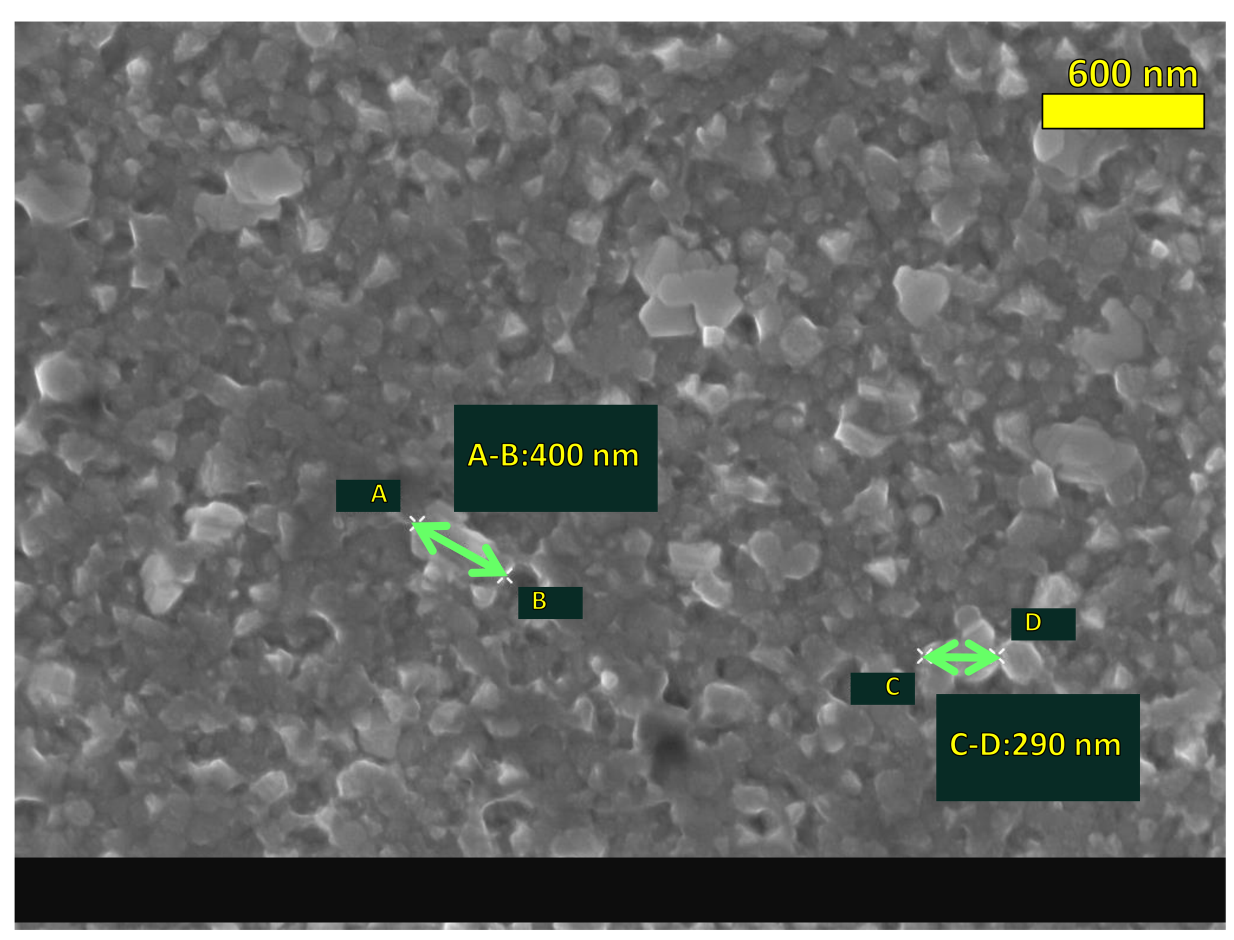


Fig. 2 (left) An illustration of perovskite PV cell, which consists of cathode and anode on different ends, perovskite layer, and semiconductor materials—p type and n type. (right) Movement of electron and "holes" when hit by photon with sufficient energy (source: wikicommon)

topological view





SEM techniques

- Ability to **produce 2D and 3D image** faster than other methods, such as AFM, and analyze different part of sample **without readjusting its physical position.**
- Topology Information:
  - **Surface Coverage**
  - **Grain Size** (200-450 nm)
- By surface coverage analysis, we can **detect pinholes**. Pinholes may create shorts that will prevent photovoltaic effect from taking place. **Higher surface coverage = less pinholes**
- Cross-section information:
  - **Film layer thickness**: in this case, the perovskite layer is 100-200 nm thick.
  - **Grain boundary research** [7, 8]

disadvantages

- Possible **sample damage** from **long exposure** of electron beams on to the sample
- **Non-conducting material must be coated** to avoid charge build-up, and reduce thermal damage. In this case, a 1 nm layer of Tungsten was used as a coating.
- While this does not apply to Perovskite, the vacuum environment inside the chamber **may not be suitable to certain samples, notably hydrated samples.**

conclusion

- Hybrid organic/inorganic perovskite PV cells can serve as an **alternate to the traditional Silicon PV cells.**
- **Scanning Electron Microscope** technique can be used to analyze both the topology and cross-section of the sample relatively quickly compared to other methods.
- The analysis can **detect pinholes** and contribute to **grain boundary effect research**. It can also determine whether any part of the layers is inadequate.
- Disadvantages include sample damage and the need for coating.

references

[1] A. Kojima, K. Teshima, Y. Shirai, and T. Miyasaka, *J. Am. Chem. Soc.* **131**, 6050–6051 (2009).

[2] S. *Collavini, S. F. Völker, and J. L. Delgado (2015). Angewandte Chemie International Edition* **54** *(34): 9757.*

[3] H. J. Snaith, *J. Phys. Chem. Lett* **4**, 3263 (2013)

[4] W. J. Yin, T. Shi, and Y. Yan, *Adv. Mater.* **26**, 4653 (2014)

[5] M. Z. Liu, M. B. Johnston, H. J. Snaith, *Nature* **501**, 395 (2013)

[6] Cross-sectional SEM image, credit to Chuanpeng Jiang

[7] J. S. Yun, A. H. Baillie, S. Huang, S. H. Woo, Y. Heo, J. Seidel, F. Huang, Y. B. Cheng, M. A. Green, *J. Phys. Chem. Lett* **6**(5), 875-880 (2015)

[8] J. J. Li, J. Y. Ma, Q. Q. Ge, J. S. Hu, D. Wang, L. J. Wan, *ACS Appl. Mater. Interfaces* **7**(51), 28518-28523 (2015)

ACKNOWLEDGEMENTS:
MSU Professor Zhang Group
P. Zhang, T. Golubev, C. Jiang, A. Tan
And Profs. C. Boehlert and P. Askeland

MICHIGAN STATE UNIVERSITY

Department of Physics and Astronomy

COLLEGE OF ENGINEERING