Thin Film Fabrication and Morphology Studies

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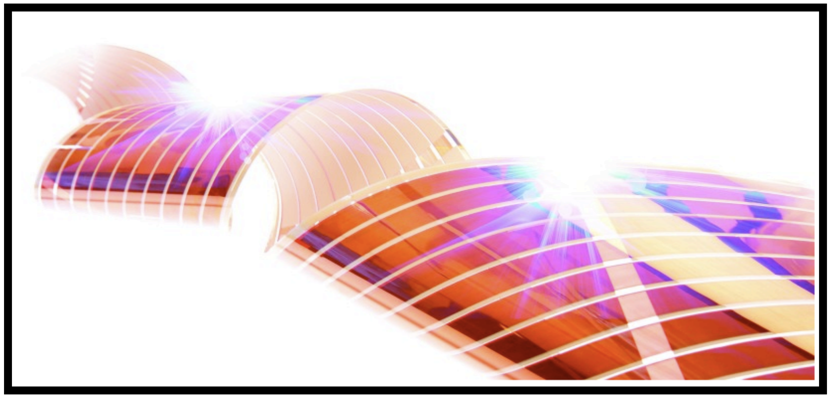
MATERIALS RESEARCH LABORATORY
the innovation engine for new materials
UC Santa Barbara

CALIFORNIA NANOSYSTEMS INSTITUTE

National Science Foundation
WHERE DISCOVERIES BEGIN

Introduction

- Organic photovoltaics (OPVs) aim to provide simple and efficient sources of clean energy
- OPVs have a maximum efficiency of ~5%
- Multiple methods of thin film fabrication



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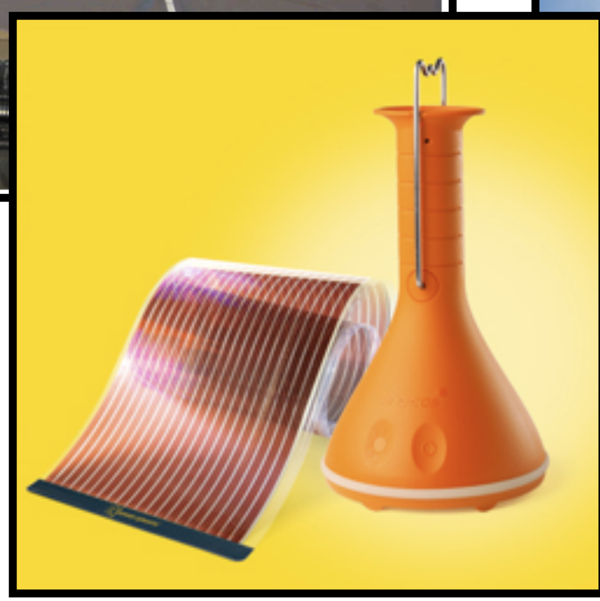
Introduction

World Record: 8.3% Efficiency
(Roll-to-Roll Printing Method)



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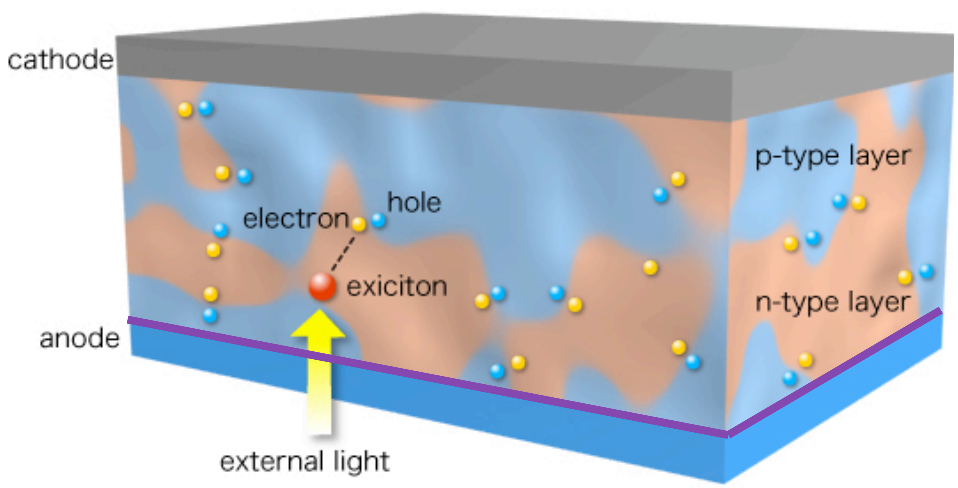
Introduction

P3HT:PCBM Photovoltaic



Aluminum Electrode

P3HT:PCBM
Active Layer ← Fabrication techniques determine morphology and cell efficiency

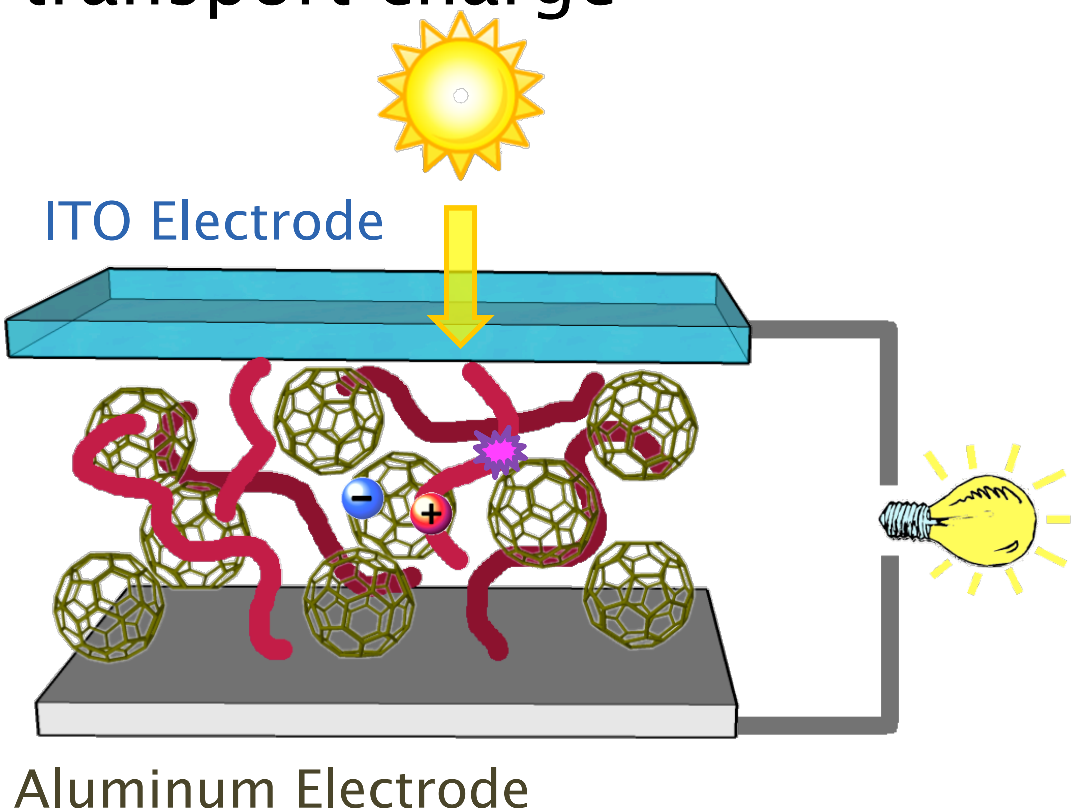
PEDOT:PSS

ITO Substrate

Courtesy of A. Muñoz

Introduction

OPVs use a electron-hole (exciton) system to transport charge

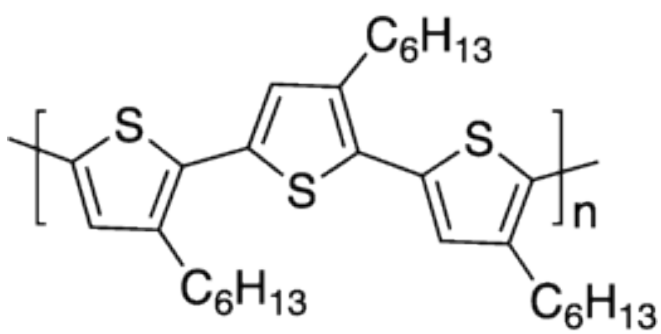


1) Light Absorption
2) Exciton Diffusion
3) Charge Separation
4) Charge Transport
5) Clean Energy

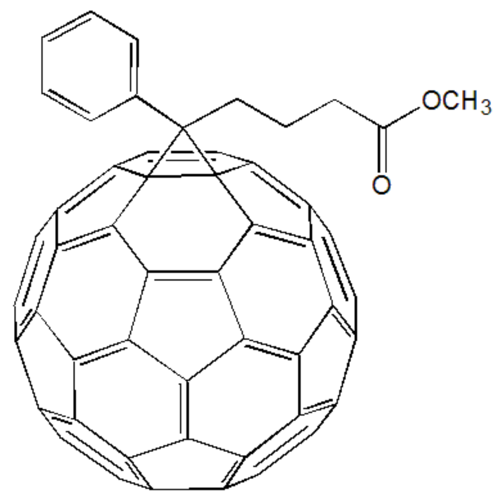
Courtesy of A. Ostrowski and B. Walker

Materials

- **P3HT:** Electron Donor
  Poly(3-hexylthiophene)
  p-type semiconductor

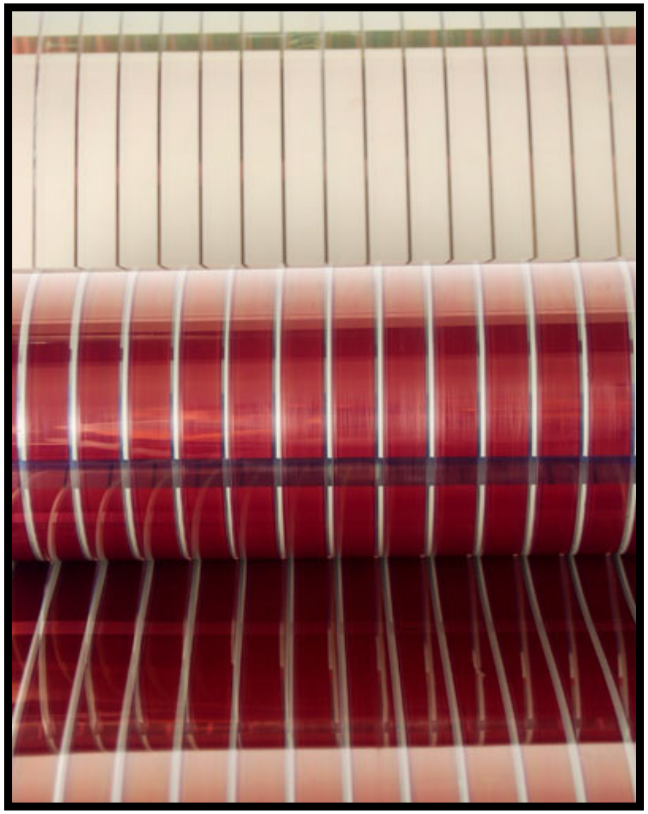


- **PCBM:** Electron Acceptor
  [6,6]-phenyl C_{61} butyric acid methyl ester
  n-type semiconductor



General Research Focus

- How can OPV technology be improved?
- How can fabrication techniques be improved without losing efficiency?



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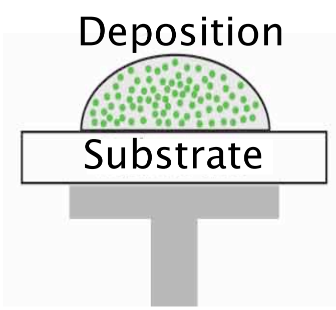
RET I Focus

- **Parameter Relationships:** How are blade coating parameters related?
- **Film Morphology:** How does morphology change for different blade coating parameters?
- **Crystallinity:** How can P3HT:PCBM crystallinity be controlled and enhance charge mobility?

Thin Film Fabrication Methods

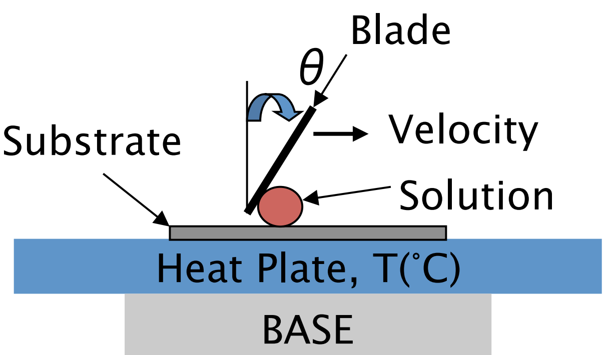
Spin Coating: Spreads film across substrate while controlling rpm and time

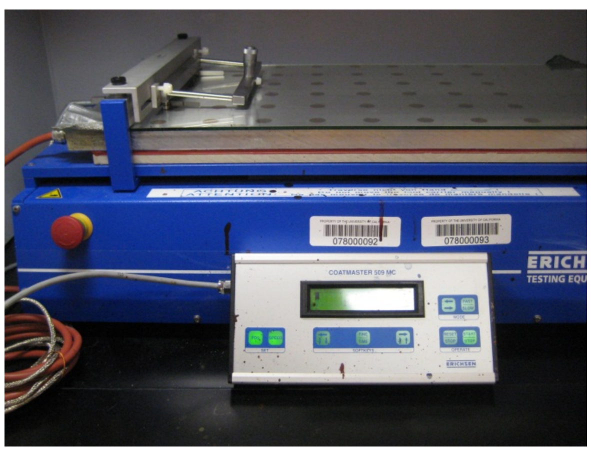


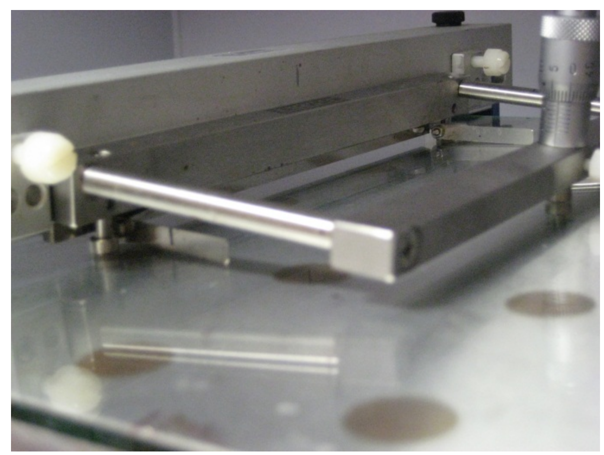
Courtesy of A. Muñoz

Thin Film Fabrication Methods

Blade Coating: Spreads film across substrate while controlling temperature, speed and blade height



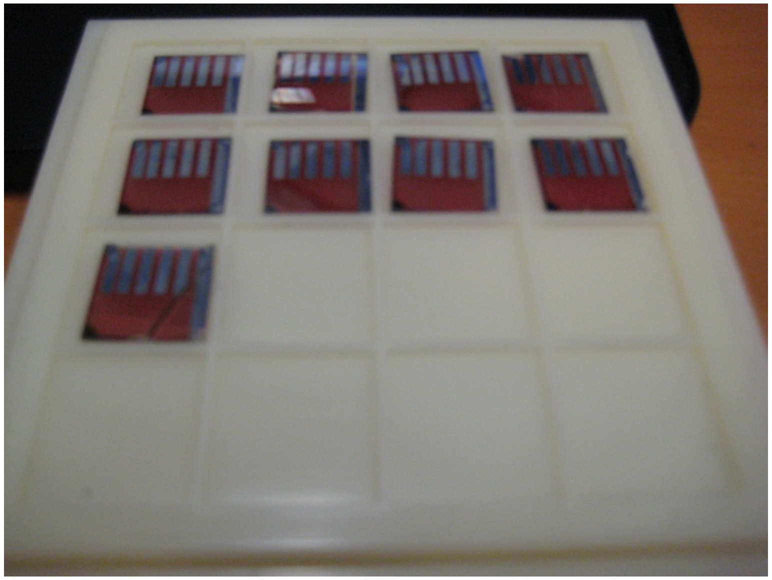




Courtesy of A. Muñoz

Thin Film Fabrication Methods

P3HT:PCBM Photovoltaics



Spin Coated OPV

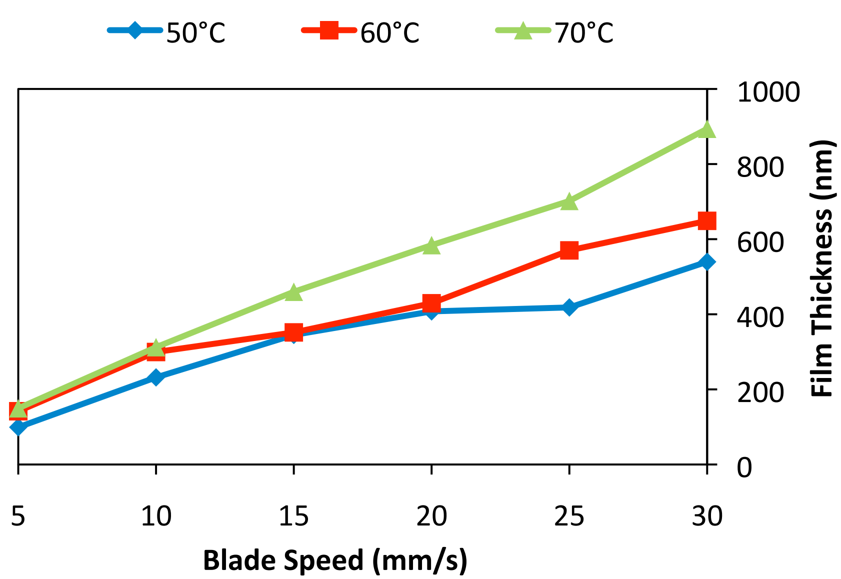
Blade Coated OPV

Thin Film Fabrication Methods

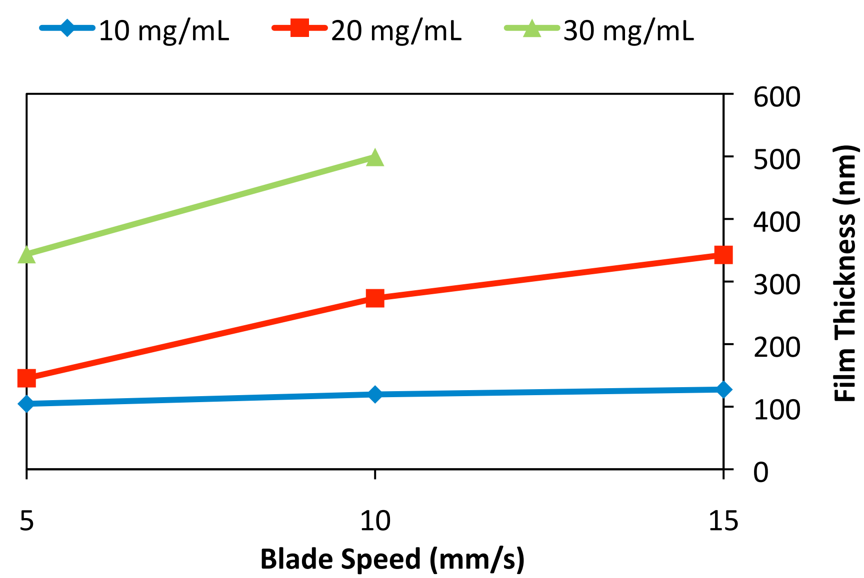
	Spin Coated	Blade Coated
Parameters	• Time • RPM	• Blade speed and height • Substrate temperature
Efficiency		
Pros		
Cons		

PS:tol Study

Thickness Measurements
20 mg/mL PS:tol



Thickness Measurements
10-30 mg/mL PS:tol



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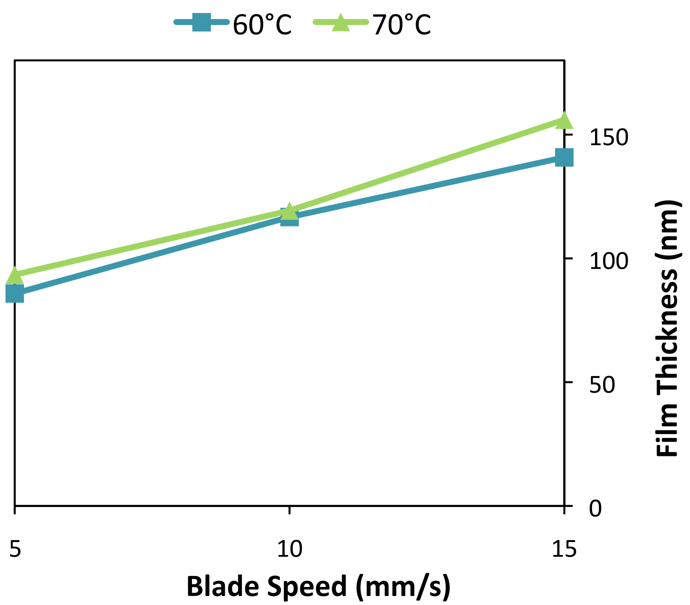
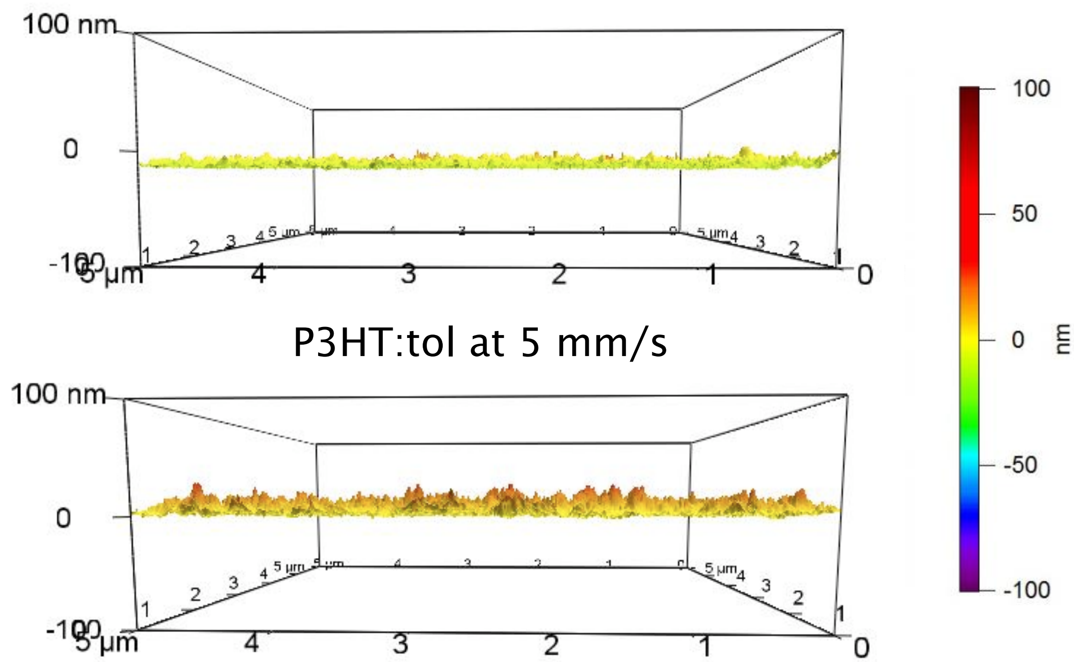
5 mg/mL P3HT:tol Study

Thickness Measurements



AFM Roughness Measurements

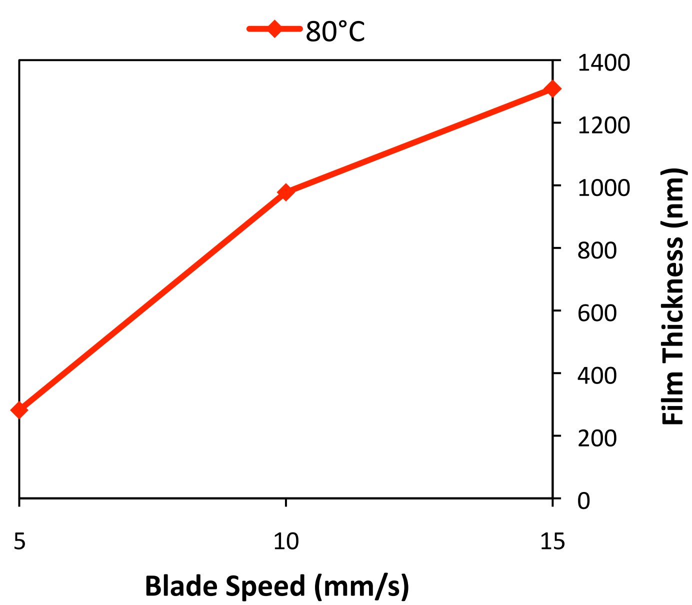


P3HT:tol at 5 mm/s

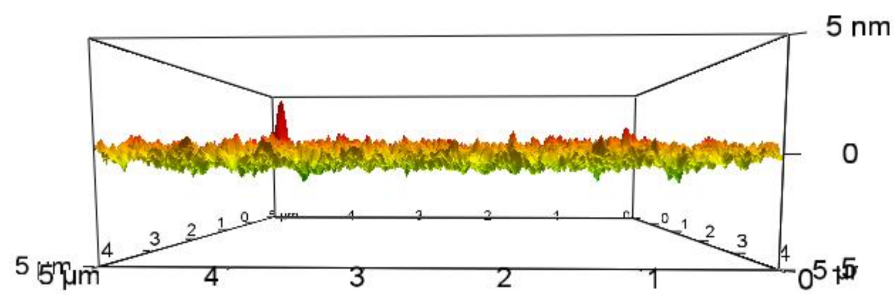
P3HT:tol at 10 mm/s

30 mg/mL P3HT:CB Study

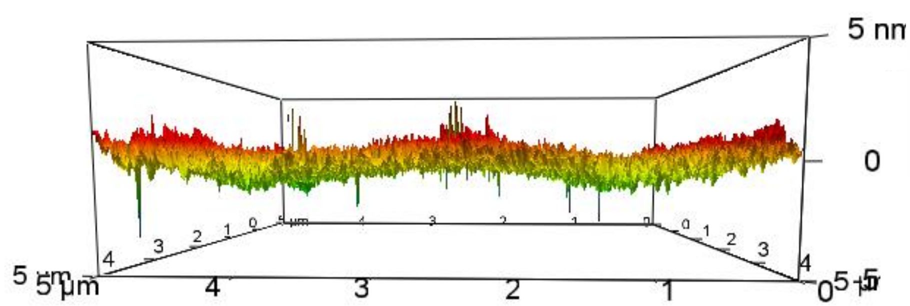
Thickness Measurements

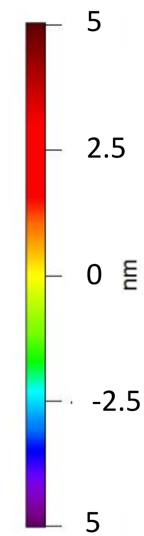


AFM Roughness Measurements



P3HT:CB at 5 mm/s
Annealed at 150°C for 20 min

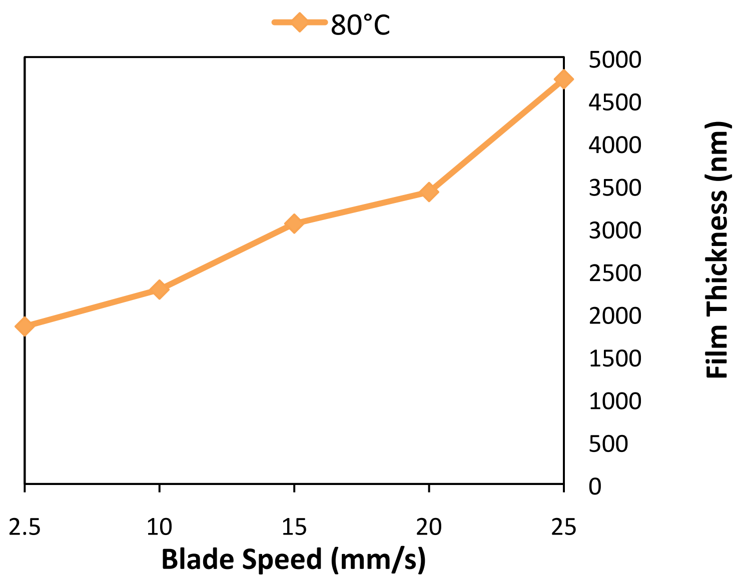




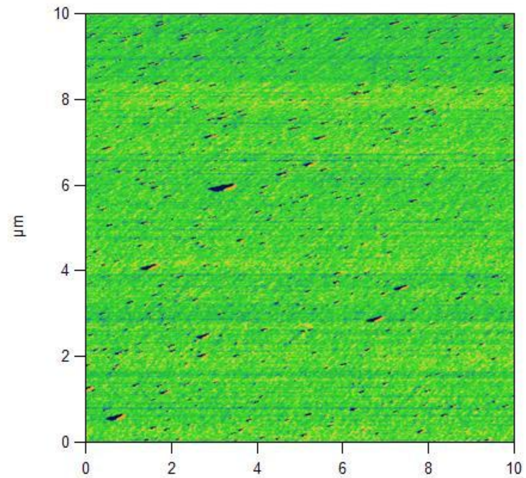
P3HT:CB at 15 mm/s
Annealed at 150°C for 20 min

90 mg/mL P3HT:CB Study

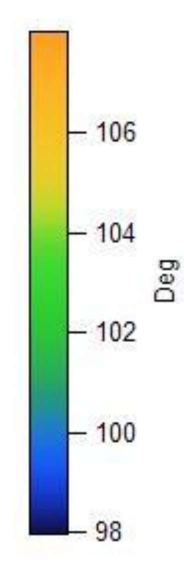
Thickness Measurements

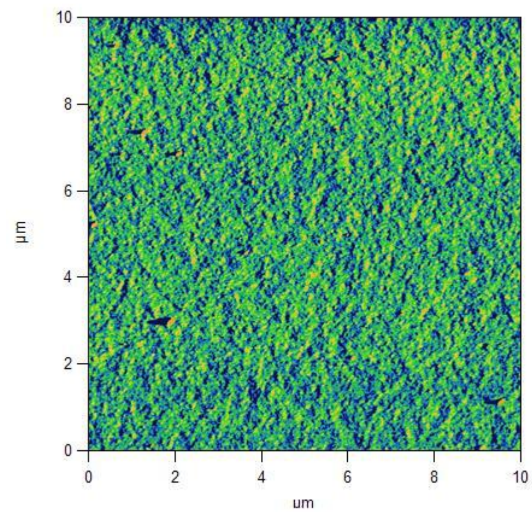


AFM Phase Comparison



P3HT:CB at 25 mm/s



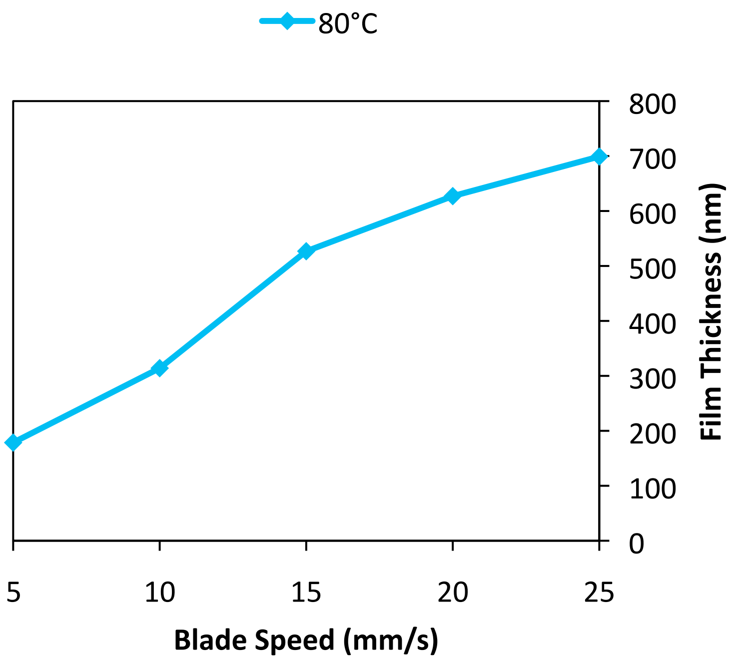


P3HT:CB at 25 mm/s

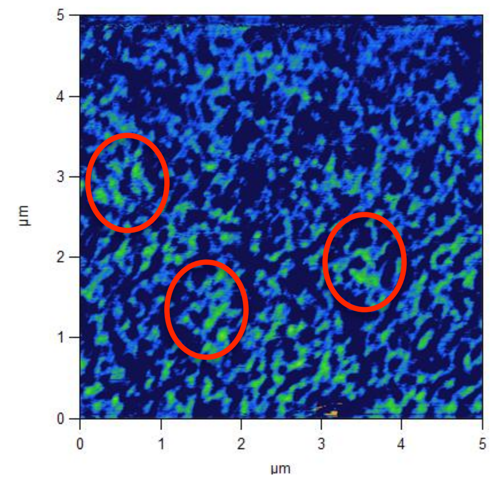
Melted at 250°C and cooled

30 mg/mL P3HT:PCBM Study

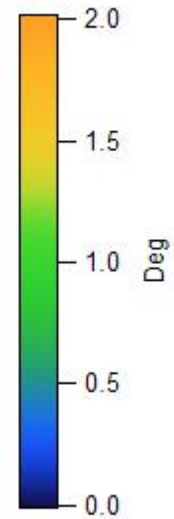
Thickness Measurements

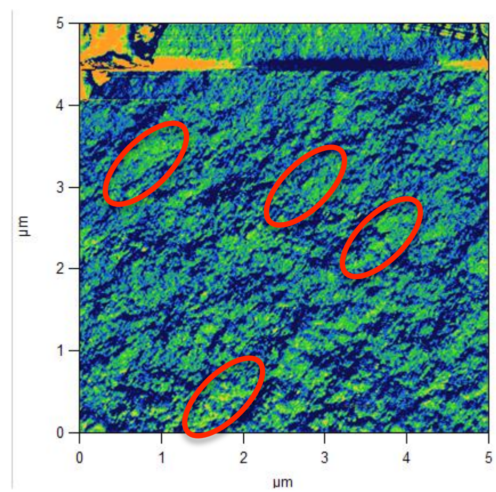


AFM Phase Comparison



P3HT:PCBM at 5 mm/s





P3HT:PCBM at 5 mm/s

Melted at 250°C and quenched

Conclusion

- **Parameter Relationships:** Film thickness is directly proportional to substrate temperature, blade speed and solution concentration increase
- **Film Morphology:** Concentration dependent; slower blade speeds decrease roughness; annealing continues to decreases film roughness
- **Crystallinity:** Blade coating forms clustered P3HT pockets; melting and rapid quenching produces longer, more evenly distributed fibrils throughout P3HT:PCBM bilayer

Next Steps

Acknowledgments

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