

EFFECT OF ALUMINA COATING IN HYBRID NANOCRYSTALLINE TITANIUM DIOXIDE / POLYMER SOLAR CELL



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Acknowledgements



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Thanks for equipment



NRC
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Thanks for equipment

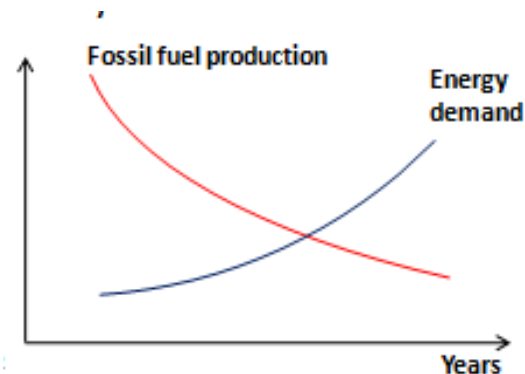


HETC Project

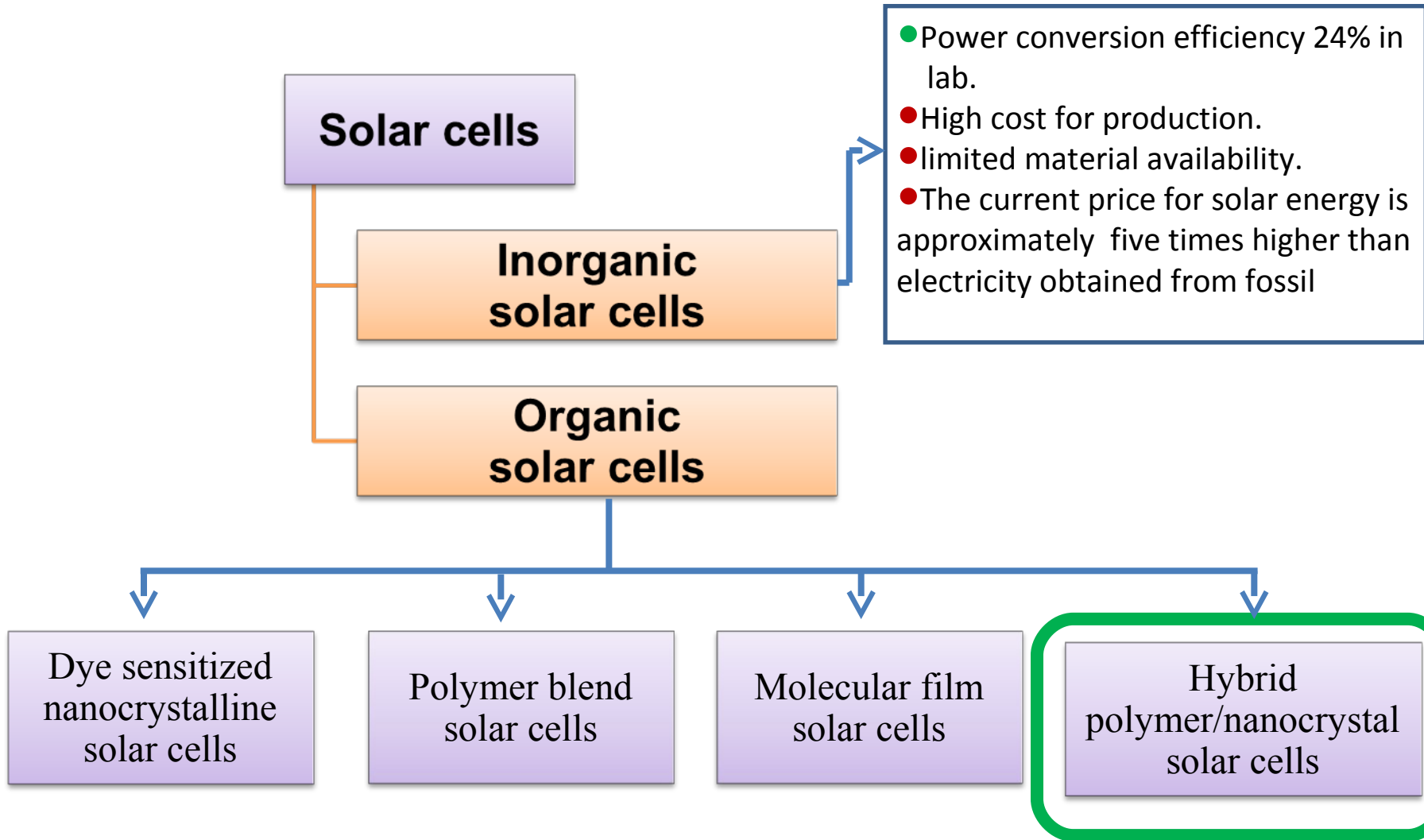
Thanks for financial assistance

Why Solar cells?

- World energy consumption is expected to rise by **more than 50 % over the next two decades**. (Source: U.S. Department of Energy)
- Since the oil energy sources are **finite** and release unwanted waste products into the environment, **alternative energy sources** are in increasing demand (wind, hydro, solar (thermal and photovoltaic)).
- photovoltaic is the best, because they
 - ✓ convert light energy directly into electricity.
 - ✓ do not require any cooling water system.
 - ✓ require little maintenance.
 - ✓ have no moving parts.
 - ✓ are silent in operations.



Major classes of solar cells

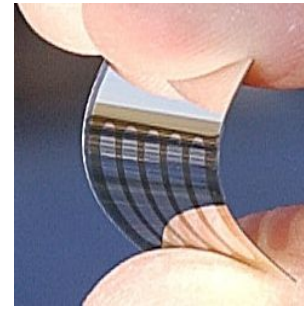


Why polymer based Solar Cell ?

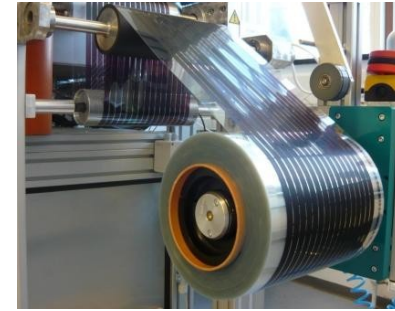
Nanotechnology may bring the cost down



Hard



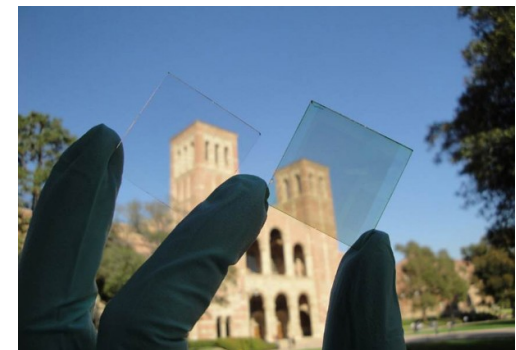
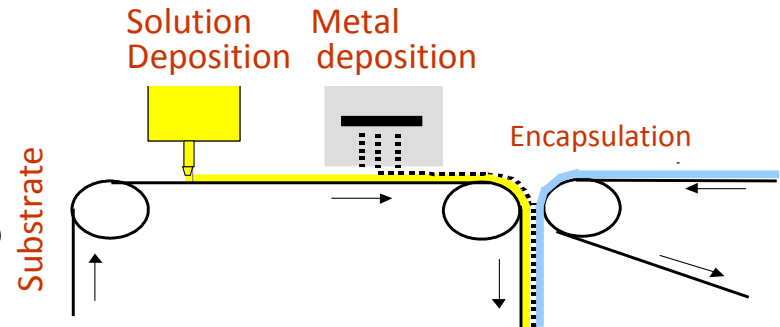
Soft



Material engineering in the nanometre scale

Advantages

- Low cost on large scale industrial production
- Low weight
- Low material requirements
- Ease of manufacture
- Mechanical flexibility
- Large field of application
- Solar Energy Windows Let the Light Shine In
- However, there are constrains such as poor stability, low efficiency for commercialisation and .



Why Metal Oxides/Polymer Solar Cells?

Organic solar cells typically made from electron and hole transporting polymers offered highest reported Power Conversion Efficiency.

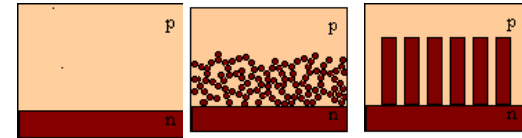
But compared to inorganic materials,

- **electron mobility** of photoactive polymers is extremely low.
- **stability** of photoactive polymers is poor.

Hybrid metal oxide/ polymer solar cells

Nanocrystalline metal oxides can be used as alternative electron acceptors in donor-acceptor solar cells:

- Effective acceptor materials (TiO_2 , ZnO , SnO_2) for photoinduced charge transfer from conjugated polymers.
- Reasonable electron mobility.
- Stability in air.
- Ease of fabrication and low cost.
- Control of morphology due to the metal oxides.

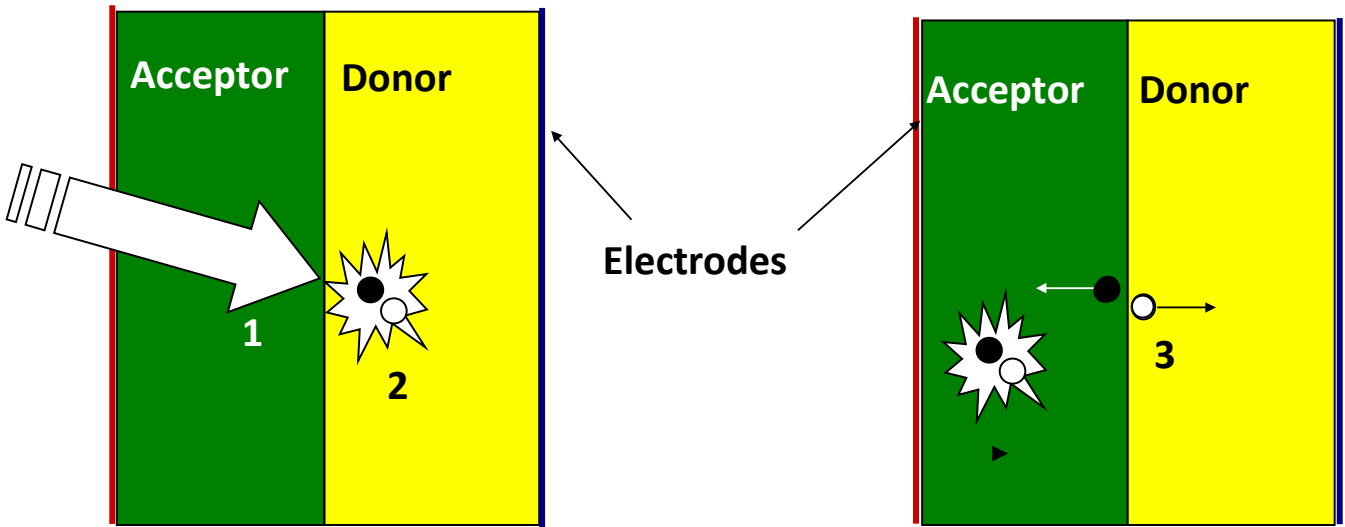


Device performance mainly influenced by

1) Photo-generation rate

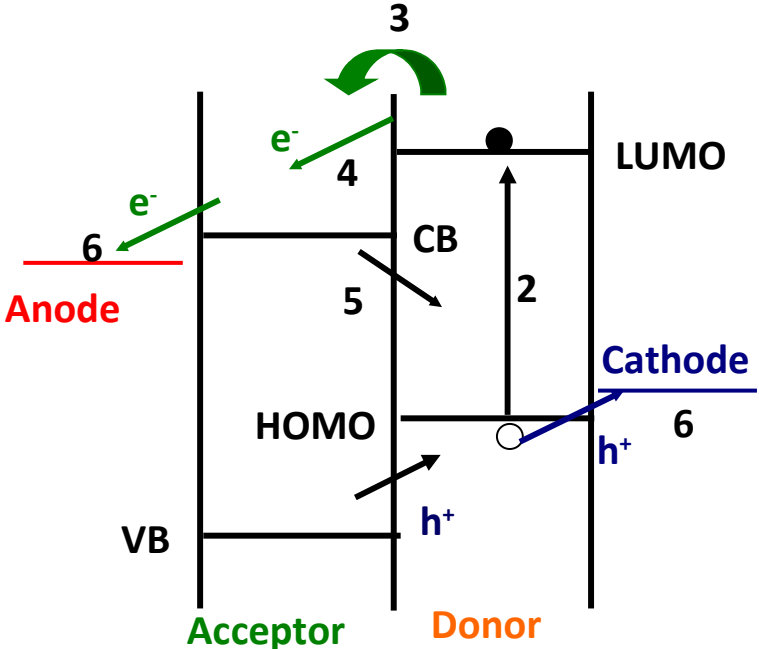
2) **Quality of interfaces** - by modifying the electronic properties of the interface we can be able to control the interfacial charge transfer rates

Photovoltaic effect in hybrid metal oxide/polymer solar cells

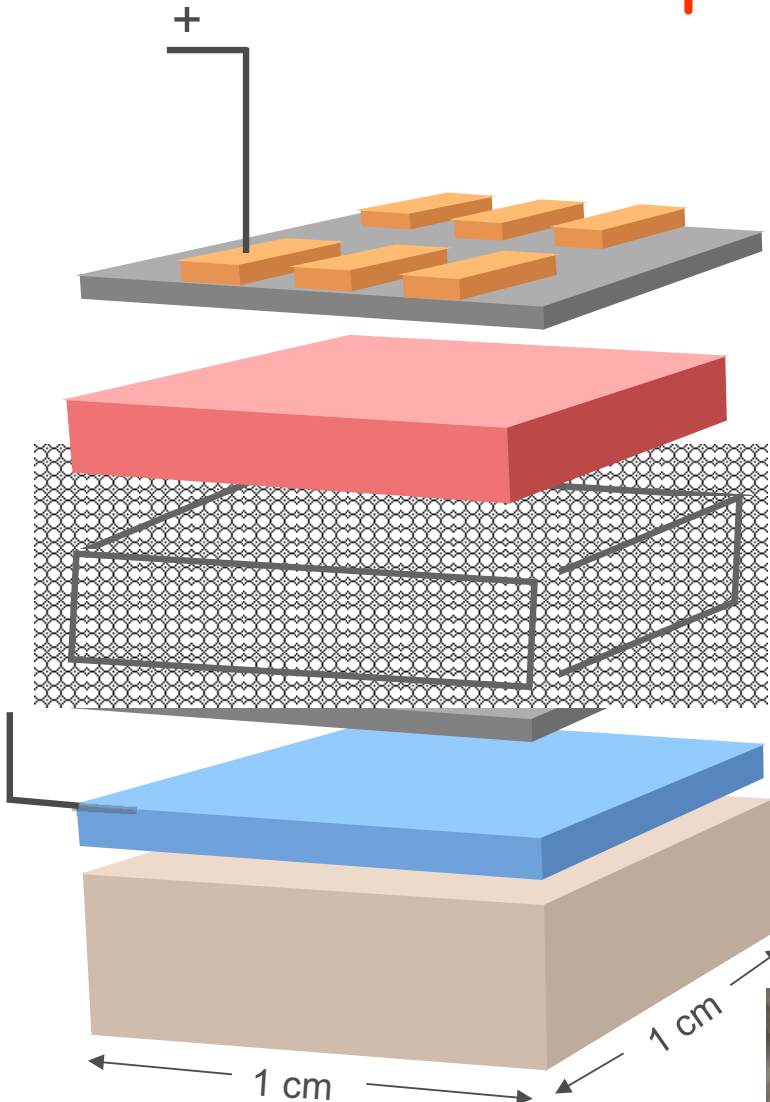


Exciton diffusion length ~ 5-20 nm

1. Absorption of light
2. Creation of electron-hole pair
3. Dissociation of electron-hole pair
4. Transport of charges
5. Recombination of charges
6. Collection of charges



Optimised device structure for Metal oxide/polymer solar cells



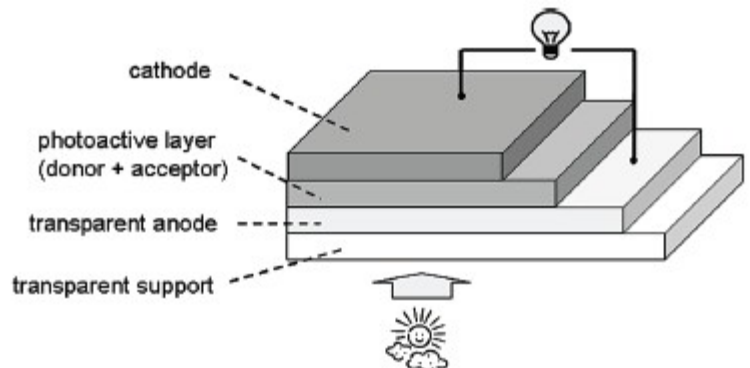
Au electrode (thermal evaporated)
PEDOT:PSS (spin-coated)

Polymer (~120 nm)
dip & spin coated

Porous metal-oxide film (~200 nm)
spin-coated and sintered

Dense compact metal-oxide film
spray pyrolysis (~ 30 nm)

ITO - transparent electrode
Glass



Device fabrication at the Department of Physics, UoJ



Nano-enclosure



Fume hood



Furnace



Programmable spin coater



Thermal Evaporator

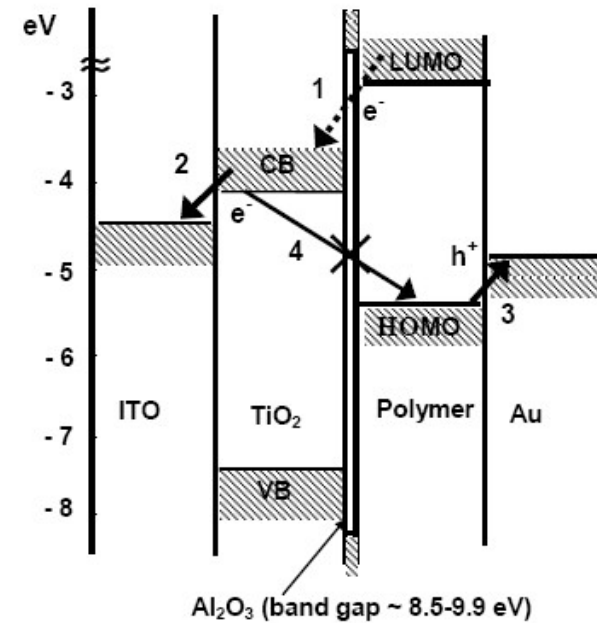
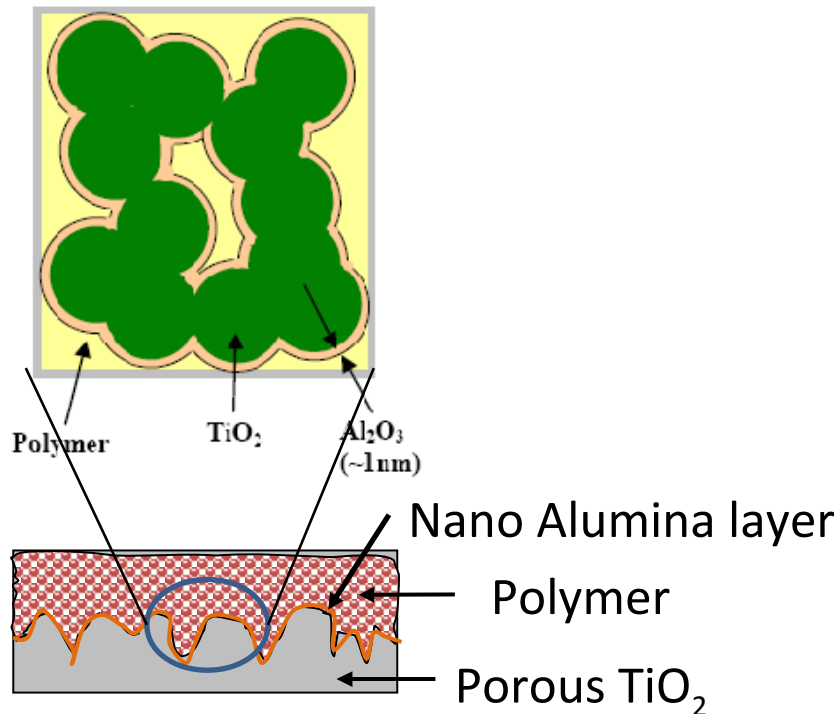


Glove box

Strategy for further optimisation

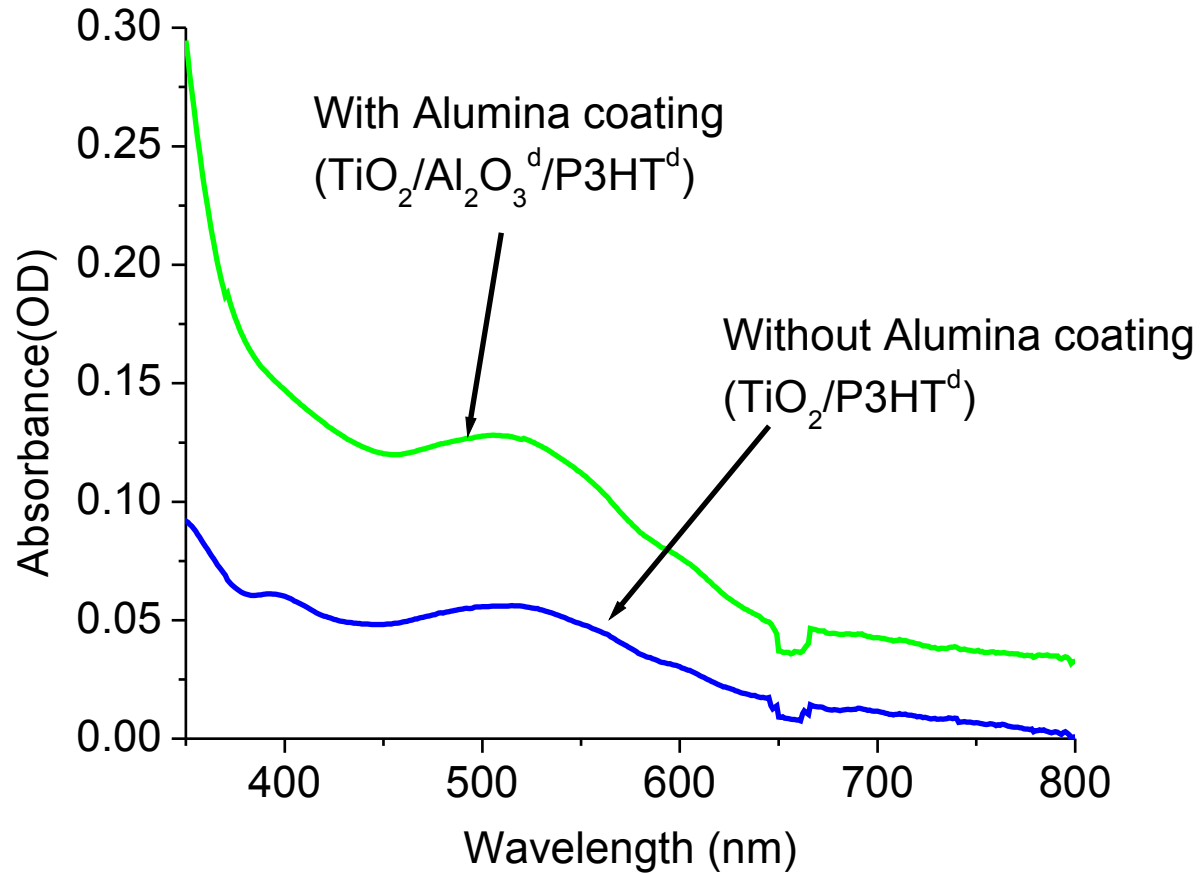
Modifying the interface

Modifying the Nano-interface with Alumina coating



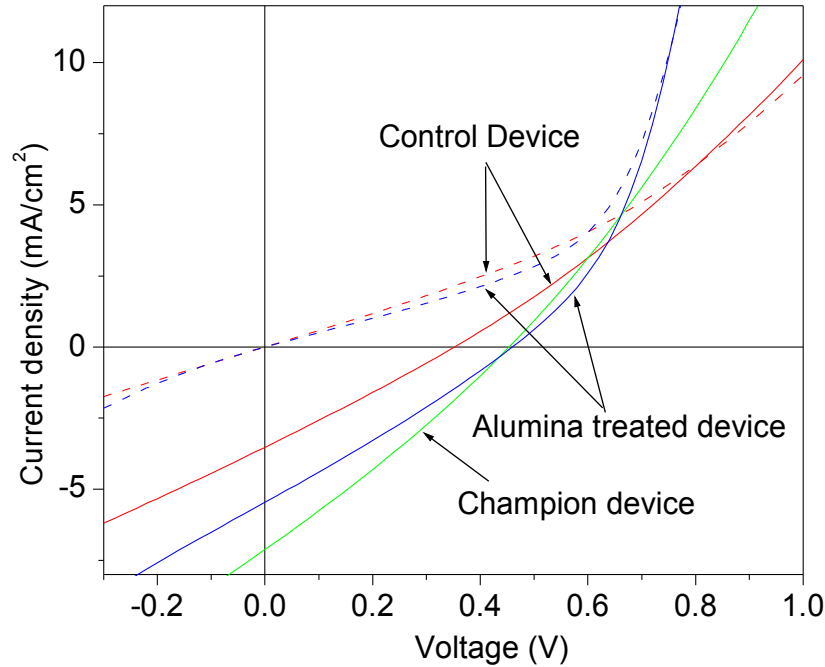
1. Concerning the interfacial energetics in a hybrid polymer / TiO₂ structure, treatment with alumina coating suppressing the interfacial recombination.
2. TiO₂ film with the alumina coating improves the polymer uptake due to the more basic surface of the alumina coated porous TiO₂ film than the bare film.

Absorbance

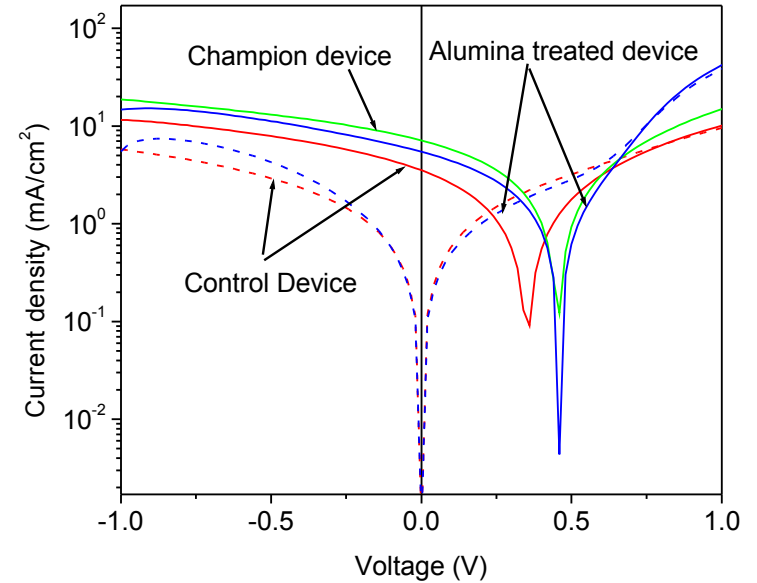


J-V characterization under solar simulator with AM1.5 filter

ITO/Dense TiO₂/Porous TiO₂/Al₂O₃^d/P3HT^d/P3HT^s/PEDOT:PSS/AU

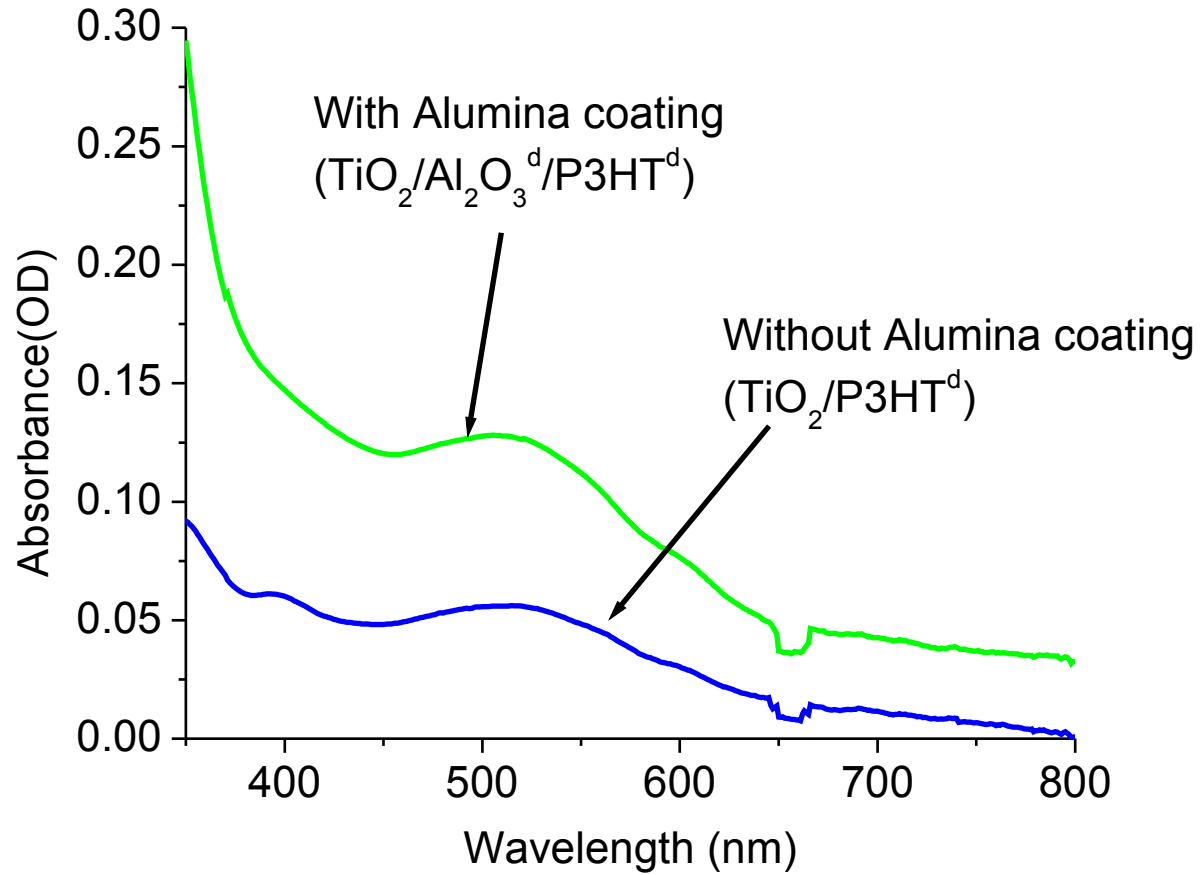


ITO/Dense TiO₂/Porous TiO₂/Al₂O₃^d/P3HT^d/P3HT^s/PEDOT:PSS/AU



Device	Jsc (mA/cm ²)	Voc (mV)	FF	Efficiency (%)
Without Alumina coated device	3.53	0.35	0.26	0.40
Alumina coated device	5.46	0.45	0.28	0.86
Best device	7.12	0.45	0.28	1.12

Absorbance



Conclusion

- Due to better polymer uptake by alumina coated electrode, the alumina coated device shows increase short circuit current density compared to devices with uncoated electrode.
- The increase in V_{oc} for alumina coated device is attributed to the suppression of interfacial recombination by the insulating alumina layer.
- Due to better attachment of polymer on alumina coated surface and suppression of interfacial recombination, the amount of charge carriers produced in the active layer reaching the top electrode are increased. Thus the alumina coating improves the overall power conversion efficiency over 100 %.

Thank You

Nanotechnology work at the Department of Physics, University of Jaffna

Research grants of over **300,000 US\$ (33 million rupees)** had been won
by the staff for the following Research Projects

Title of the Projects, Status and Principle investigator(PI)	Source	Amount LKR	List of Major equipments received under these grants
<p>Optoelectronic properties of hybrid Metal oxide / Polymer Nano–composites (Revised title since May 2005) - Completed Dr. L. Jeyanathan (PI) (2000 – 2005) Dr. S. Sivaraya (2000 – 2008) Dr. P. Ravirajan (2005 – 2008)</p>	<p>NRC Sri Lanka</p>	<p>11,000,000 (100,000US\$)</p>	<p>Turbo Molecular Pump, Closed Cycled Cryostat, Compressor, Tube Furnace, Photoluminescence Spectrometer assembly</p>
<p>Hot Electron Spectroscopic Studies of indirect tunnel barriers-Completed Dr. S. Sivaraya (2004 – 2005)</p>	<p>TWAS Italy</p>	<p>770,000 (7,000 US\$)</p>	<p>Source Measure Unit</p>
<p>Low cost solar cells based on Nanocrystalline titanium dioxide and vegetable dyes – Completed Prof. P. Ravirajan (PI) (2006 – 2009)</p>	<p>IFS Sweden</p>	<p>1,100,000 (10,000 US\$)</p>	<p>Solar Simulator, Digital Scope</p>
<p>Fabrication and Characterization of Hybrid organic / metal oxides Nanostructured photovoltaic devices – Completed Prof. P. Ravirajan (PI) (2006 – 2009)</p>	<p>NRC, Sri Lanka</p>	<p>8,350,00 (75,000 US\$)</p>	<p>Thermal Evaporator, Programmable Spin processor, Pulsed Laser, Monochromator</p>
<p>Characterization of Nanostructured polymer / Fullerene solar cells under sun light – Completed Prof. P. Ravirajan (PI) (2007 – 2011)</p>	<p>NSF Sri Lanka</p>	<p>1,900,000 (17,000 US\$)</p>	<p>Glove box</p>
<p>Improving the performance of Hybrid Nanocrystalline Titanium Dioxide (TiO₂) / Polymer solar cell using interface modifiers – In progress. Prof. P. Ravirajan (PI) (2011 – 2014)</p>	<p>NRC Sri Lanka</p>	<p>8,000,000 (72,000 US\$)</p>	<p>Box furnace Fume cupboards Thickness monitor Nano-enclosure UV Visible spectrometer</p>

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