Macroporous TiO_2 Photoanodes for High Efficiency PSI-Based Biohybrid Photovoltaics

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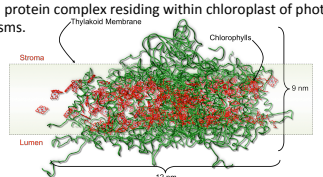
Introduction

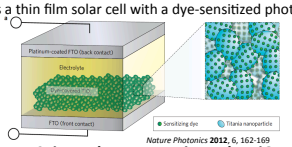
Photosystem I (PSI)

PSI is a protein complex residing within chloroplast of photosynthetic organisms.



Dye-Sensitized Solar Cell (DSSC)

DSSC is a thin film solar cell with a dye-sensitized photoanode.



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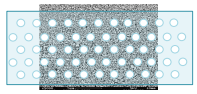
Problem: PSI is too large to get in to the TiO_2 coating.

Mesoporous TiO_2:
Pore size less than 50nm

PSI size:
Diameter greater than 100nm when solubilized by surfactants



Our approach:
make macroporous TiO_2 coating with pore size larger than the diameter of PSI through sacrificing templating.

Methods

Procedure:

Make a TiO_2 dispersion with templating materials

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Doctorblade the templated TiO_2 dispersion on FTO

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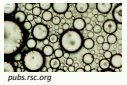
Sinter the film at 500 °C for 30 mins

↓

Cool overnight

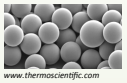
Templating materials:

- Oil-in-water emulsion



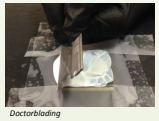
60% paraffin oil, 40% water, Span 80, and Tween 80.

- Polystyrene latex



Aqueous suspension; 1 µm in diameter.

Doctorblading:



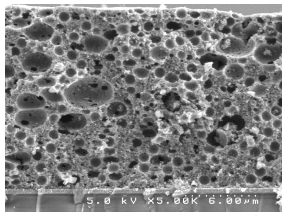
TiO_2 is spread out on FTO by a razor blade.

Results of Macrotemplating

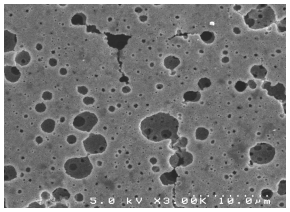
Templated macroporous films have been made from TiO_2 powder:

- SEM: macroporous films exhibit high porosity and interconnected pores.

Templated by 60% oil-in-water emulsion and 1 µm polystyrene

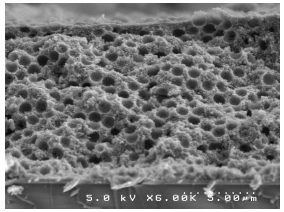


Cross section



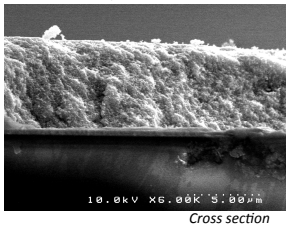
Top view

Templated by 1 µm polystyrene



Cross section

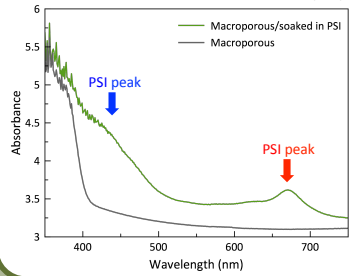
Control: untemplated film



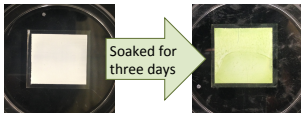
Cross section

- UV-Vis Spectrophotometry: after soaked in PSI solution for three days, macroporous films demonstrate high PSI incorporation.

60% oil-in-water emulsion and 1 µm polystyrene templated TiO_2 Films

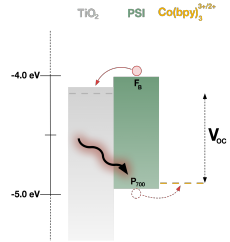


Macroporous TiO_2 film turns green after soaking in 1µM PSI solution:

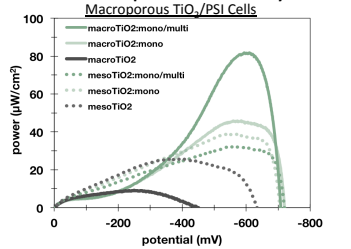


Electrochemical Analysis

Macroporous films exhibit significant enhancement in power and efficiency:



Macroporous TiO_2/PSI Cells



Cell	P_{MP} (µW/cm²)	Efficiency	Enhancement
macroTiO_2	9	.010%	- ("a")
macroTiO_2:monoPSI	46	.048%	**5.0 x a**
macroTiO_2:monoPSI/multiPSI	82	.086%	**9.0 x a**
mesoTiO_2	26	.027%	- ("b")
mesoTiO_2:monoPSI	39	.041%	**1.51 x b**
mesoTiO_2:monoPSI/multiPSI	33	.034%	**1.26 x b**

Conclusion

- Macroporous TiO_2 films have been successfully made. They exhibit high porosity and interconnected meso (less than 50nm in diameter) and macro (on the order of micrometer) pores under SEM.
- The macroporous TiO_2 films demonstrate increased absorbance of PSI according to UV-Vis spectrophotometry.
- Using the designed macroporous TiO_2 film as a photoanode largely enhances the overall power and efficiency of PSI-based biohybrid photovoltaics due to the high integration of PSI and TiO_2.

Future Work

Further research will be carried to:

- continue to study the effect of the added porosity on PSI and TiO_2 interface through cell performance studies;
- to reduce diffusional constraints by raising the mediator concentration.

References

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