Organic Copolymer Semiconductor for Direct Detection of Ionizing Radiation

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2023 LANNS Symposium-2

LANNS

LABORATORY FOR ADVANCED NUCLEAR NONPROLIFERATION AND SAFETY

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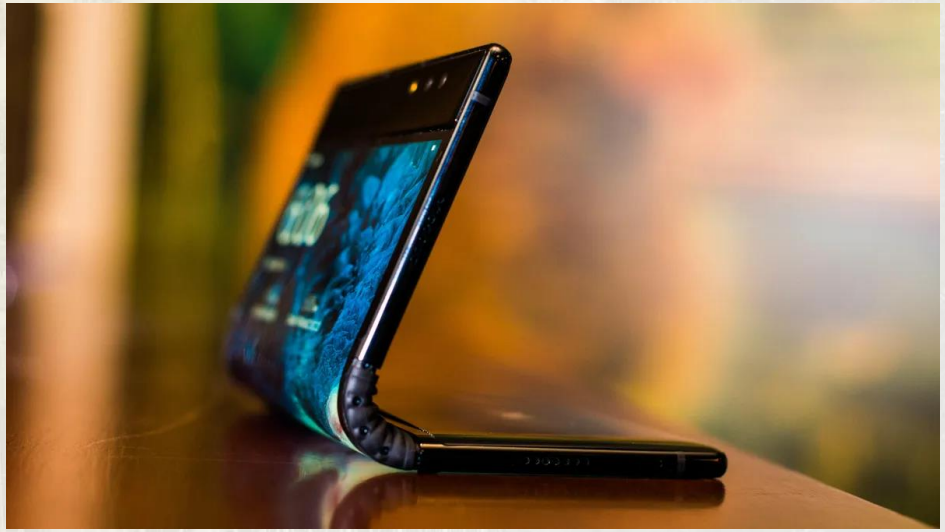
Background

What are organic based semiconductors?

- Carbon and Hydrogen based materials

Current uses

- Organic LED (OLED)
- Organic based Solar Cells (OSC)
- Organic Transistors (OFET)



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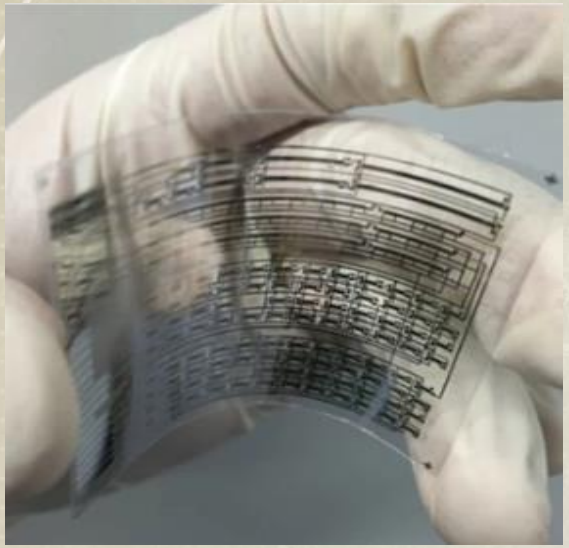

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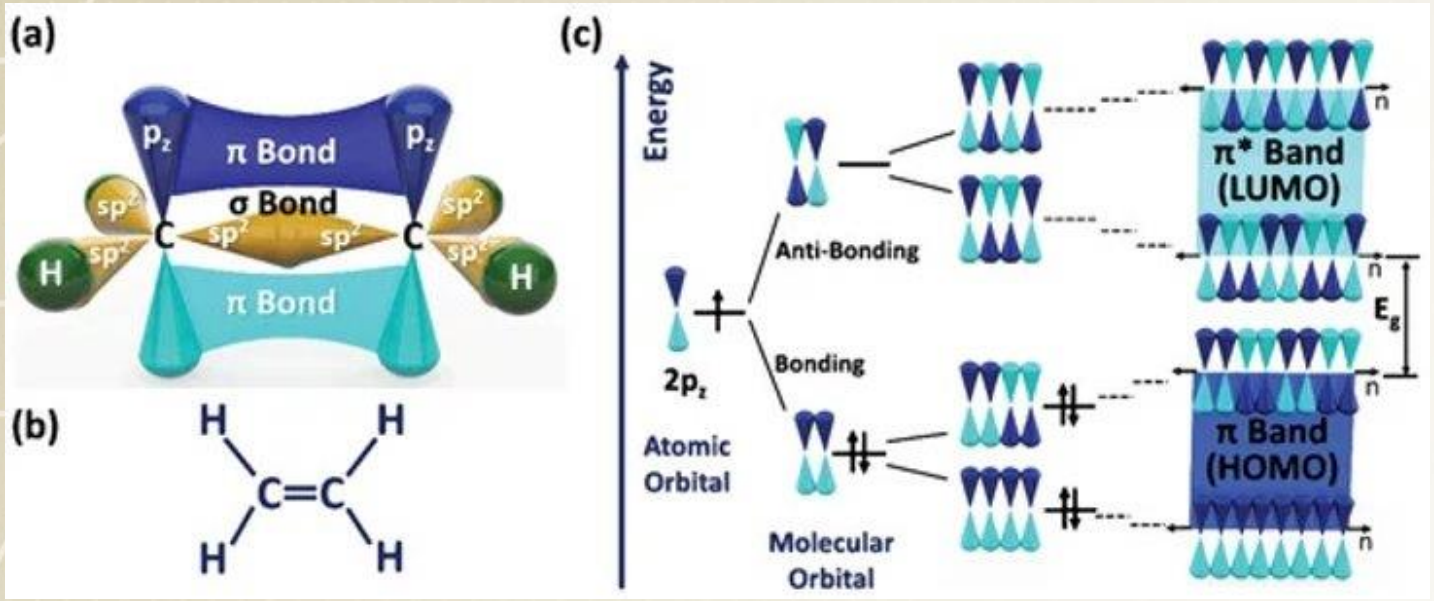
Background



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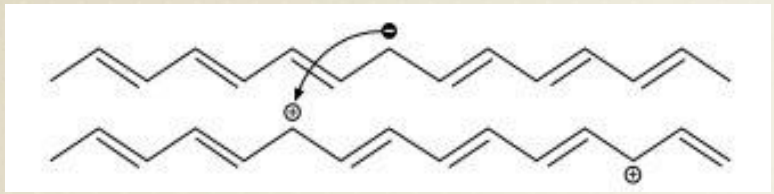
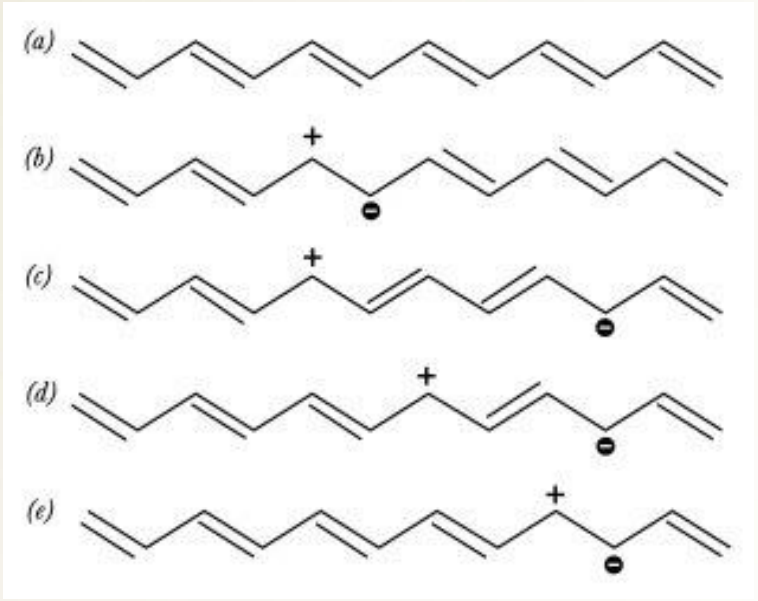


Heeger Alan, et al



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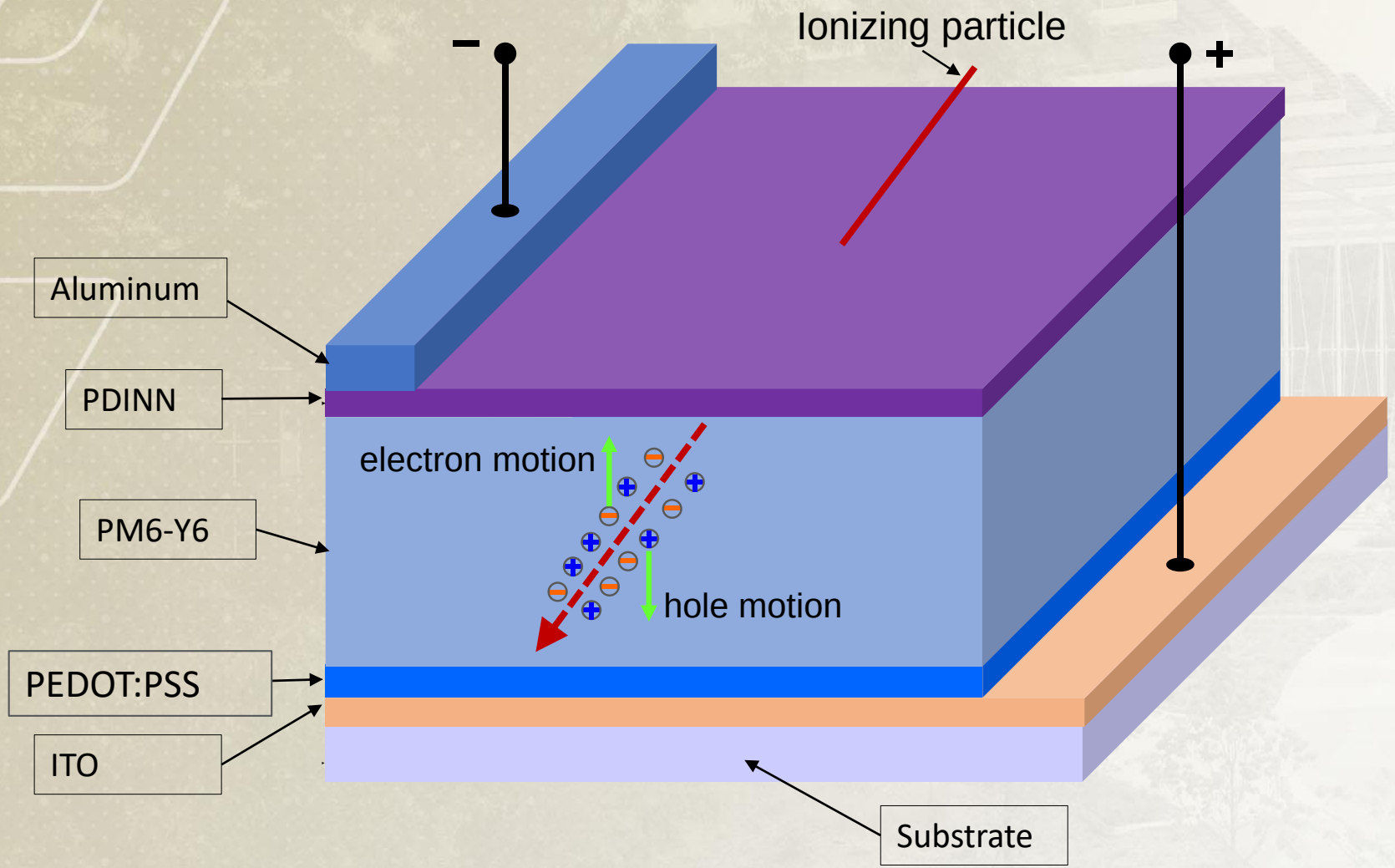
HOMO

- Highest Occupied Molecular Orbit

LUMO

- Lowest Unoccupied Molecular Orbit

Current Research



Depiction by Yuguo Tao

- Glass Substrate
- Two electrode films (Al and ITO)
- Interaction Volume (PM6-Y6 or Y7)
  - Copolymer Film
  - Bulk Heterojunction

- Buffer Layers
  - Hole Transport Layer (HTL)
    - PDOT:PSS or ZnO
  - Electron Transport Layer (ETL)
    - PDINN or MoO_3

Procedure

Substrate Preparation (Wet Bench Required)

Cleaning of Glass or Silicon Slides

- Hydrofluoric Acid
- Piranha Solution
- IPA
- Water

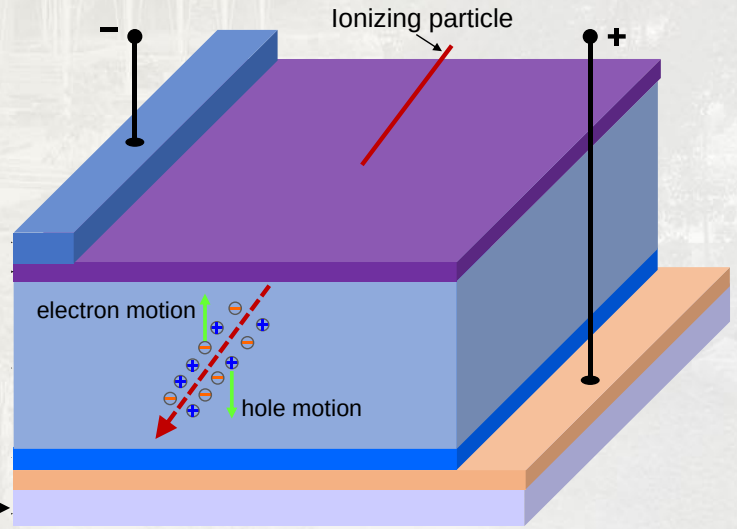
Manufacturer Recommendations

- Sonicate 20 minutes in Acetone
- Dry off
- Sonicate 20 minutes in IPA
- UV Ozone Treatment
- Vacuum Oven

Substrate Preparation

Cleaning of ITO Glass Slides

- Acetone
- Ethanol
- IPA
- Water



Depiction by Yuguo Tao

Procedure

Development of PM6-Y6

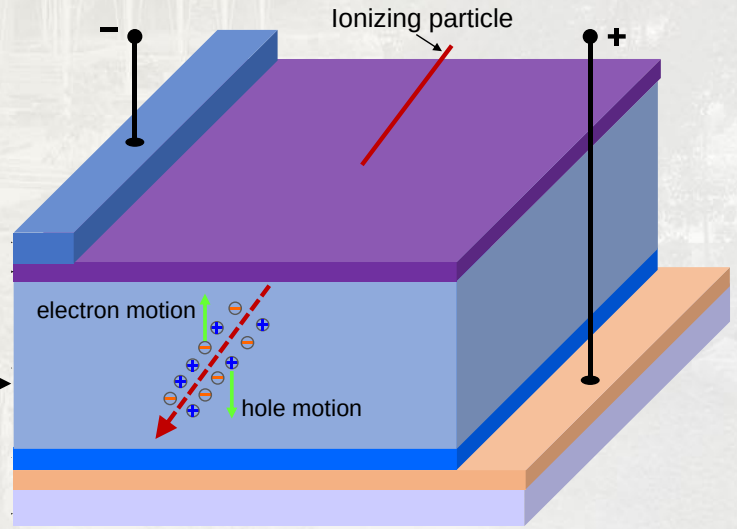
- Polymer Blend of 1:1.2
- Dissolved in Chlorobenzene at 10 mg/mL
- Mixed for at least 3 hours before deposition

Deposition of PM6-Y6

- Spin Coat on top of PEDOT:PSS
  - 15-50 micro-liters
  - Dynamically
  - 100-4000 RPM
  - Annealing at 90 Degrees Celsius

Variation of Thickness & Method of Deposition

- Methods
  - Spin Coater
  - Drip Coating
- Thickness Variation
  - 1-10 um



Depiction by Yuguo Tao

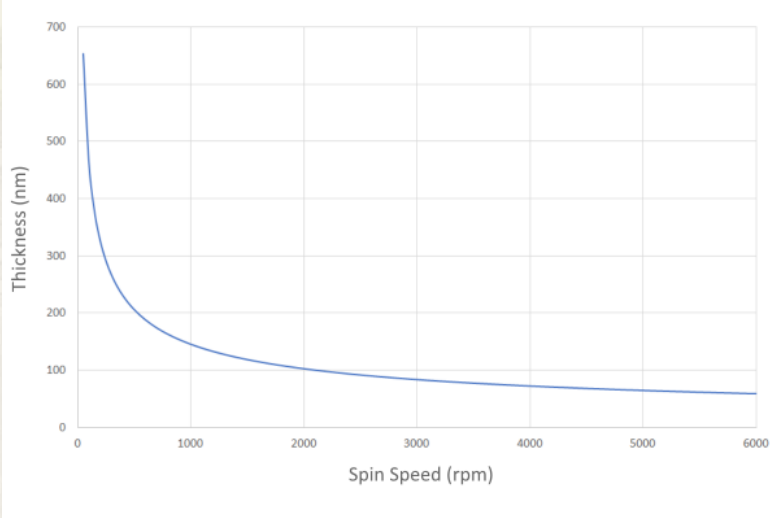
Procedure

Development of PEDOT:PSS

- Filtration with Nylon Filter

Deposition of PEDOT:PSS Layer (HTL)

- Spin Coater
  - Target Thickness 70 nm (Friedel)
    - RPM 4000 for 30 sec.
    - Annealing Temperature 200 °C



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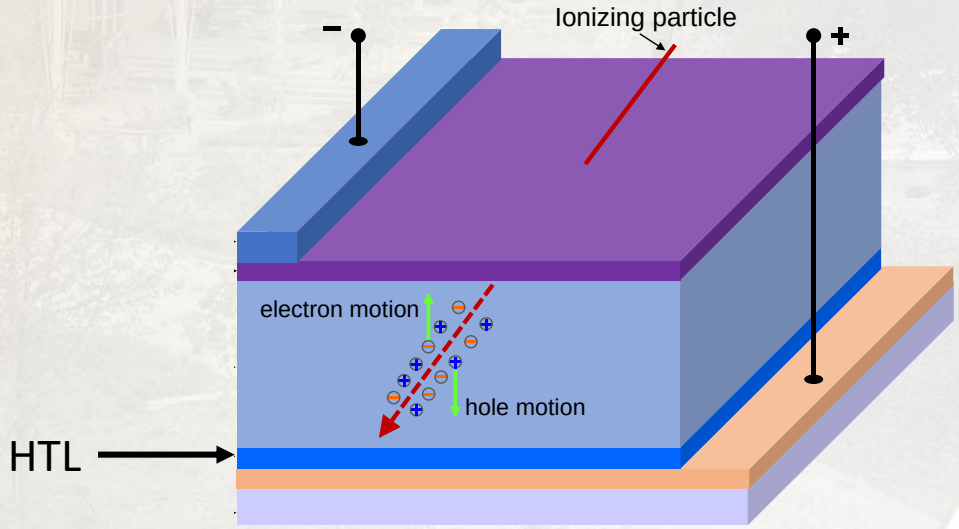


Depiction by Yuguo Tao

Procedure

Preparation of PDINN (ETL)

- Dispersion into Methanol
  - 1 mg/mL

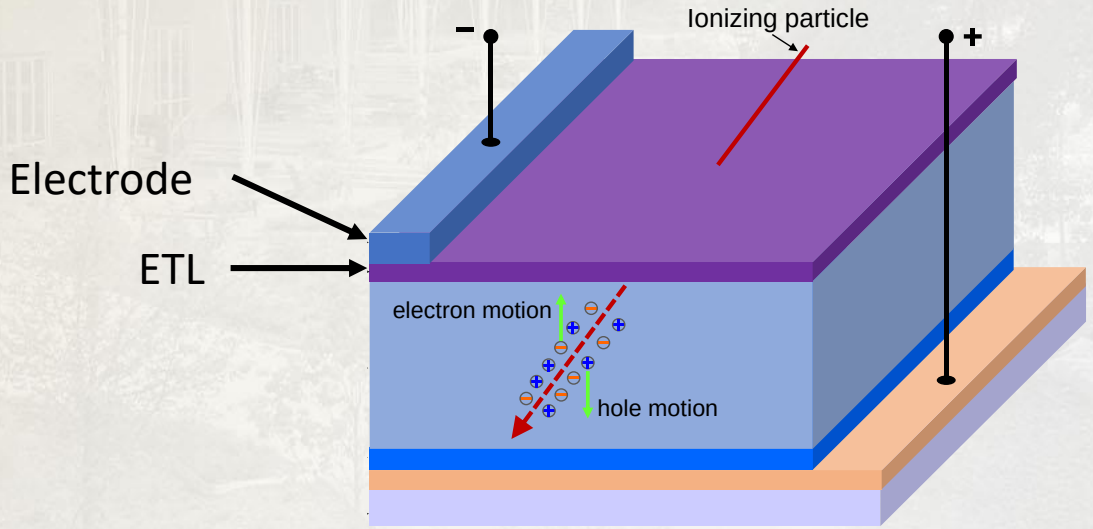
Deposition of PDINN

- Spin Coat
  - 3000 RPM for 30 seconds
  - Target Thickness 5-10 nm

Deposition of Ag (Silver) or Al (Aluminum)

- Thermal Evaporation
  - Ag Target Thickness of 100 nm
  - Al Target Thickness of 90 nm

Glove Box from TE



Depiction by Yuguo Tao

Testing

Verification of Performance
- Fill Factor (FF)
- Efficiency (n)

$$FF = \frac{J_{\max} V_{\max}}{J_{\mathrm{SC}} V_{\mathrm{OC}}}$$

Marder, S. R.

Radiation Testing
- Current vs Voltage (Real Time)
  - Electron Beam
  - Proton Beam
  - X-ray Beam

$$\eta = FF \frac{J_{\mathrm{SC}} V_{\mathrm{OC}}}{P_{\mathrm{in}}}$$

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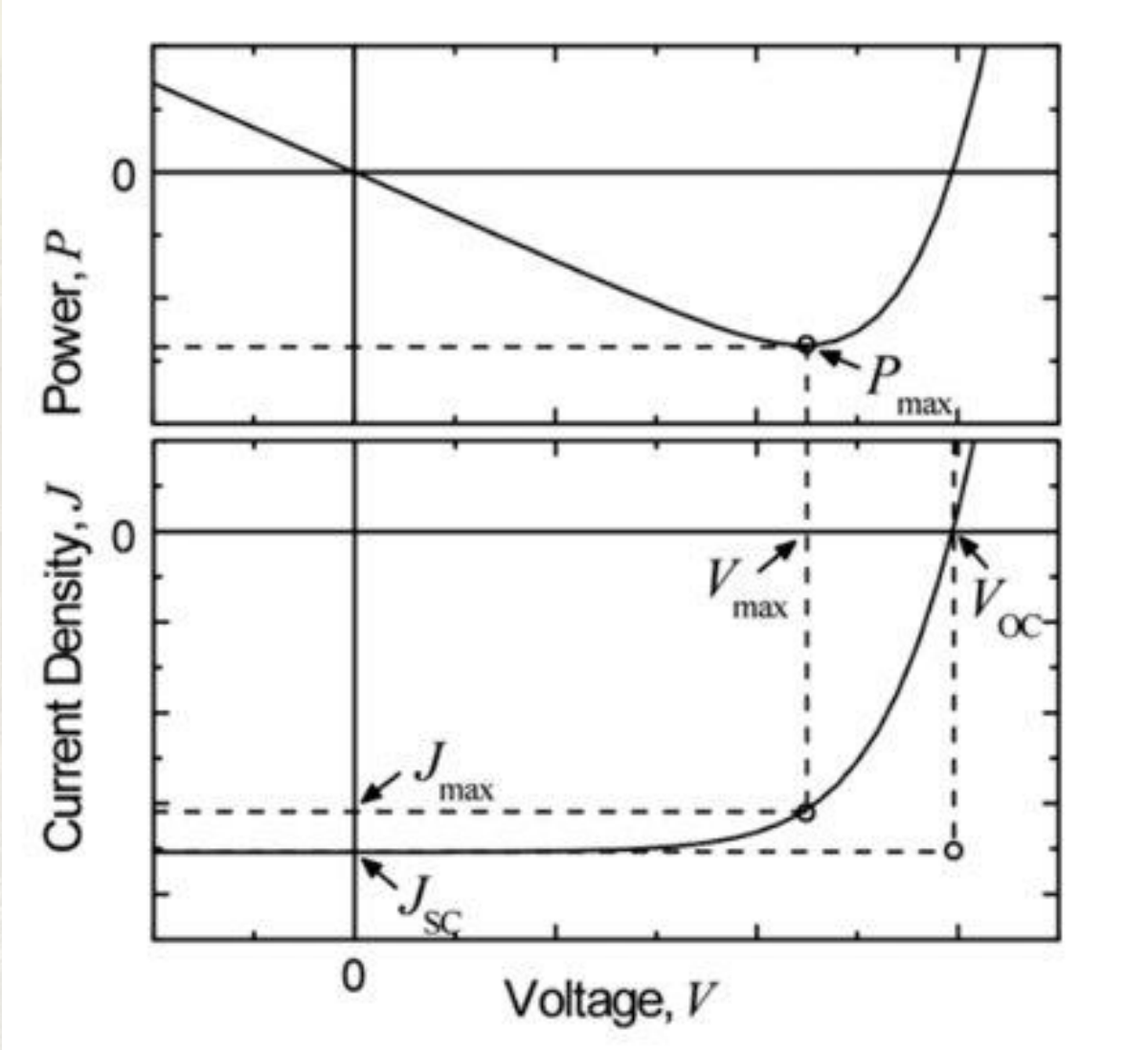
Radiation Degradation Testing
- Fill Factor and Efficiency before and after radiation exposure



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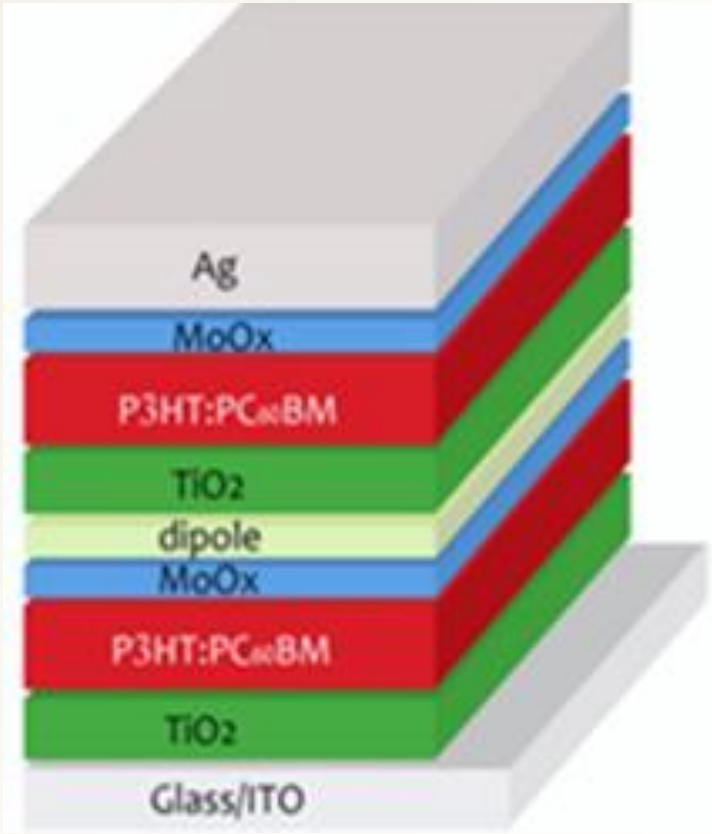
Future Research

- Fabrication Optimization
  - Annealing Temperatures
  - Plasma Treatment
  - BHJ deposition
- Improvement of BHJ
  - Tertiary Polymer Film
  - Changes in Donor and Acceptor Polymer
- Flexible substrates
  - Improved Geometric Efficiencies
- Multi-Layered OPV
  - Larger Detection Volume



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