Efficient Organic Excitonic Solar Cells with Carbon Nanotubes Replacing In_2O_3:Sn as the Transparent Electrode

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NREL/PR-520-39849

Presented at the 2006 IEEE 4th World Conference on Photovoltaic Energy Conversion (WCPEC-4) held May 7-12, 2006 in Waikoloa, Hawaii.

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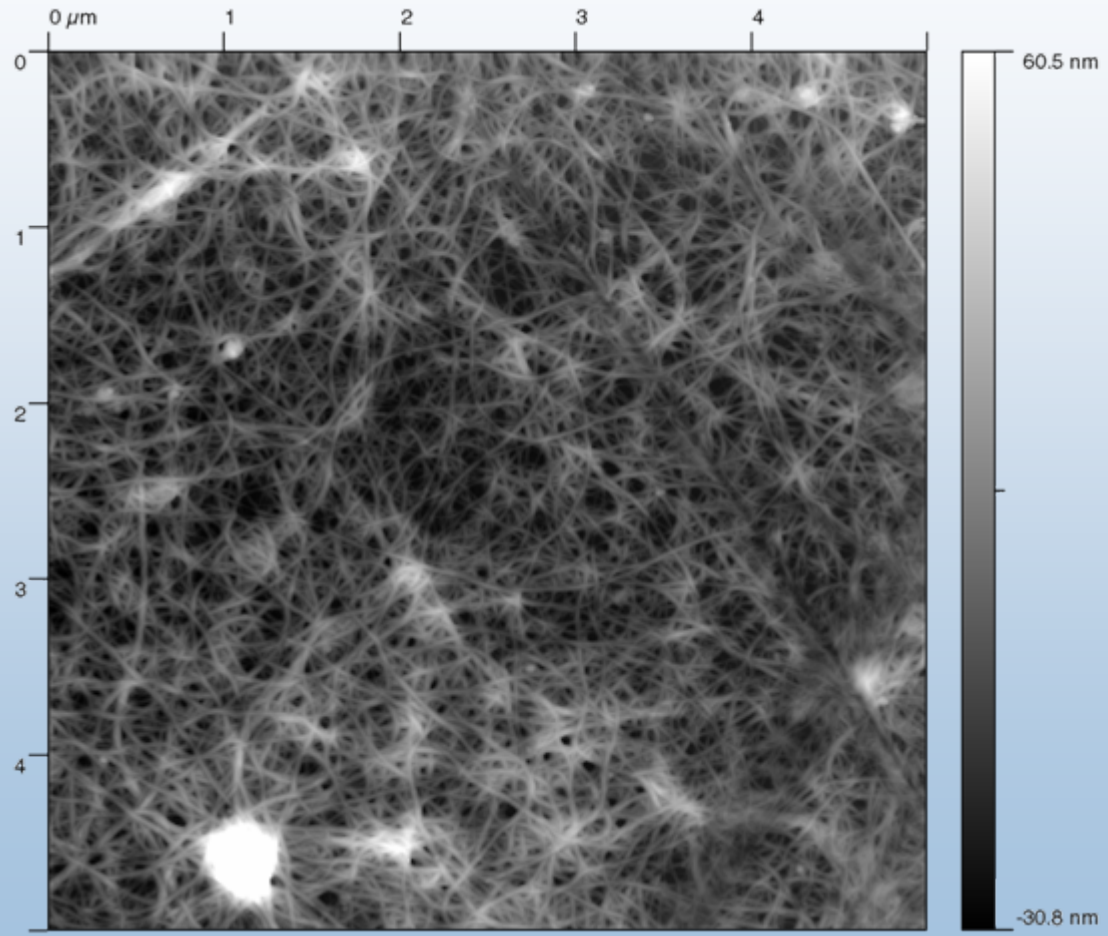
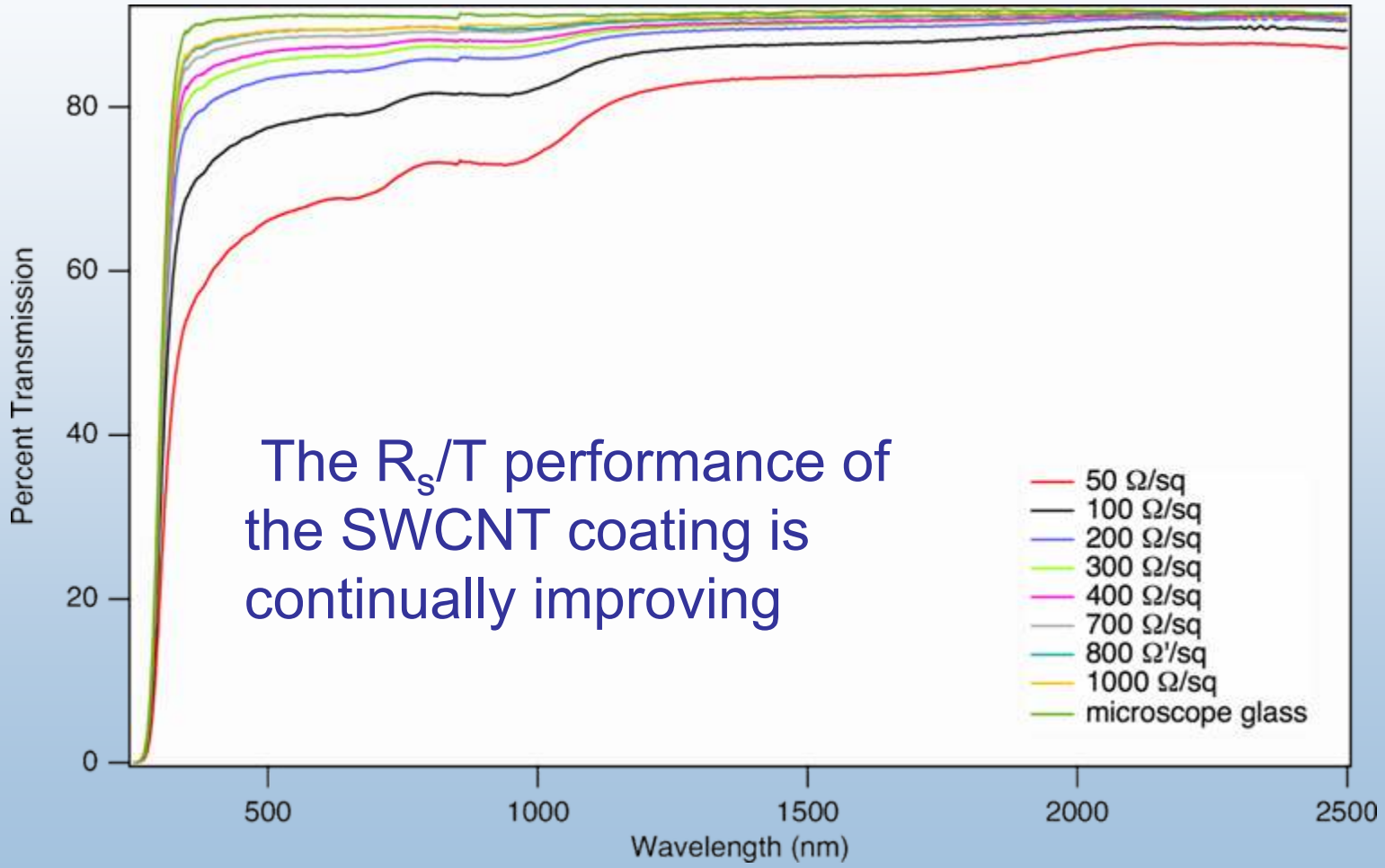
Why replace ITO?

- ITO is not ideal
- CNT contact could interpenetrate into the active layer
- Potentially hole selective contact
- Solution processable - fully printed cell
- Work function similar to that of ITO



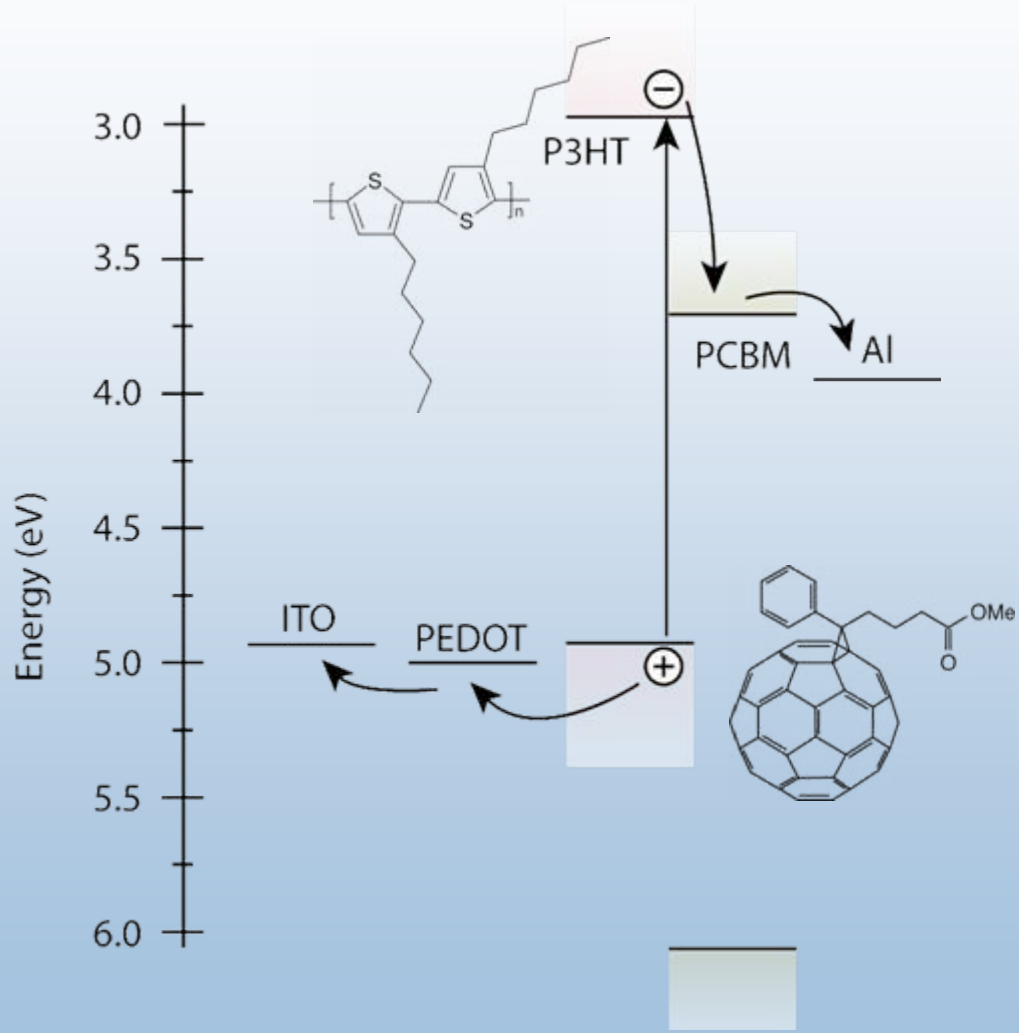
Resistance vs. Transmittance of SWCNT layers



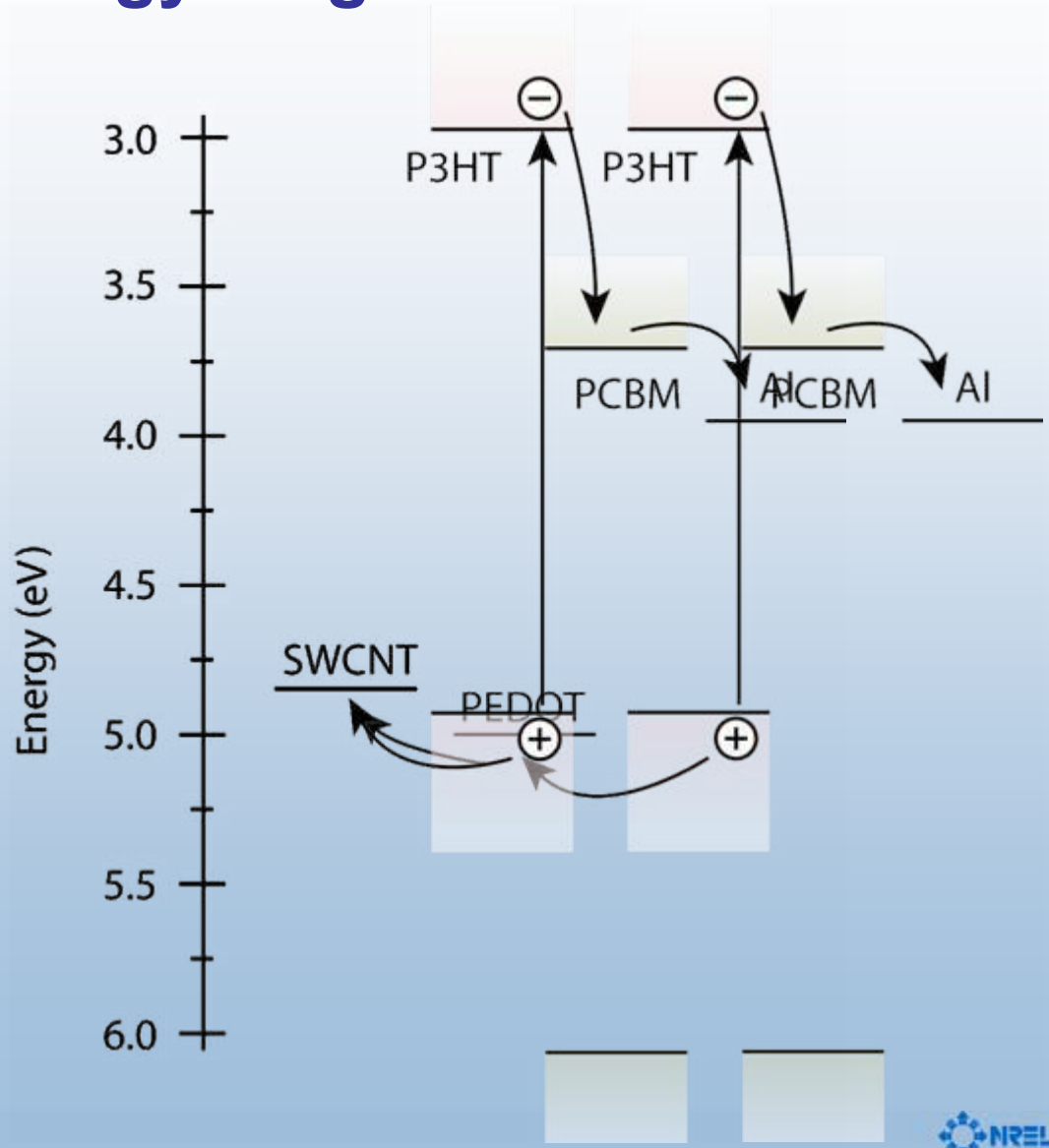
The R_s/T performance of the SWCNT coating is continually improving

‘Conventional’ excitonic solar cell

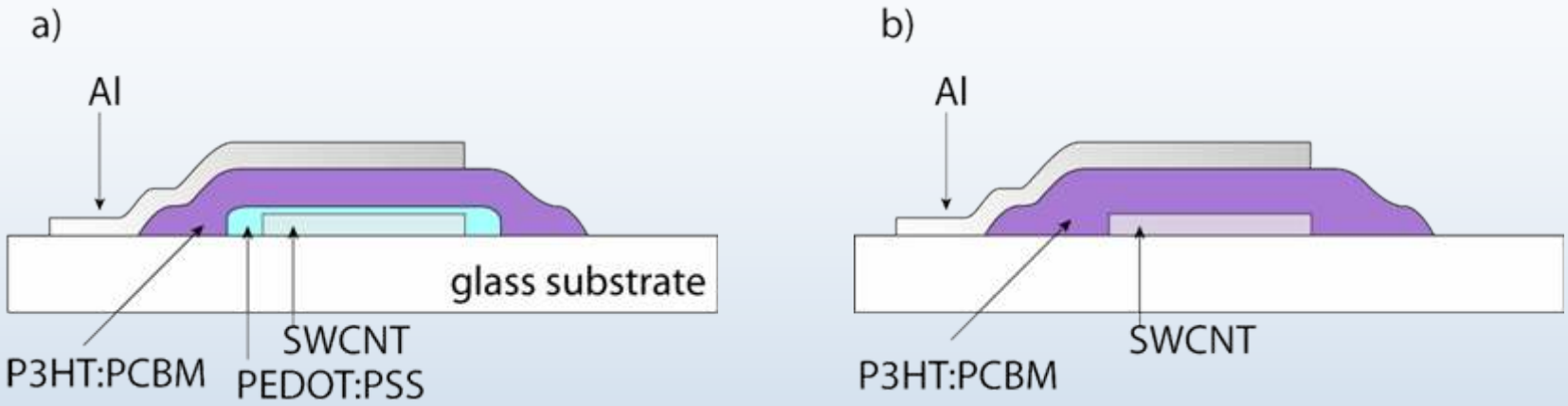
- Interpenetrated hole and electron conductors.
- Excitons dissociate at interface between P3HT and PCBM.
- Holes are transported in P3HT to PEDOT, where they transfer to ITO.

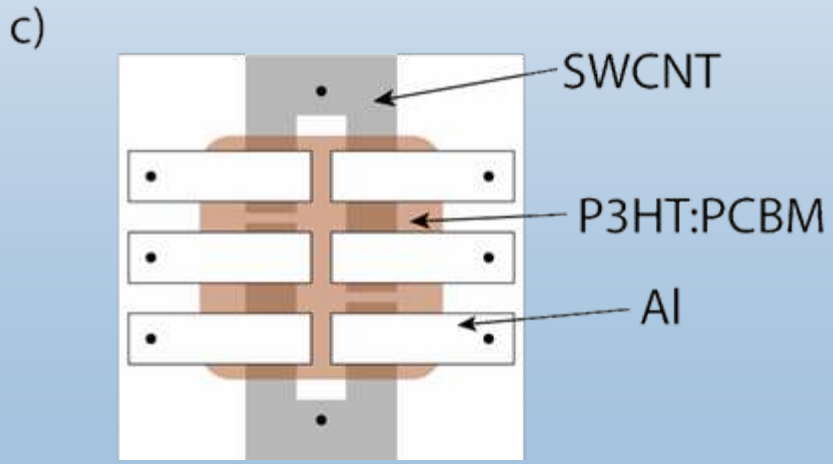


Energy diagram SWCNT based cell



Device structures

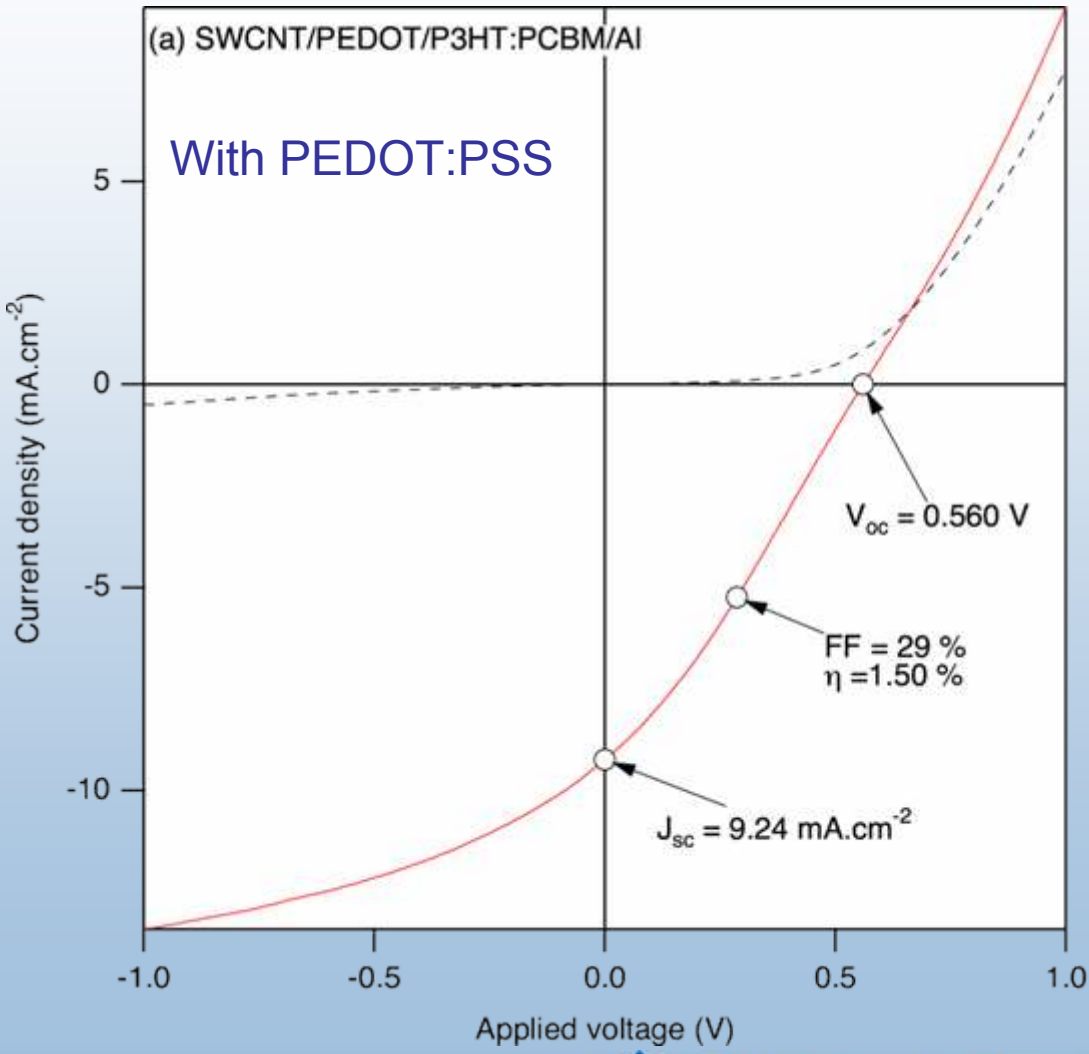




- SWCNT Deposition by spraying of nanotube dispersion in ethanol onto heated (65°C) substrates
- PEDOT:PSS deposited by spin coating
- P3HT:PCBM deposited from chlorobenzene by drop casting or spin coating
- Al vapor deposited

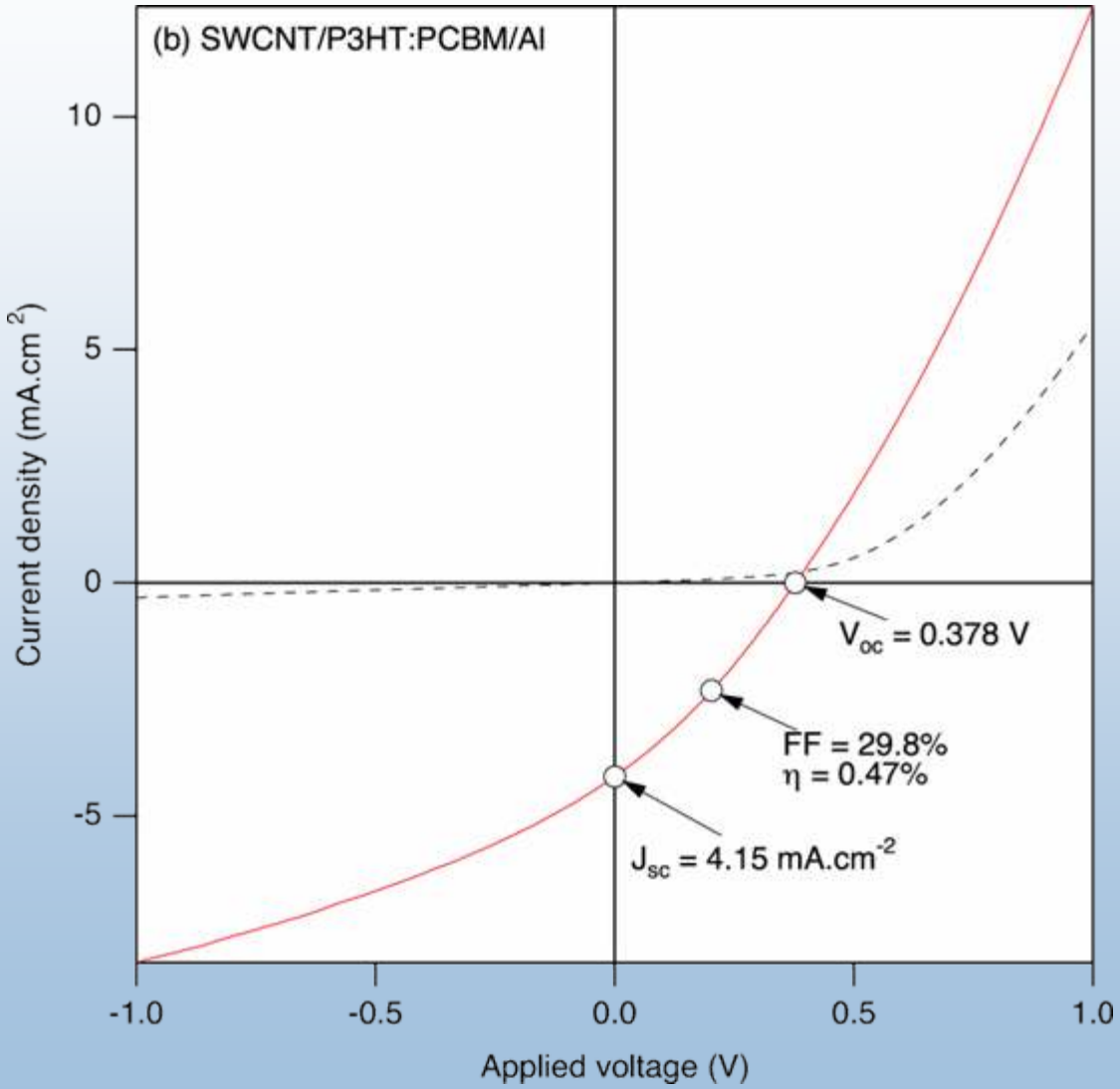
Devices made by drop casting

- Active layer thickness of 500-1000 nm
- Strong rectification - SWCNT is hole specific contact



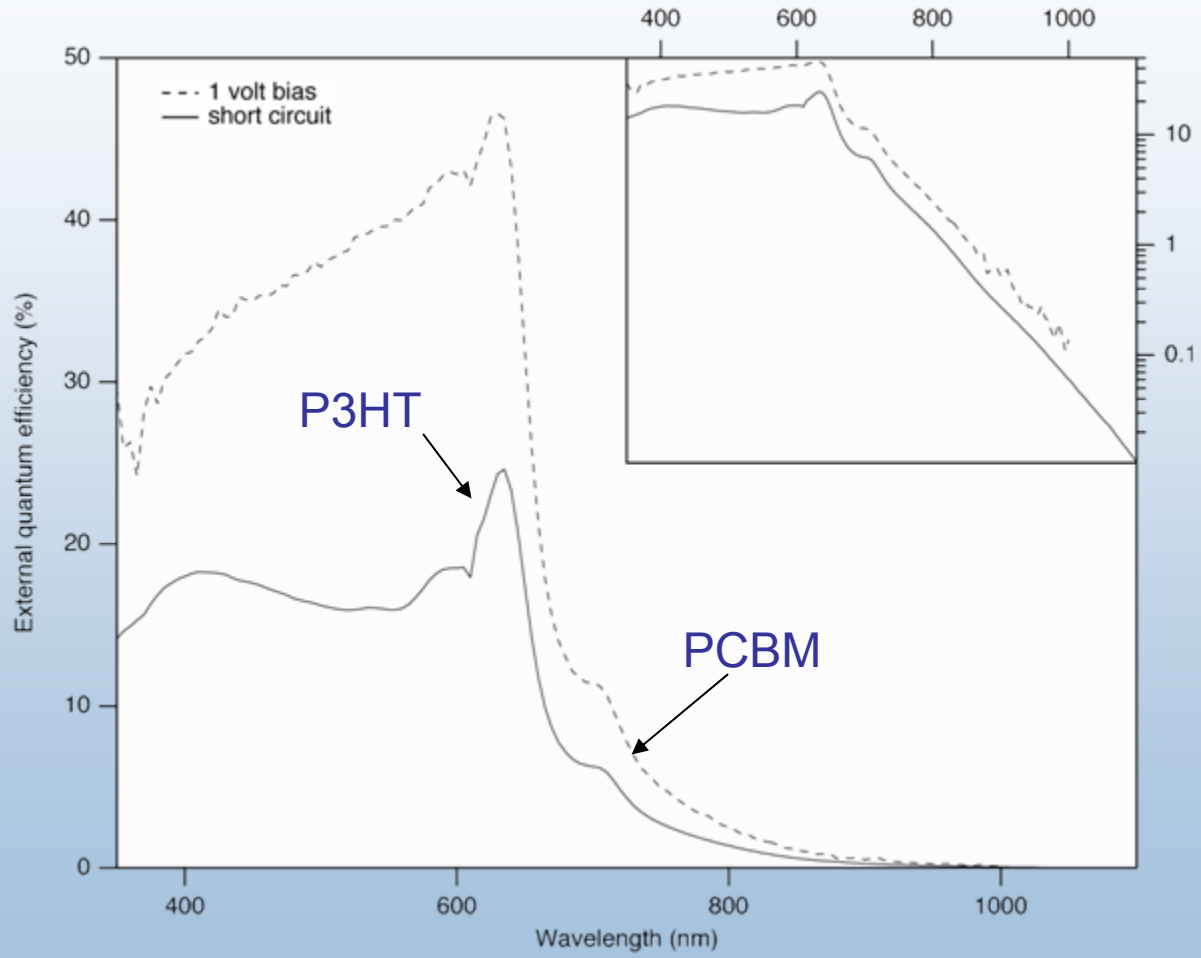
Device without PEDOT

- Lower efficiency, but still rectifying.
- Room for improvement
  - Layer thickness
  - Solvent
  - Reduce contact resistance
  - Increase shunt resistance

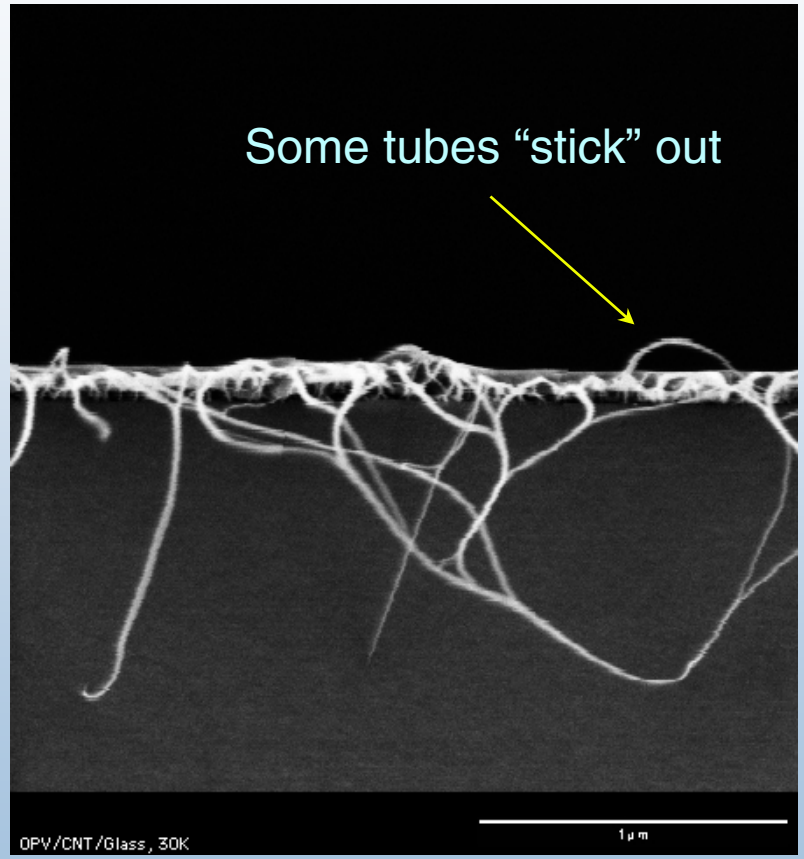


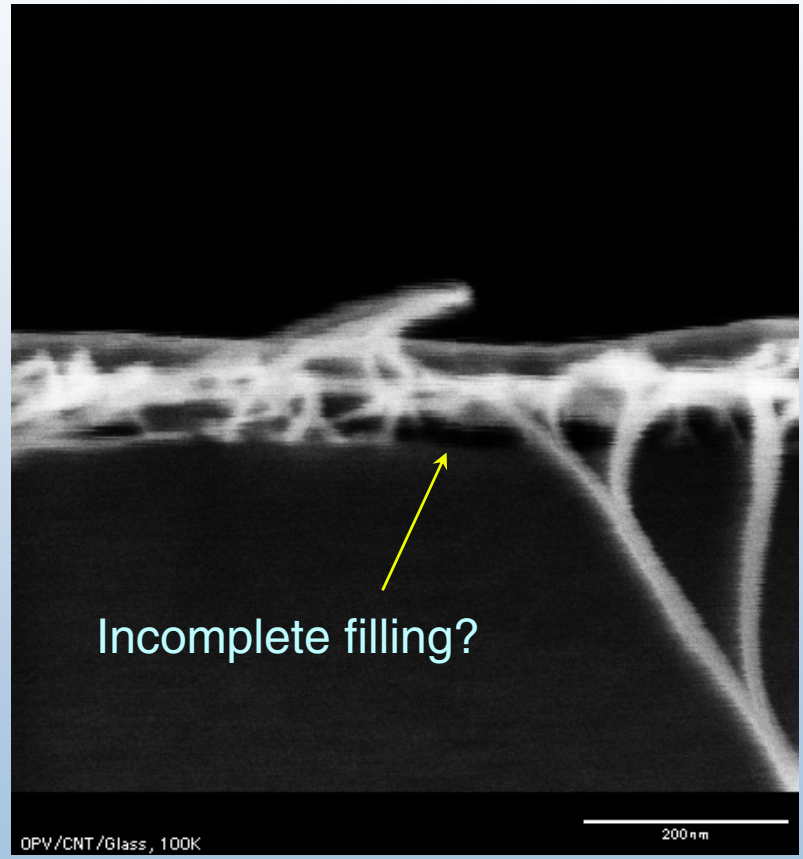
EQE of device without PEDOT

- Large amount of recombination in the bulk of the device.
- Needs optimization of layer thickness - spin casting!

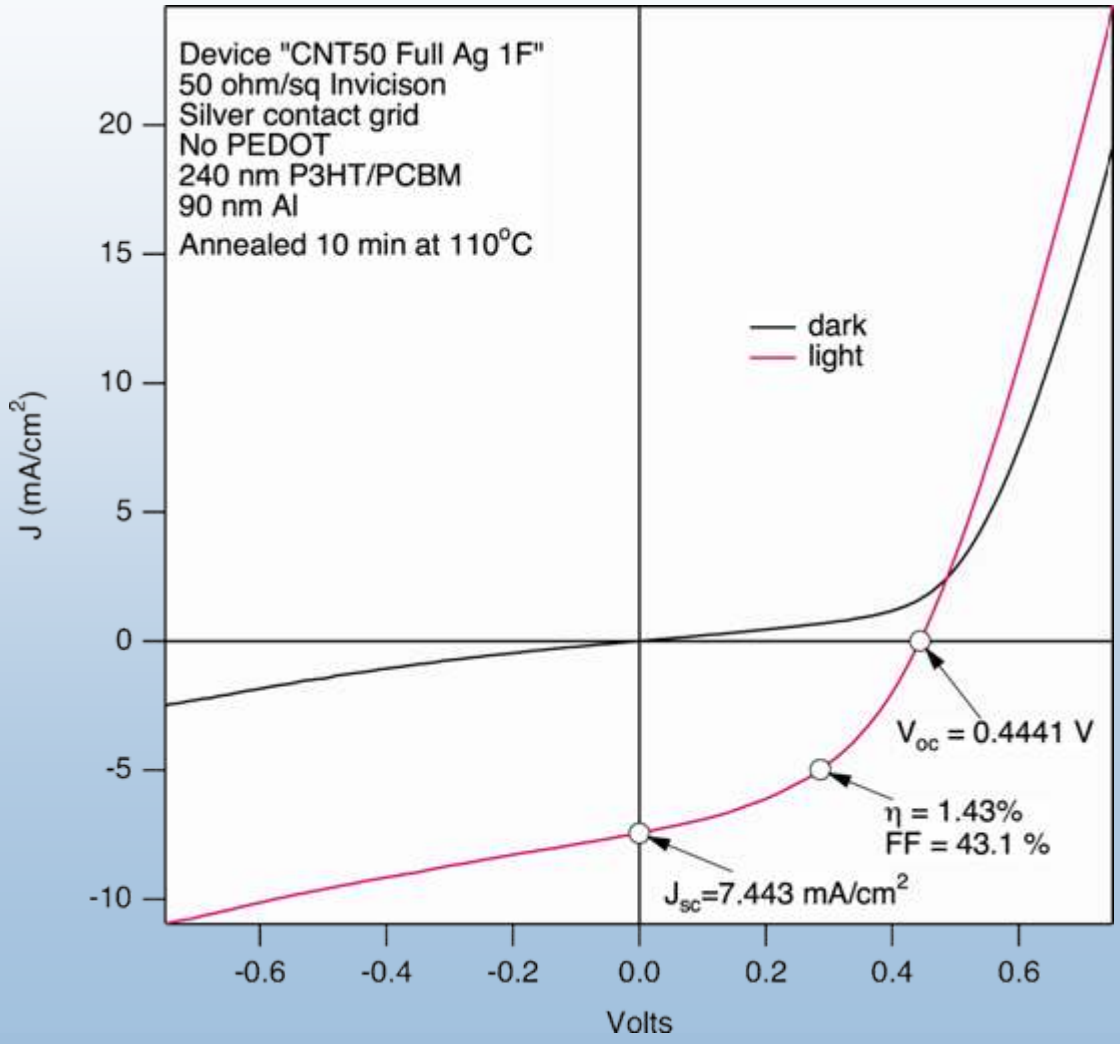


SEM cross section of spin cast devices of 100 nm-thick active layer



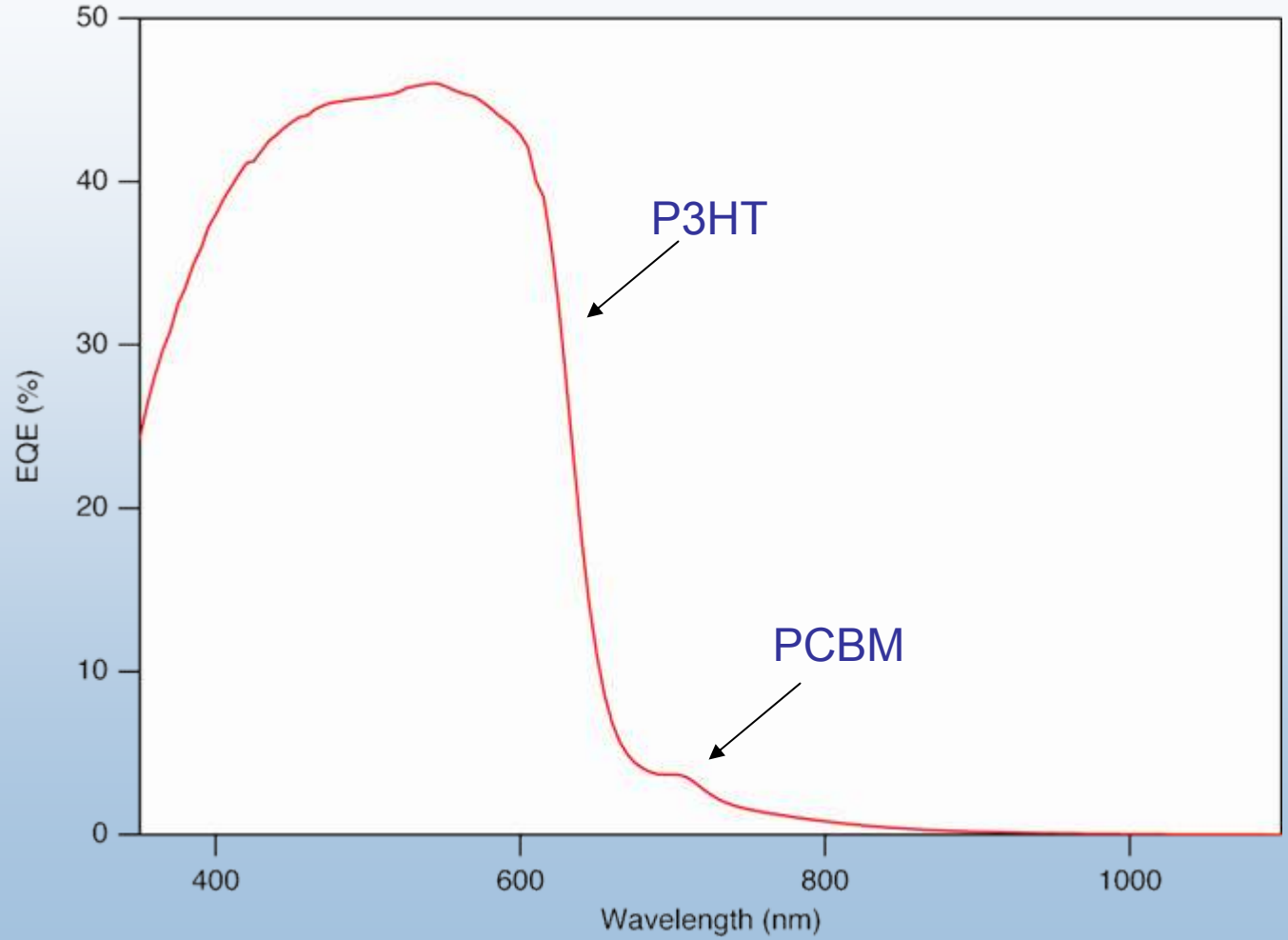


1.4 % Device without PEDOT



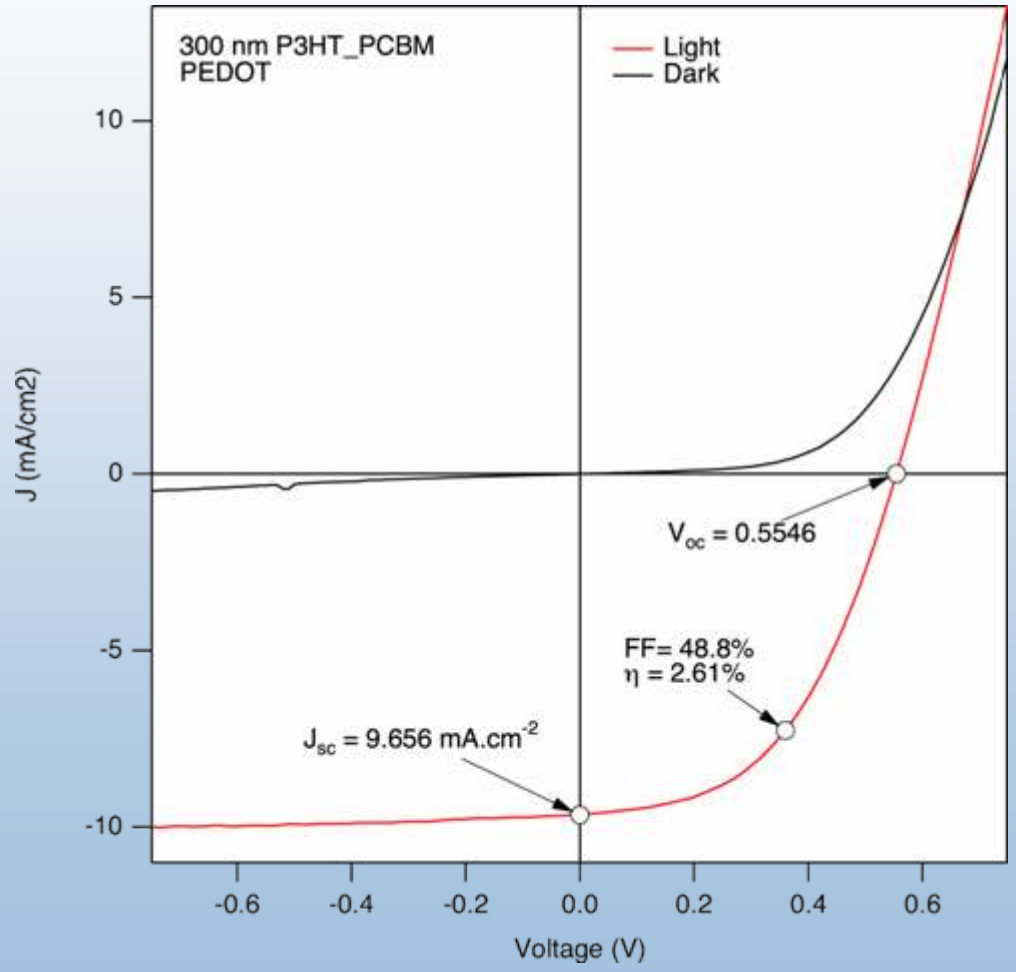
- Device is still slightly shunted.
- 1.4% efficiency is 3 times higher than the drop cast device
- Further optimization is possible.

External Quantum efficiency of 1.4% device



SWCNT-based Device with PEDOT:PSS

- Di-chlorobenzene solvent
- Efficiencies of 2.6%
- Very good rectification
- Less recombination than device without PEDOT
- Contact of nanotubes with PCBM in the active layer is detrimental?



Conclusions

- Organic solar cells with efficiencies of up to 1.43% conversion efficiency that use no ITO and no PEDOT:PSS, are demonstrated.
- A cell without ITO, but with PEDOT:PSS gave 2.6% conversion efficiency
- Due to porous nature of SWCNT substrates, optimization of the active layer is essential.
- SWCNT electrodes bring one step closer the goal of a fully printable, organic solar cell.