Konarka Technologies, Inc.

DOE SAI Peer Review

April 17, 2007

Outline

- Introduction
- Technology Overview
- SAI Program
- Summary

High Performance Photovoltaics

A family of coatable, printable photoactive materials for high volume roll-to-roll manufacturing of large area modules

Three Related Approaches

- **Dye Sensitized Titania (DSSC)**
- **Solid State Hole Carrier (ssPV)**
- **Organic Polymer Photovoltaics (OPV)**

Three Related Approaches for the Active Layer

- Dye Sensitized Titania (DSSC)

titania nanoparticles + sensitizing dye + liquid electrolyte
(electron carrier) (light absorber) (charge carrier)

- Solid State Hole Carrier (ssHC)

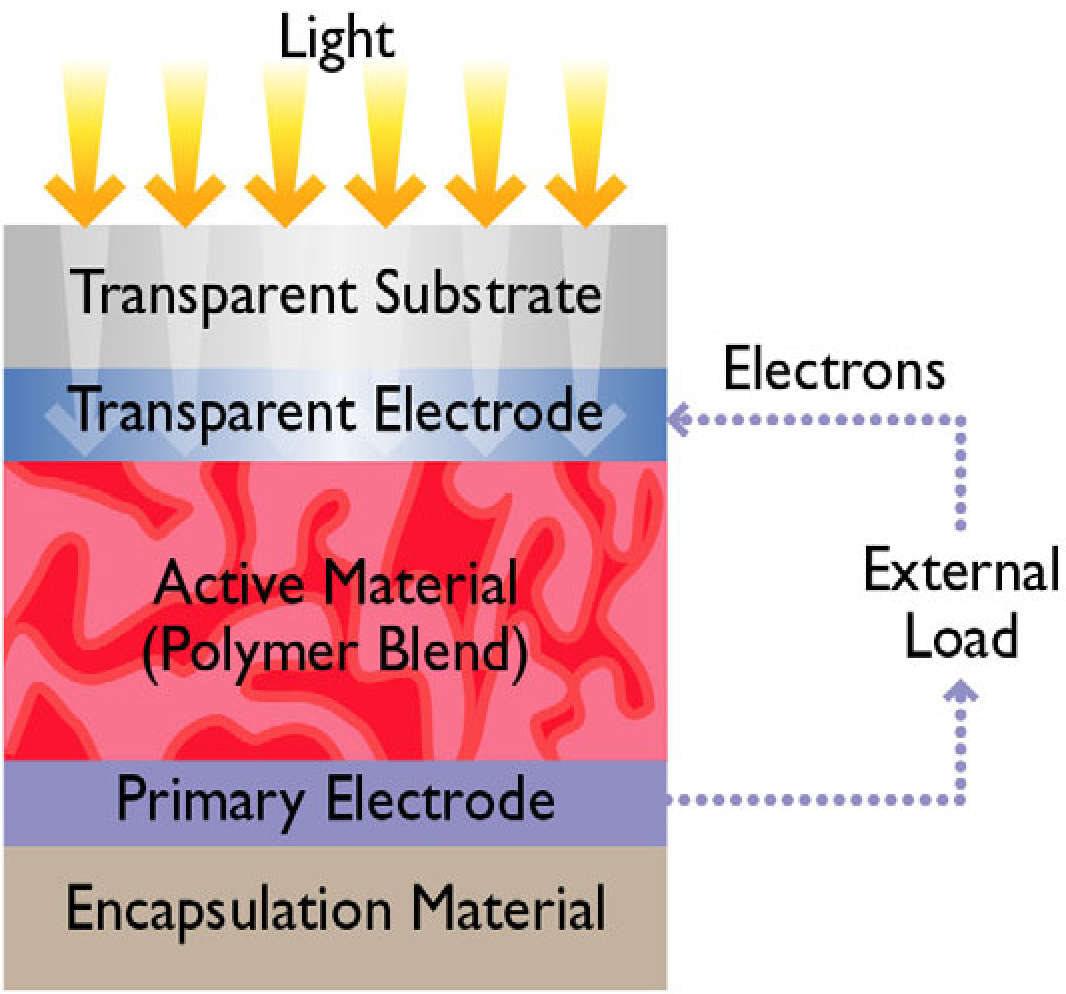
titania nanoparticles + sensitizing dye + solid hole carrier
(electron carrier) (light absorber) (charge carrier)

- Organic Polymer Photovoltaics (OPV)

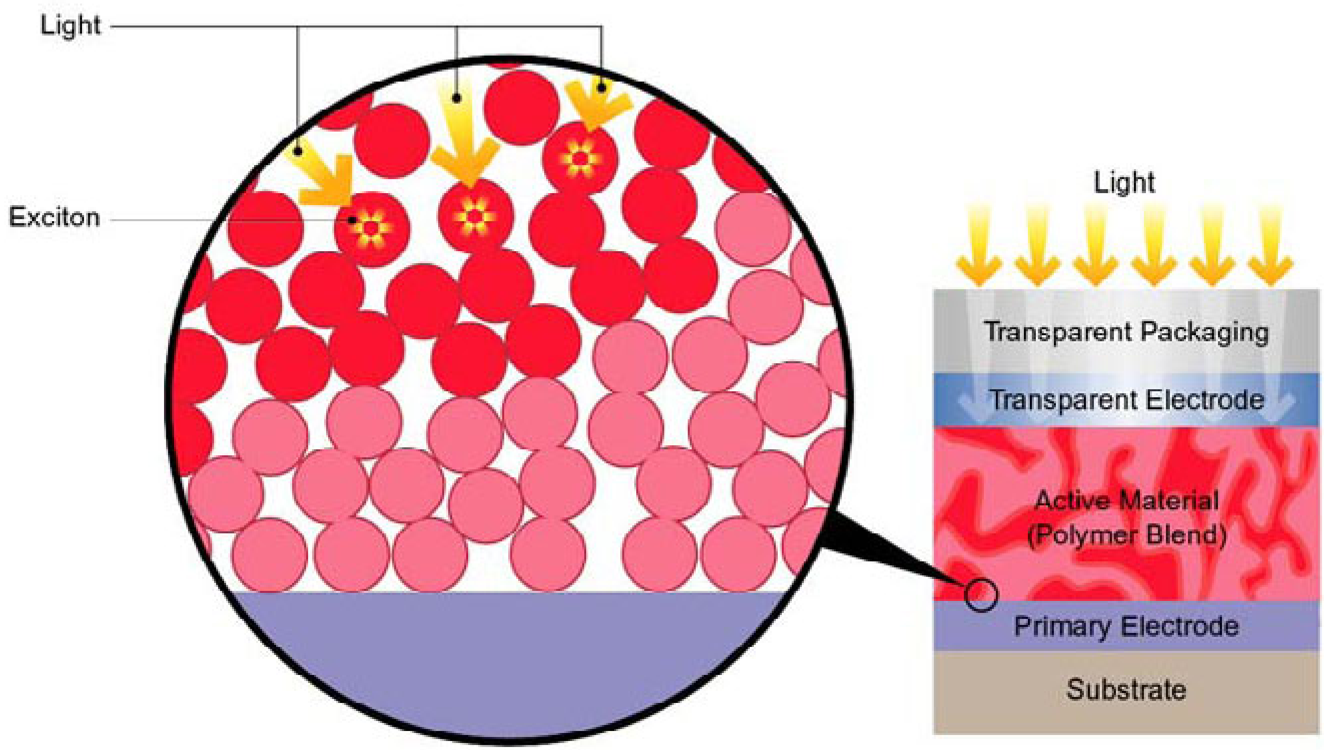
fullerene + polymer
(electron carrier) (light absorber, charge carrier)

Technology Overview

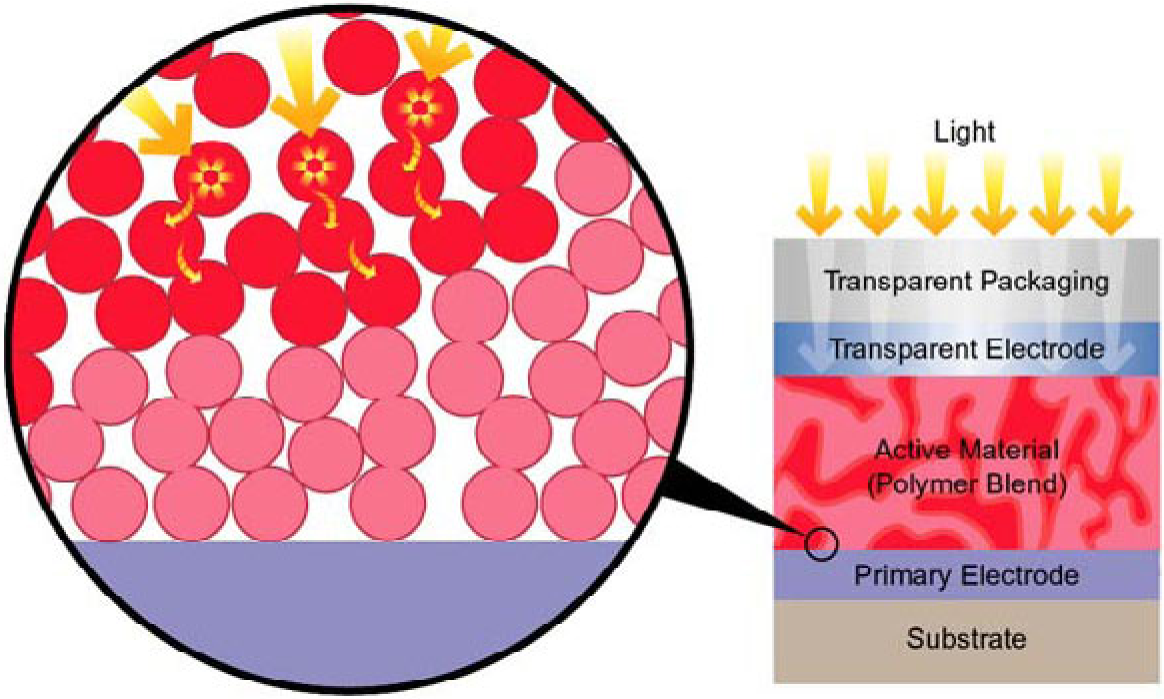
OPV Cell Schematic



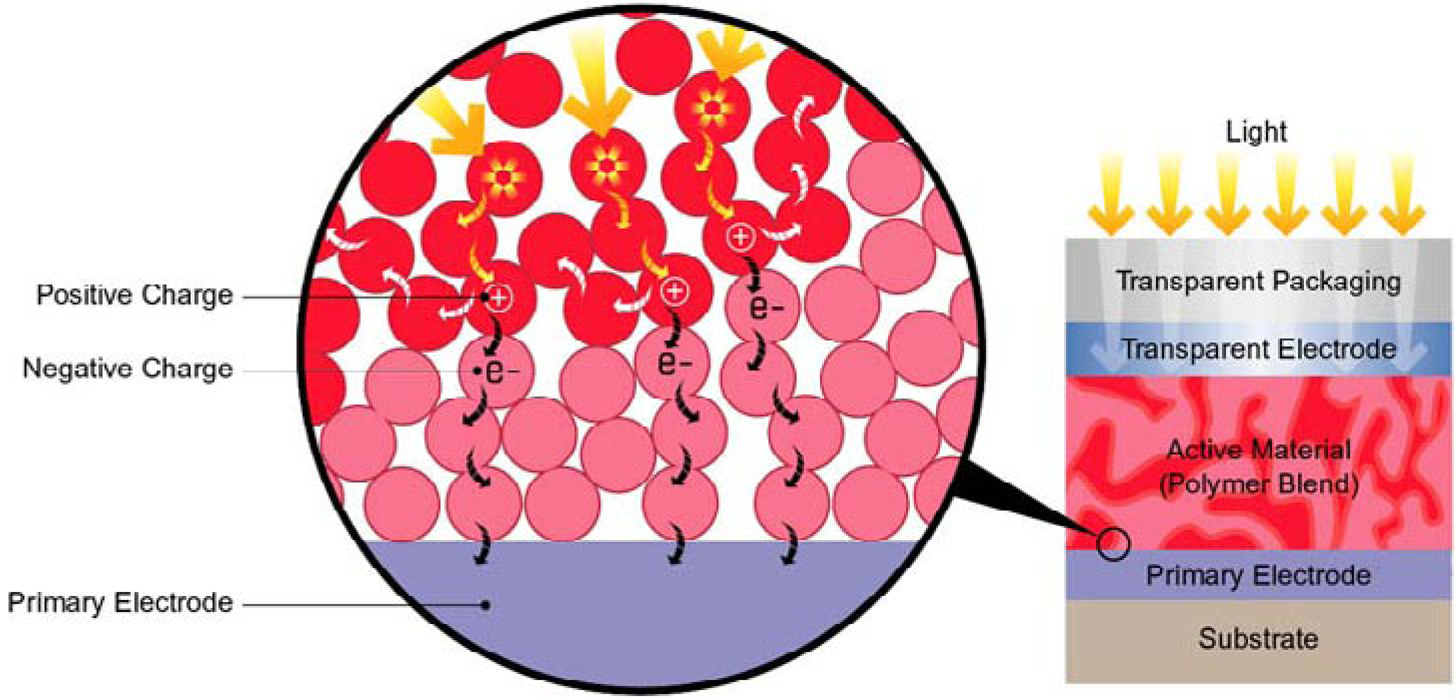
Active Layer Schematic



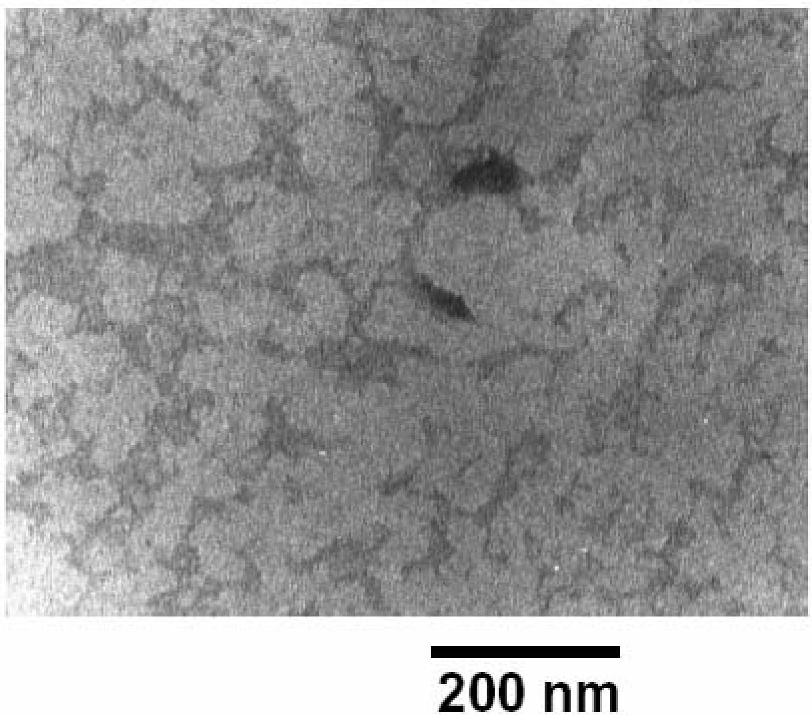
Active Layer Schematic



Active Layer Schematic

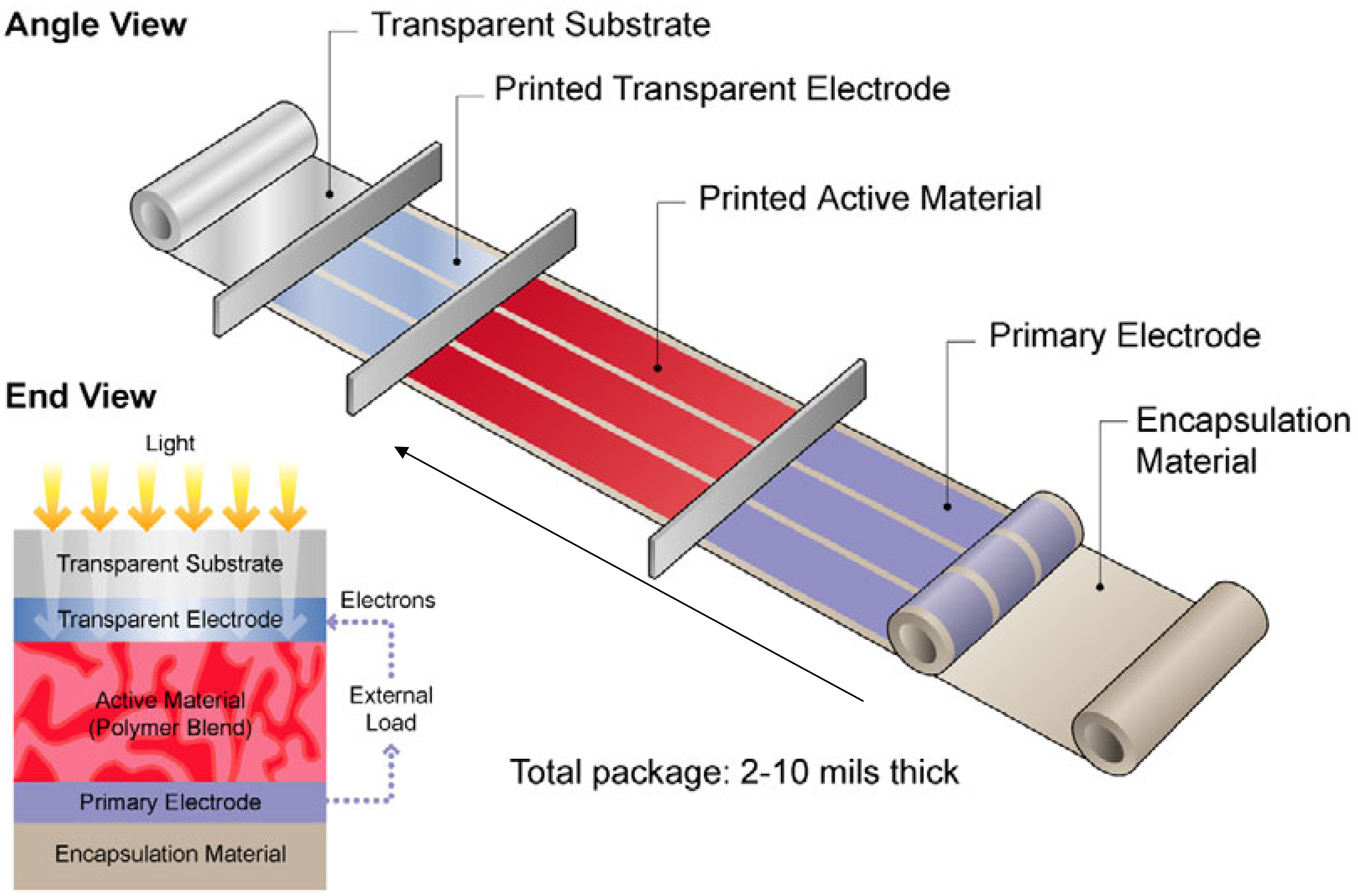


Bulk Heterojunction Cell
Active Layer
Electron Micrograph



Hole carrier polymer doped with electron carrier fullerene

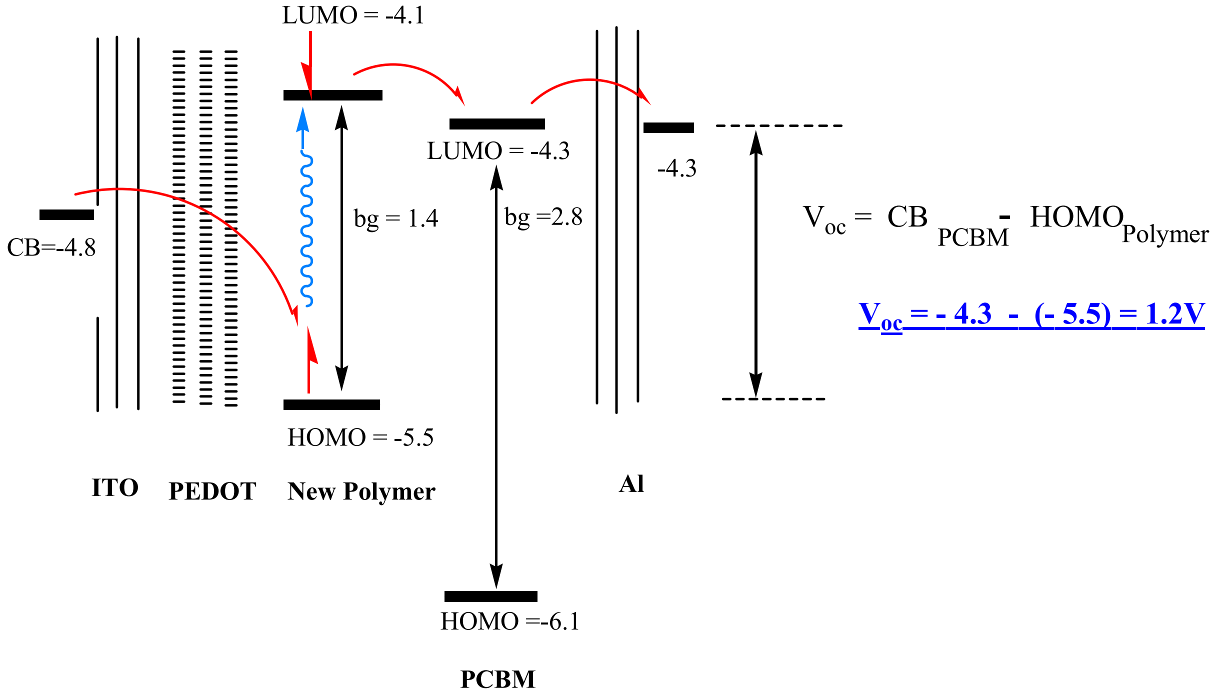
Power Plastic ™



Process Development Coater

Lowell, MA

Optimized Polymer/(PCBM) Cell - Voltage



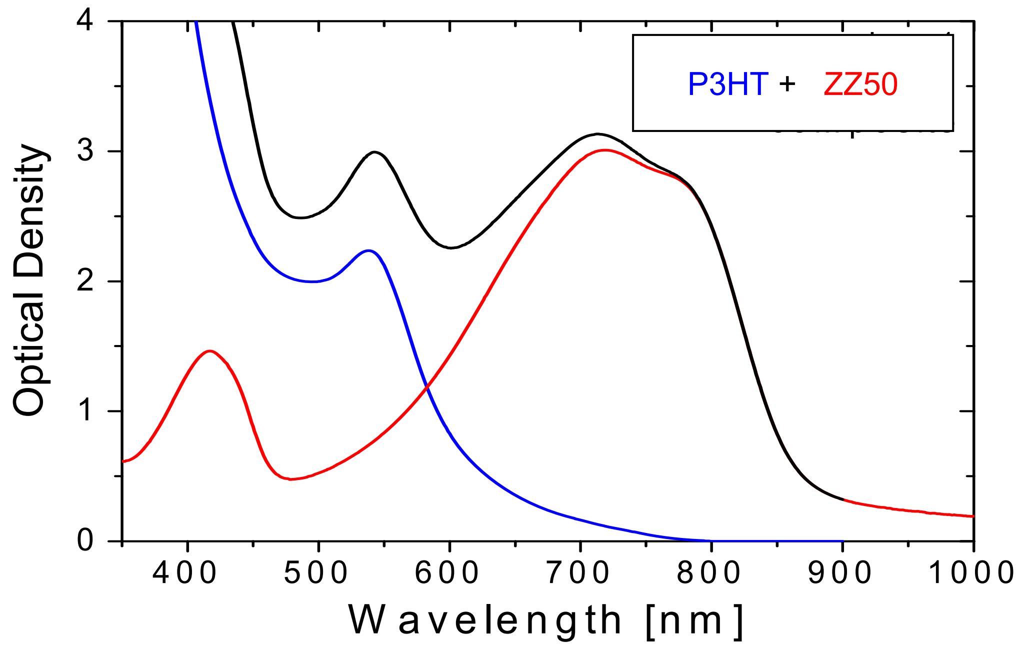
Note: for efficient electron transfer between states, the energy difference ≥0.2eV.

Voltage (V_{oc}) determined by the difference between the LUMO of PCBM and the HOMO of the polymer

Polymer band gap = 1.4eV (900nm)

Conclusion: high cell voltage attainable by optimizing alignment of polymer (donor) and fullerene (acceptor) energy levels

Two-Polymer Composite Cell
Calculated Current Density



Photocurrent Generation Potential (EQE =0.8) – **25.3 mA/cm²**

Cell Performance Estimates

Polymer Cell **(assumptions: EQE = 0.8, FF = 0.75)**

Efficiency equation: $$\eta = \frac{V_{OC} I_{SC} FF}{P_{Light}}$$

Composite

I_{sc} = 25.3mA/cm^2; V_{oc} = 1.2V → 0.9

(dark current correction to voltage)

Efficiency : $\eta = 17\%$ **TARGET: >7%**

Tandem (in-series)

I_{sc} = 18 - 24; V_{oc} = 1.8V

(includes 2x voltage with dark current correction)

Efficiency : $\eta = 24 - 32\%$ **TARGET > 10%**

Solar America Initiative Program

Solar America Initiative Objectives

1] Improve Stability

Task: develop more effective water and oxygen barriers

Approach: combine best commercial barriers with barrier adhesives

2] Improve Performance

Task: replace ITO with metal grid

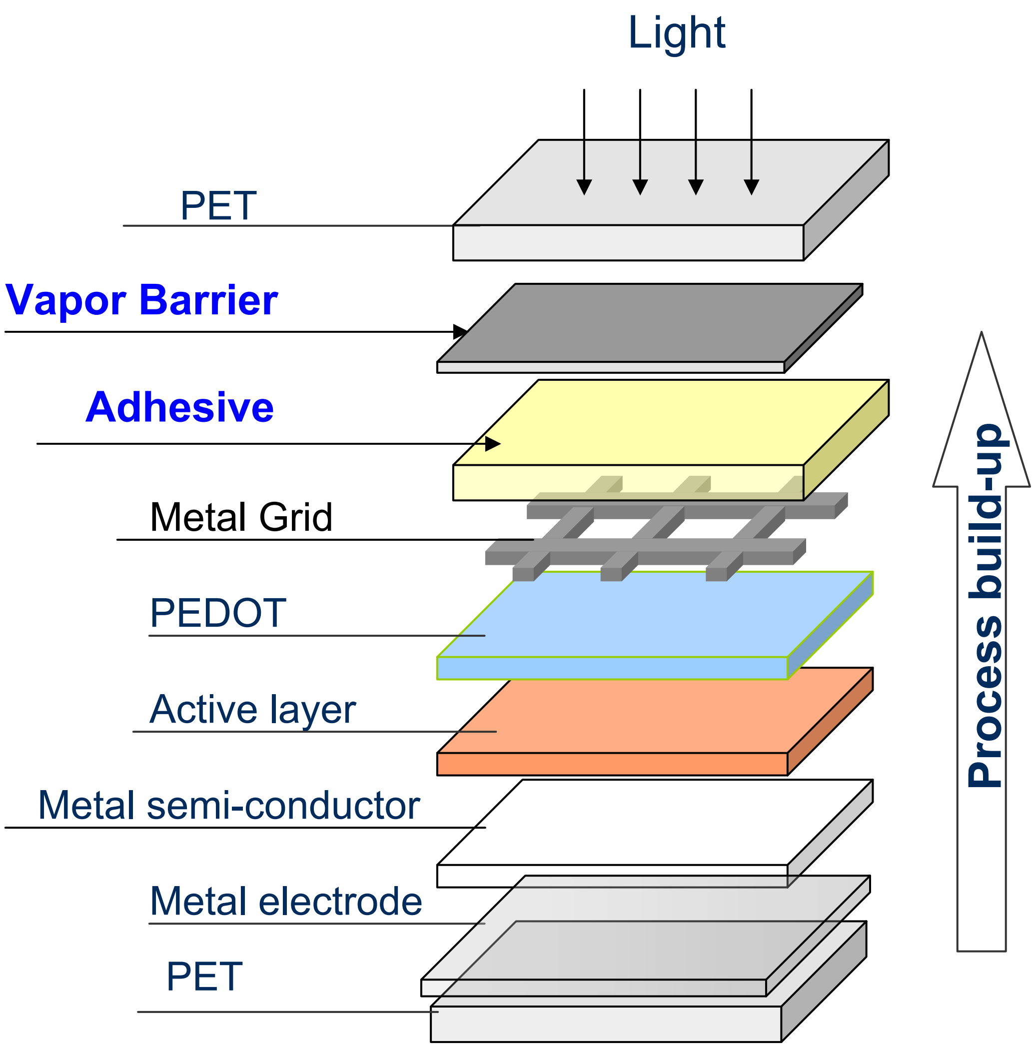
Approach: develop a process for printing a metal grid

3] Improve Performance

Task: replace fullerene with high performance electron carriers

Approach: create a new class of polymers or small molecules

PV Cell Architecture
Water/Oxygen Vapor Barriers



Water/Oxygen Vapor Barriers

Test Conditions
- 85^oC, ambient
- 85^oC, I sun
- light soaking; 1.3suns/ 40^oC
- 65^oC/85%RH

Pass Criterion:
- <20% decrease in efficiency @ 1000 hrs.

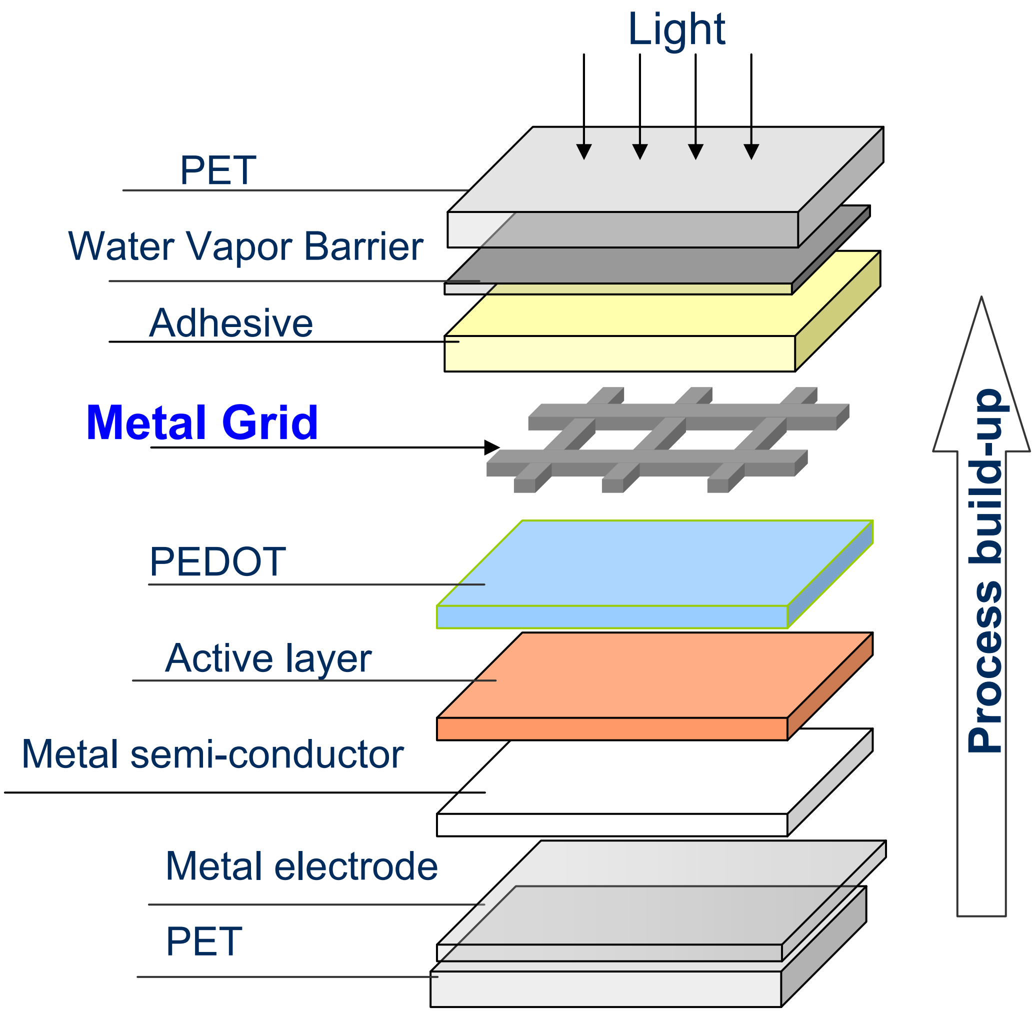
Results:
- Glass encapsulated: passes all tests (1000hrs, <5% eff. loss)
- Flexible substrates:
  - 85^oC, ambient – passes 500hrs (<10% eff. loss)
  - 85^oC, I sun – passes 500 hrs (<10% eff. loss)
  - light soaking; 1.3suns/ 40^oC – passes 500 hrs (<10% eff. loss)
  - 65^oC/85%RH – passes 250hrs.

Commercial Barriers:
- Target WVTR = $10^{-3}g/m^2/day$ @ 65^oC/85%RH
- Available :10^{-2} -$10^{-5}g/m^2/day$ @ 38^oC/85%RH
  $10^{-2}g/m^2/day$ @ 65^oC/85%RH
- Cost : <<$\$1/m^2$

Commercial Adhesives:
- Target WVTR = $10^{-3}g/mm^2/day$ @ 65^oC/85%RH
- Available : > $1g/m^2/day$ @ 65^oC/85%RH

Strategy:
- Find better commercial barrier substrates
- Develop adhesives with fillers to achieve WVTR equal to barrier substrates

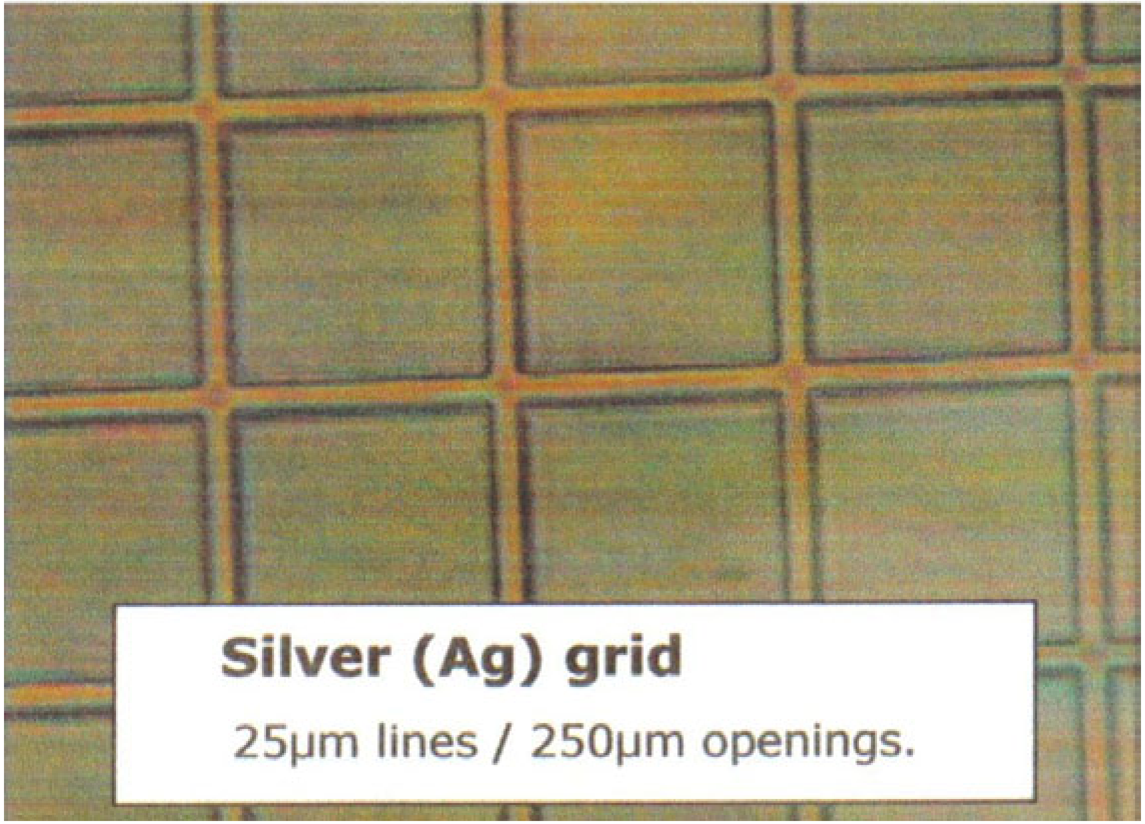
PV Cell Architecture
Metal Grid



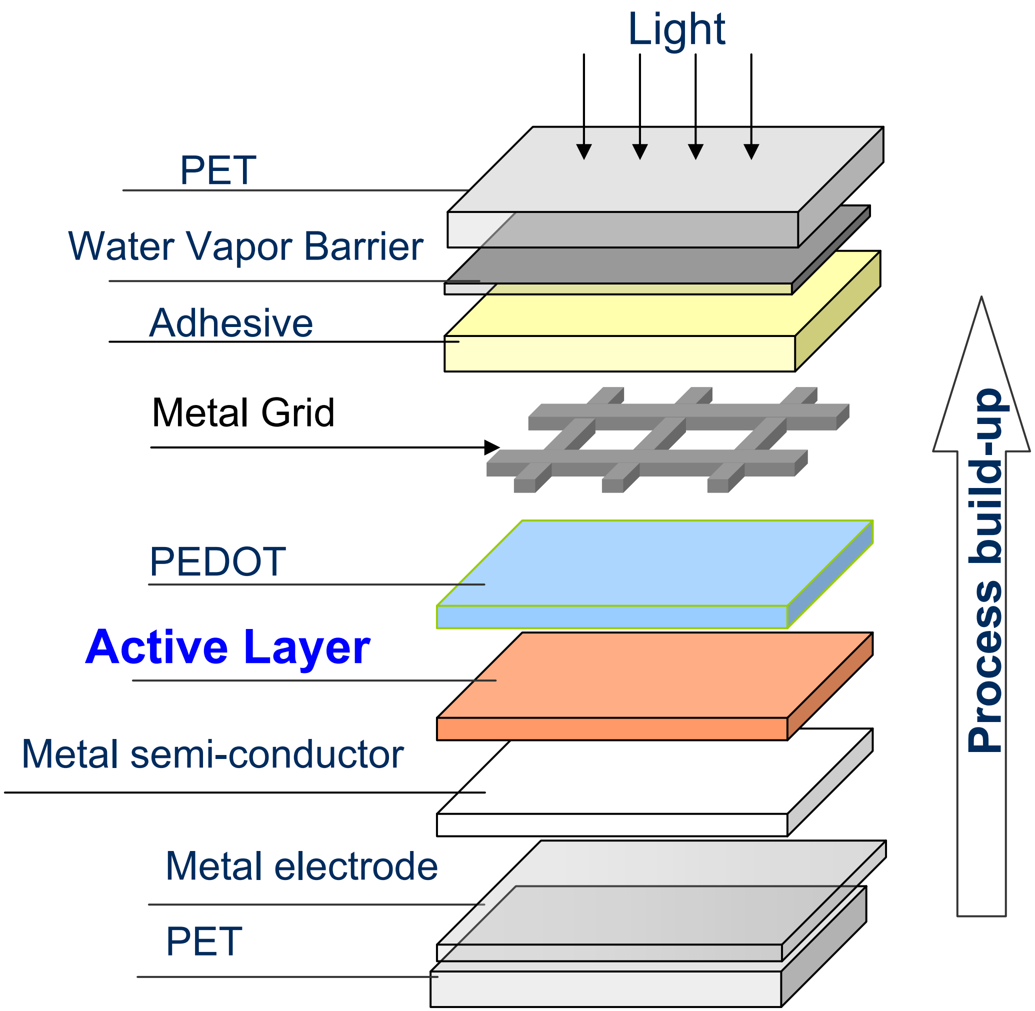
Transparent Conductive Electrode

Metal Grid: 90%T @ 3ohms/sq ***vs.*** **ITO ~75%T @ 8ohms/sq**

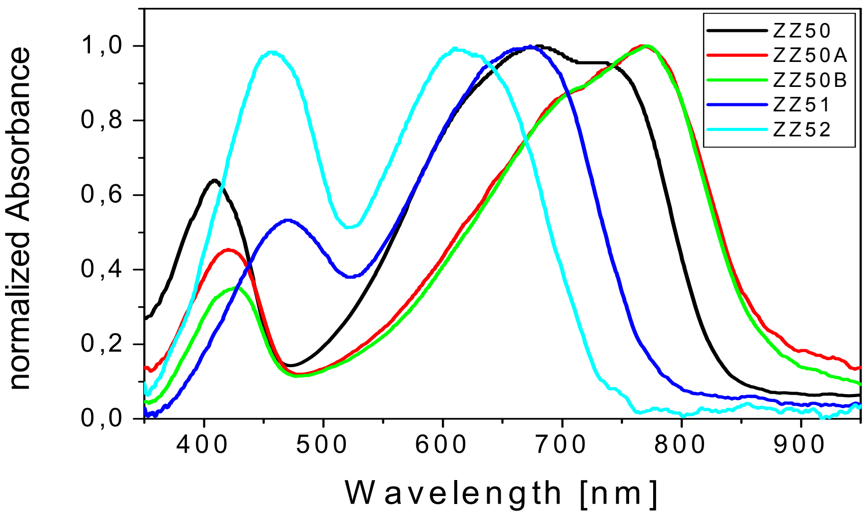
<$10/m² ***vs.*** **~$35 - $40/m²**

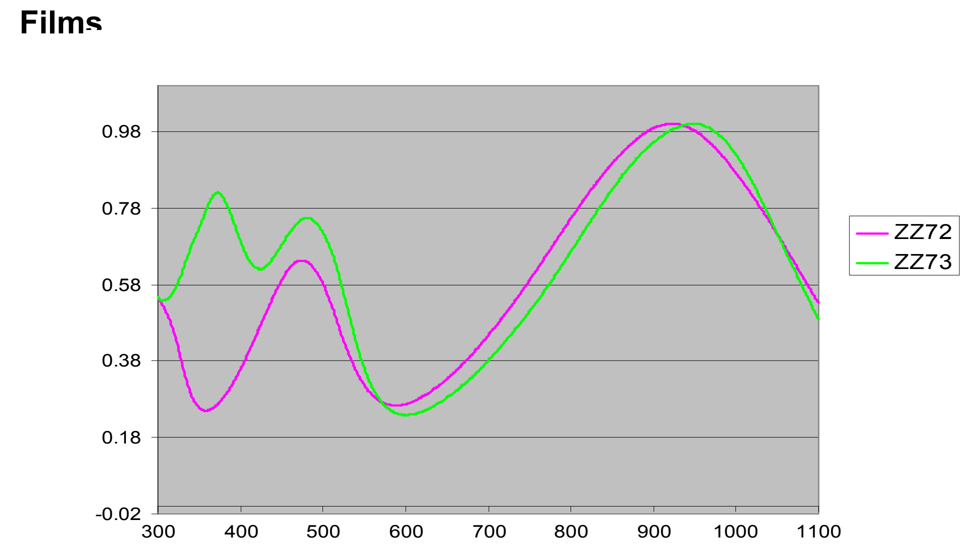


PV Cell Architecture
Active Layer



Absorption Spectra of p-Type Polymers





Developed new families of polymeric hole carriers

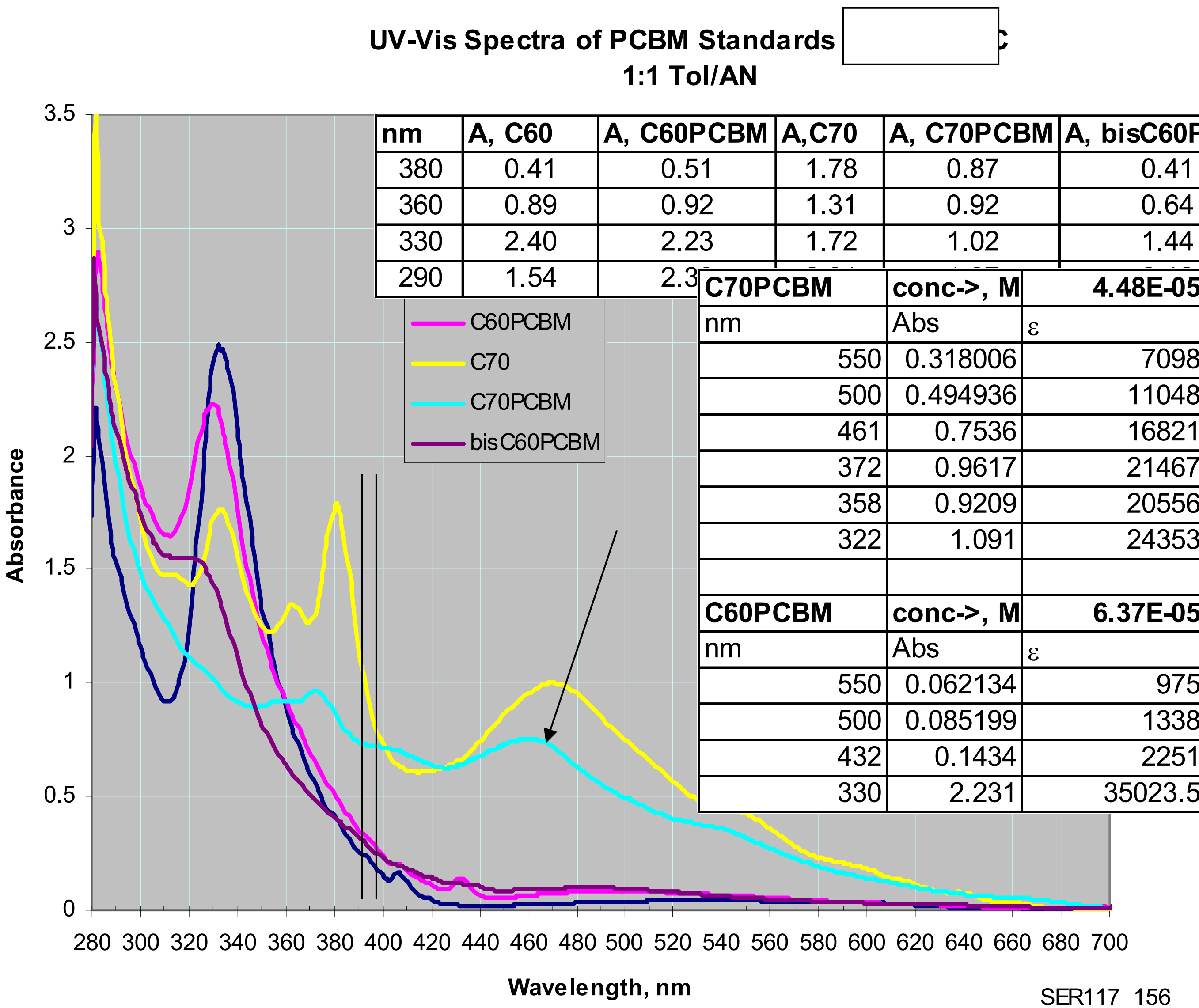
Band gap = 0.9 – 2.0eV

HOMO = - 4.9 to -5.5eV

LUMO = - 3.8 to -4.0eV

Electron mobility ~ 10^{-2} - 10^{-3} cm^2/Vs

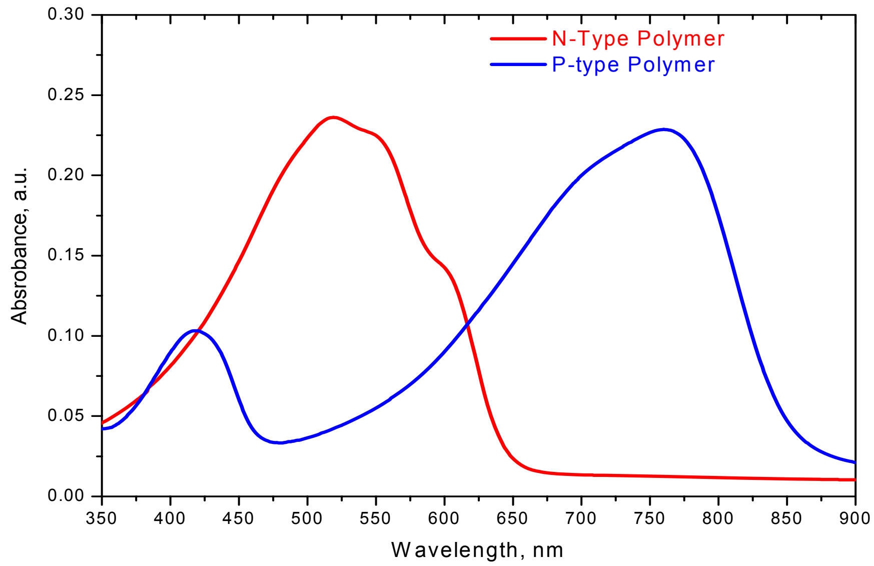
n-Type Carriers Fullerene Derivatives



nm	A, C60	A, C60PCBM	A,C70	A, C70PCBM	A, bisC60PCBM
380	0.41	0.51	1.78	0.87	0.41
360	0.89	0.92	1.31	0.92	0.64
330	2.40	2.23	1.72	1.02	1.44
290	1.54	2.3[illegible]	[illegible]	[illegible]	[illegible]

C70PCBM	conc->, M	4.48E-05
nm	Abs	ε
550	0.318006	7098
500	0.494936	11048
461	0.7536	16821
372	0.9617	21467
358	0.9209	20556
322	1.091	24353
C60PCBM	**conc->, M**	**6.37E-05**
nm	Abs	ε
550	0.062134	975
500	0.085199	1338
432	0.1434	2251
330	2.231	35023.5

Combination of n-Type Carriers and p-Type Carriers



Target properties to compliment the hole carrier:

- **blue-green absorption**
- **absorptivity ~100K**
- **electron mobility (μ_-) ~$10^{-2}cm^2/Vs$**
- **HOMO ~ -6.5eV**
- **LUMO ~ -4.3eV**

Summary

Developments have clarified the directions required that will enable Konarka to manufacture high performance, light weight solar modules at low cost.

2010 Targets

- **Thickness = 0.3mm (current)**
- **Weight = 450g/m^2 (current)**
- **Efficiency : 7%**
- **Power to weight ratio: >150mW/g**
- **Power/area = 70mW/m^2**
- **Stability : 10 year roof top**
- **Module Cost : <$1/kWh and <$1/Wp**