Fabrication and Characterization of Organic Semiconductors For Use in Photovoltaics

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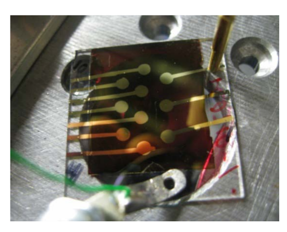
Introduction

Organic photovoltaics (OPVs) are under intense research for their ability to provide low-cost solar energy. OPV materials are unique in that film morphology and processing conditions drastically affect photon harvesting and charge transport. The current methodology to understand and optimize these parameters utilizes device-level testing to connect film processing conditions with OPV performance; however, a more fundamental understanding of the nanoscale processes that affect macroscale performance is necessary. In this work, dark and light I-V measurements on devices were combined with nanoscale characterization to evaluate how film morphology, charge transport, and solar conversion efficiency relate to processing.

Why Are Organic Semiconductors Important?

Silicon Solar Cell



Organic Solar Cell

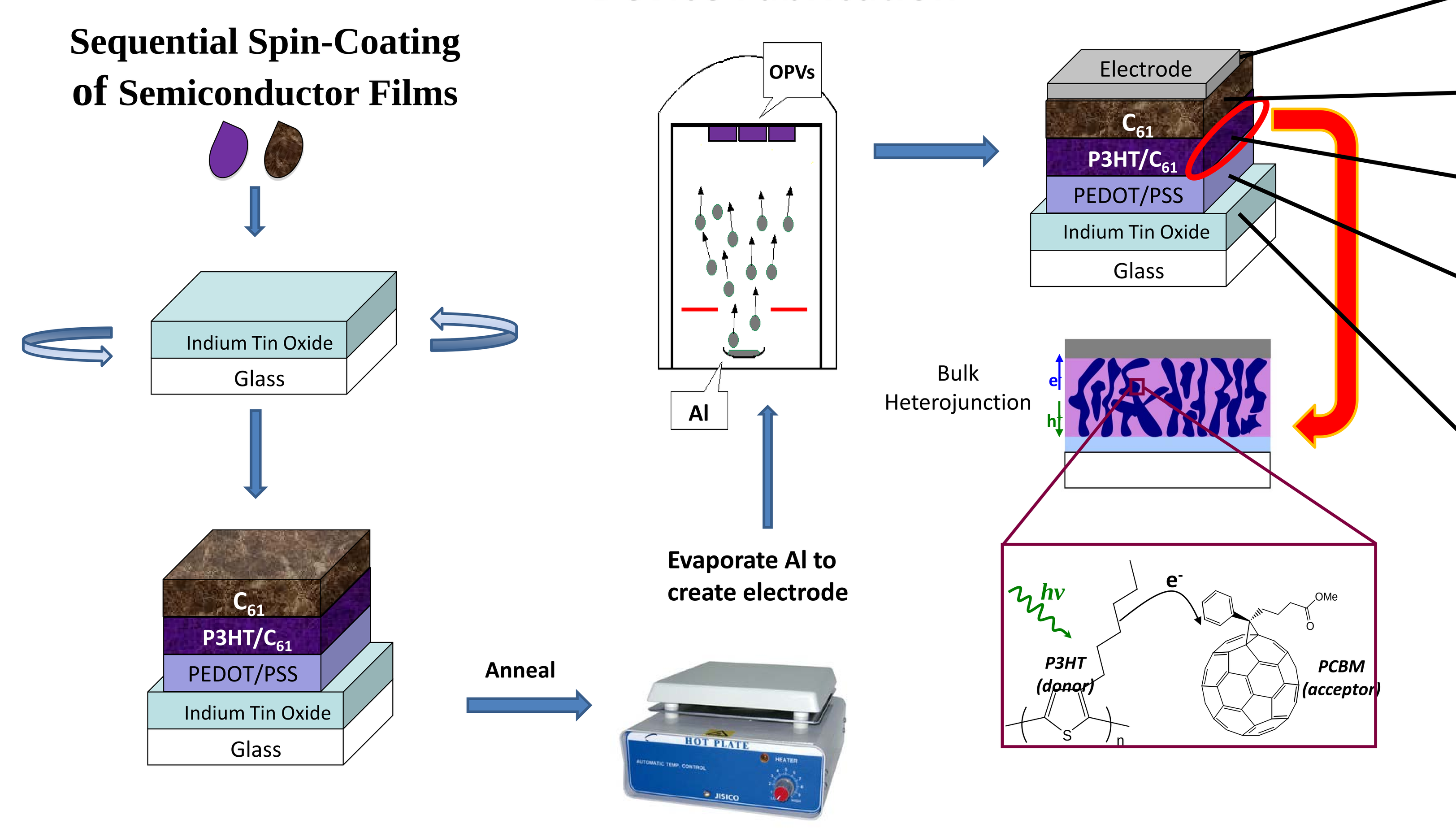
- Silicon needs to be purified to 99.9999% (no impurities/defects)
- Time and energy to produce Si is costly
- Payback time can take many years

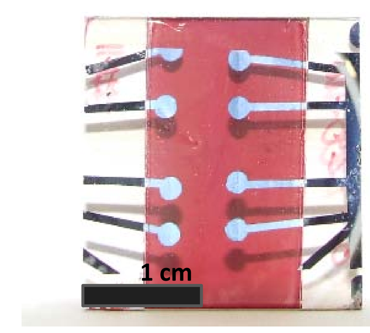
- Easy to mass produce…much cheaper
- Materials defects/impurities are tolerable
- Flexible substrates, large area solar cells

However, efficiencies are low… processing *really* affects film morphology

Understanding organic semiconductors at multiple length scales (device-level to nano) is a key to increasing efficiency

Device Fabrication

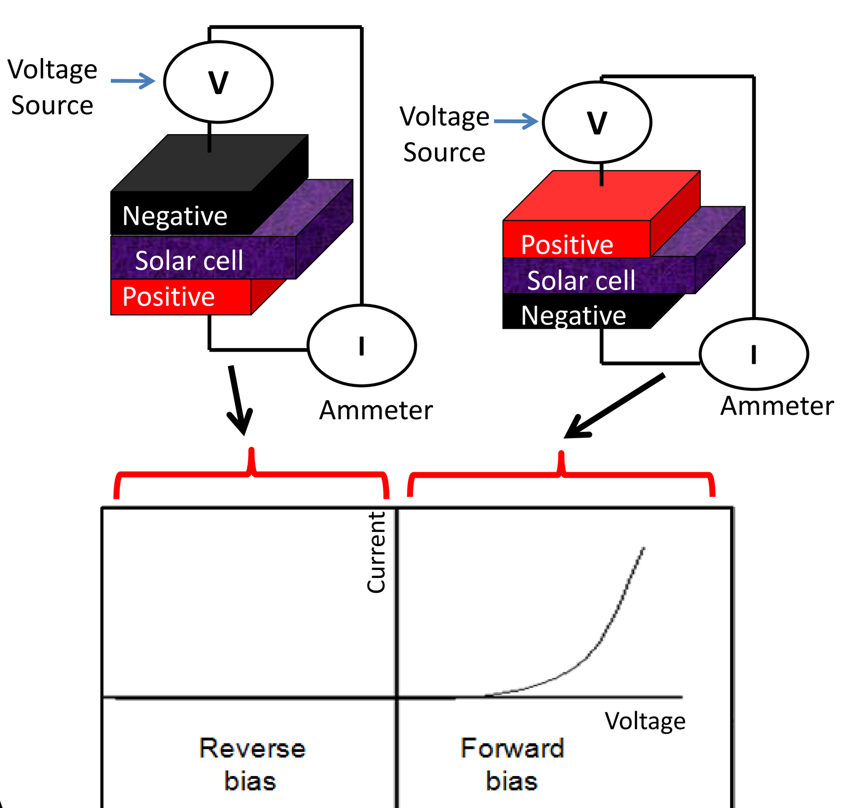




OPV device generated in lab.

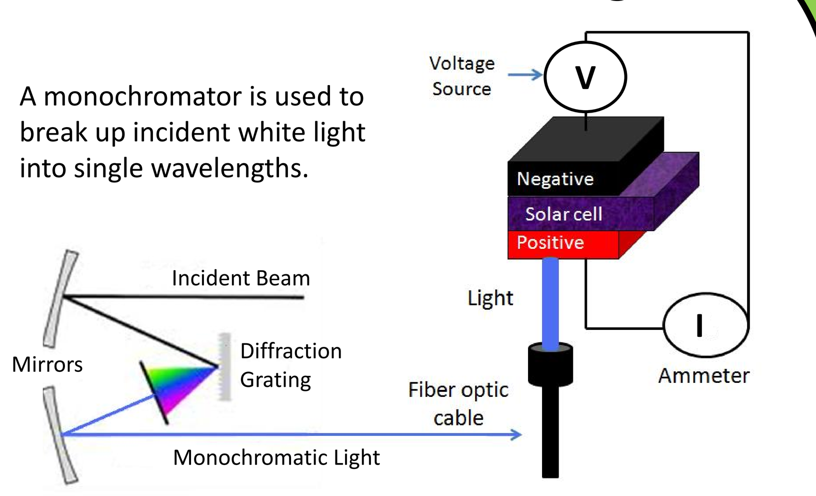
Dark Current Testing

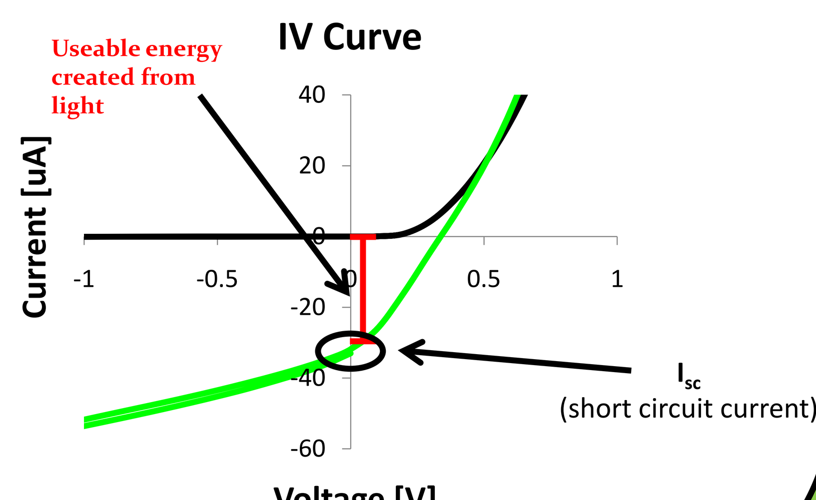
To test for proper OPV operation, a dark current test is done to check for diode-like behavior. If a diode curve is seen, the device is functioning properly and photocurrent testing can take place.



Photocurrent Testing

A monochromator is used to break up incident white light into single wavelengths.

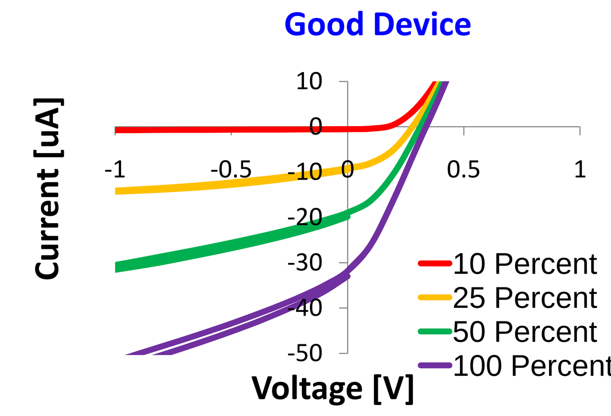


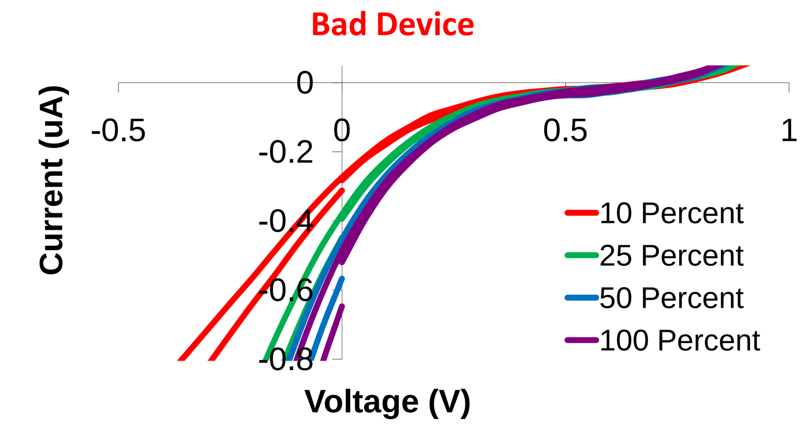


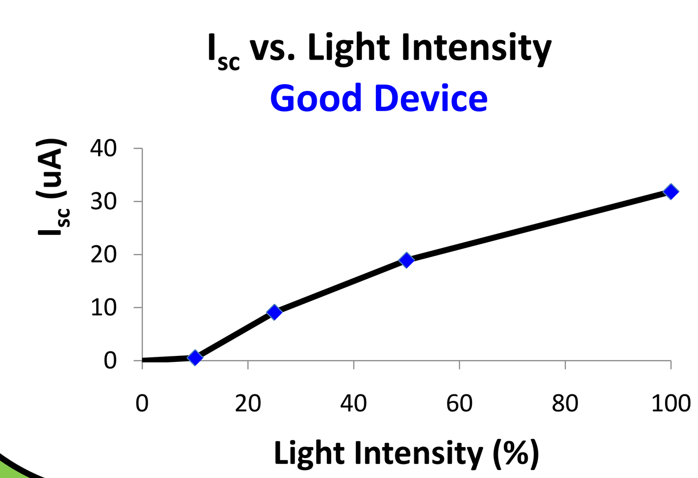
Good Performance vs. Bad Performance

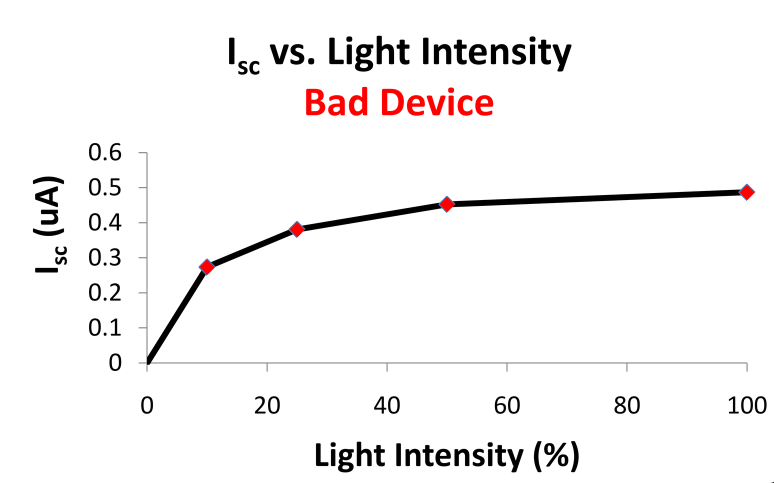
IV curves for two devices with the same stack structure are depicted below. In the good device, exposure to oxygen and light were minimized, while the bad device was exposed to ambient conditions for extended periods. Large changes in OPV performance were seen:

1. Short circuit current, I_{sc}, was greatly reduced with exposure to oxygen and light
2. In an oxygen controlled environment, I_{sc} has a linear relationship with light intensity







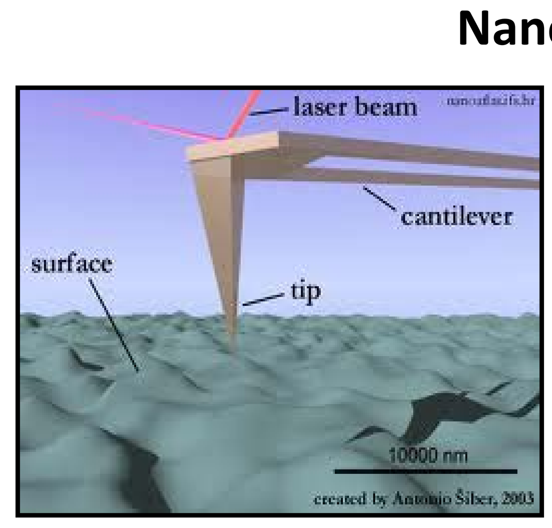


Conclusions from macroscopic studies:

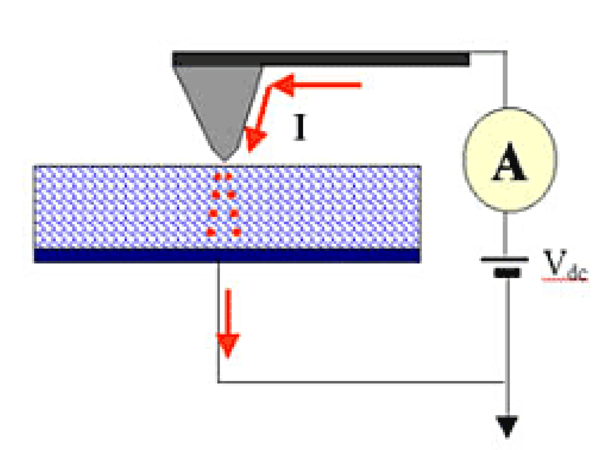
- Polymer dissolution was critical in spinning high quality films
- Slowing down solvent evaporation during and after spin coating fosters polymer chain organization, increasing charge transport
- A BHJ (Bulk Heterojunction) bi-layer device composed of P3HT/PCBM with a PCBM overlayer gave the best performance
- Oxidative damage to the conjugated polymer inhibited charge transport

In order to understand **HOW** to make a better device we need to know more on the nanoscale...

Nanoscale Testing

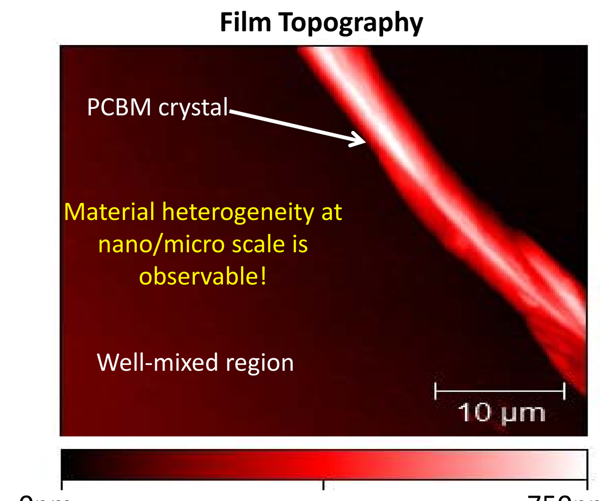


Topographical analysis with the Atomic Force Microscope (AFM) reveals PCBM crystal formation in the sample. How does this affect current flow?

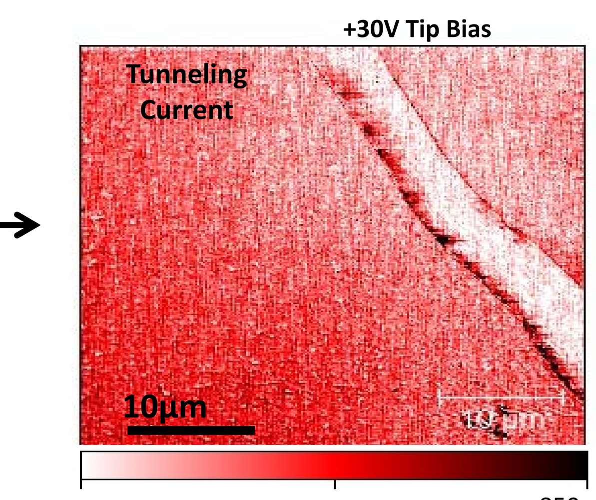


Tunneling AFM (TUNA) allows a point-by-point current test. This allows nanoscale observation of how crystal formation in the film may help or hinder current flow.

Film Topography



+30V Tip Bias



Conclusion

Testing at the nanoscale reveals information about film morphology that drastically affects how OPV devices perform. It is crucial to further understand processes occurring at the nanoscale. Future research involves nanoscale investigations of tunneling current, film morphology, and chemistry to learn how nanoscale film variations cause differences in macroscale performance. By identifying and understanding the nanoscale processes that affect macroscale performance, better OPV devices can be engineered.

Acknowledgements

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