Porphyrin-based Solar Cells

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ICTP
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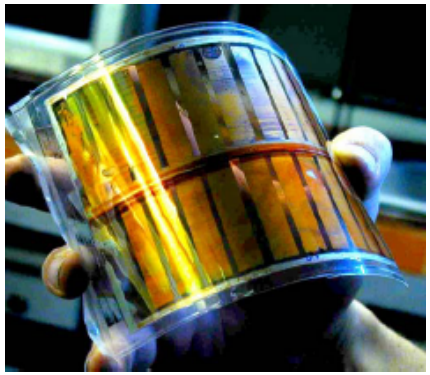
My Current Research Interest:

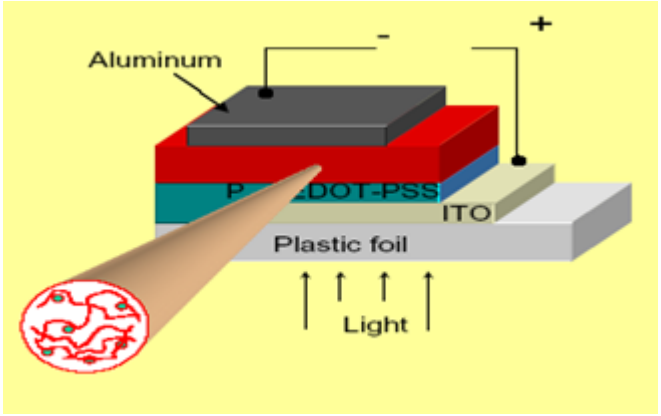
Porphyrin- and Phthalocyanine-based Materials for

- Organic Solar Cells

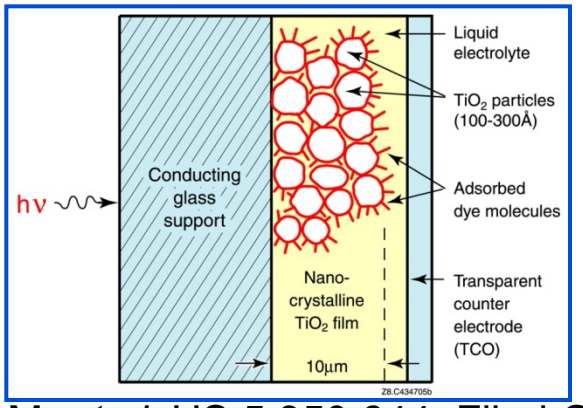


- Photo-/Photoelectrocatalysis
  - CO_2 reduction
- Petroleum Markers
- Biomedical applications

- **Bulk-heterojunction solar cells (BHJ-SCs)**



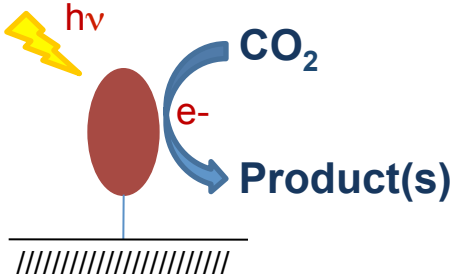
Sariciftci, N. S *et al.* US.5,331,183. Filed Aug 17, 1992. Issued Jul 19, 1994.



- **Dye-sensitized solar cells (DSSCs)**

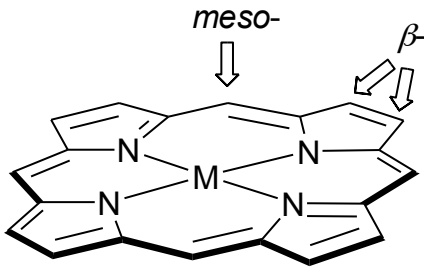
Grätzel, M. *et al.* US.5,350,644. Filed Oct 15, 1992. Issued Sep 27, 1994.

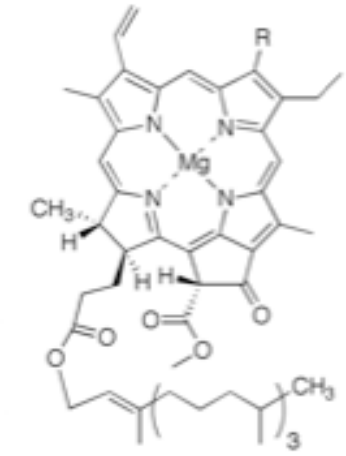
- **Photo- and photoelectrochemical CO_2 reduction**



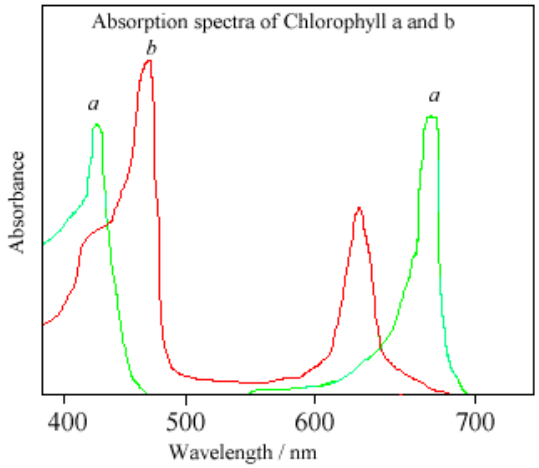
Porphyrins

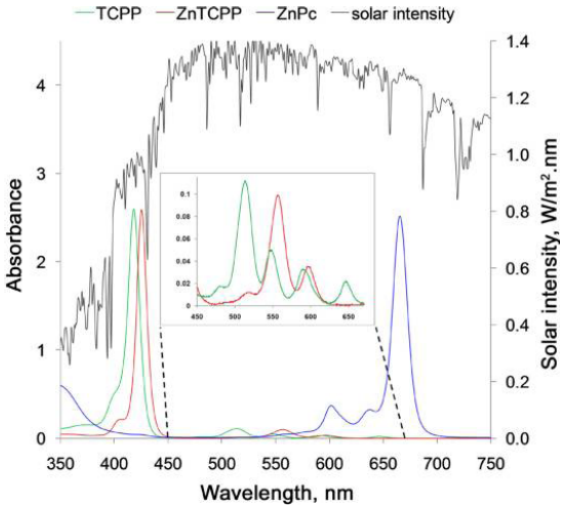
- 16-membered aromatic ring with 18-π electrons
- Close derivative of chlorophylls and heme
- Adjustable ground-state optical characteristics and excited-state properties





R = CH_3 Chlorophyll a
R = CHO Chlorophyll b





Picture from *J. Porphyrins Phthalocyanines* 2010; **14**: 761–792.

Porphyrin-Sensitized Solar Cells with Cobalt (II/III)–Based Redox Electrolyte Exceed 12 Percent Efficiency

Aswani Yella,[1] Hsuan-Wei Lee,[2] Hoi Nok Tsao,[1] Chenyi Yi,[1] Aravind Kumar Chandiran,[1] Md.Khaja Nazeeruddin,[1] Eric Wei-Guang Diau,[3]* Chen-Yu Yeh,[2]* Shaik M Zakeeruddin,[1]* Michael Grätzel[1]*

The iodide/triiodide redox shuttle has limited the efficiencies accessible in dye-sensitized solar cells. Here, we report mesoscopic solar cells that incorporate a $Co^{(II/III)}$tris(bipyridyl)–based redox electrolyte in conjunction with a custom synthesized donor-π-bridge-acceptor zinc porphyrin dye as sensitizer (designated **YD2-*o*-C8**). The specific molecular design of **YD2-*o*-C8** greatly retards the rate of interfacial back electron transfer from the conduction band of the nanocrystalline titanium dioxide film to the oxidized cobalt mediator, which enables attainment of strikingly high photovoltages approaching 1 volt. Because the **YD2-*o*-C8** porphyrin harvests sunlight across the visible spectrum, large photocurrents are generated. Cosensitization of **YD2-*o*-C8** with another organic dye further enhances the performance of the device, leading to a measured power conversion efficiency of 12.3% under simulated air mass 1.5 global sunlight.

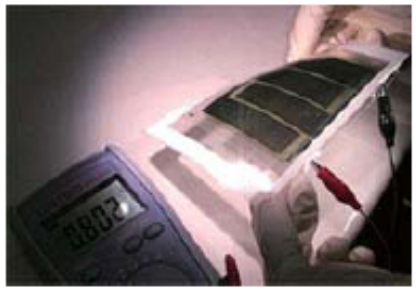
www.sciencemag.org **SCIENCE** VOL 334 4 NOVEMBER 2011

+Plastic ELECTRONICS
Independent Analysis for Organic and Printable Electronics

Mitsubishi OPV achieves 8.5% efficiency

18 Apr 2011

Japan's Mitsubishi Chemical has developed the world's first solution conversion type organic photovoltaic (OPV) and is aiming for 10% efficiency by the end of 2011.



According to recent press reports the company has announced efficiencies of 8.5%, though these have yet to be verified by an independent testing lab.

Where a conventional silicon solar cell works by integrating p-type and n-type semiconductors to convert light energy into electricity, Mitsubishi's OPV is produced by adding two coatings of organic compounds to a film substrate. Benzoporphyrin acts as the p-type semiconductor, and a fullerene layer acts as the n-type semiconductor.

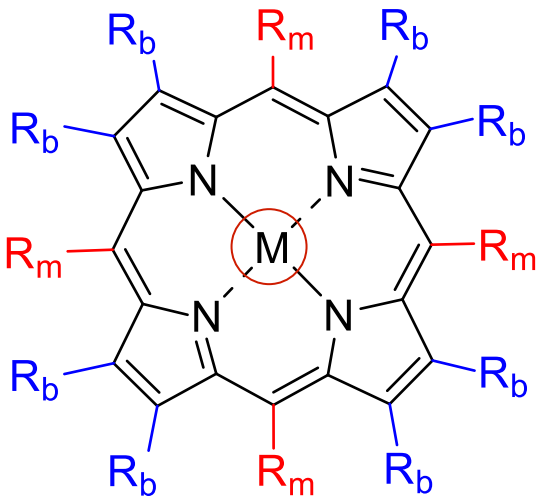
The nanolayers of active cell enable the production of thin, highly flexible and easily bendable PVs.

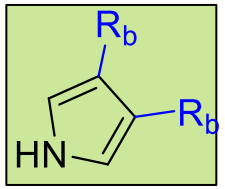
Mitsubishi Chemical is aiming to commercialise the OPV by 2015 and is targeting efficiencies of 15% by then. The technology has been developed by the company in cooperation with the University of Tokyo and Ehime University. Good conductivity and durability have been demonstrated.

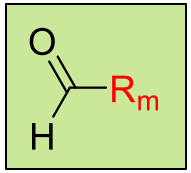
Target applications include building-integrated PV products. Mitsubishi has an existing PV business based on crystal and thin-film amorphous silicon technologies.

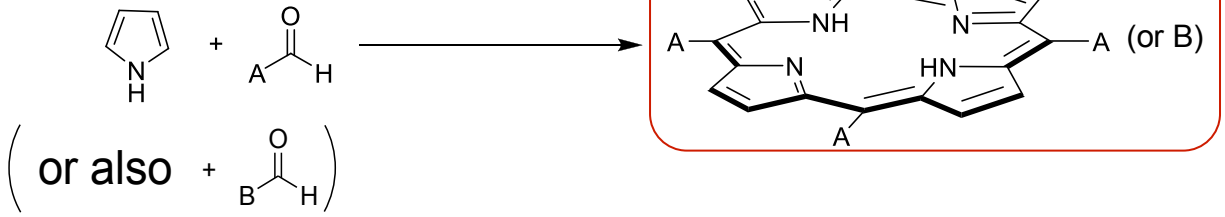
Structural Modification for Various Applications

Porphyrin

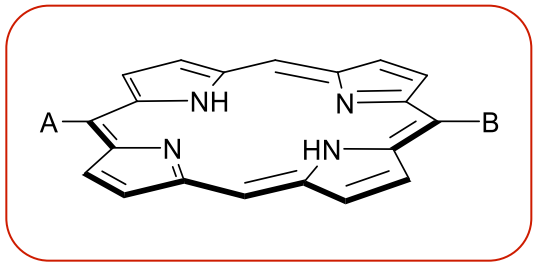




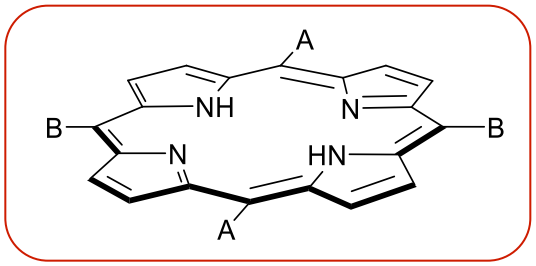




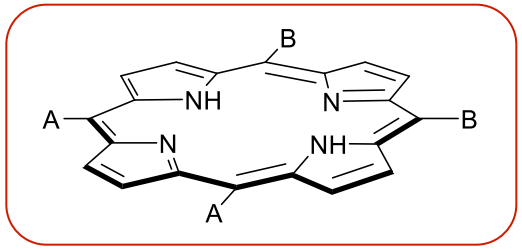
A_4-Porphyrin
or
A_3B-Porphyrin



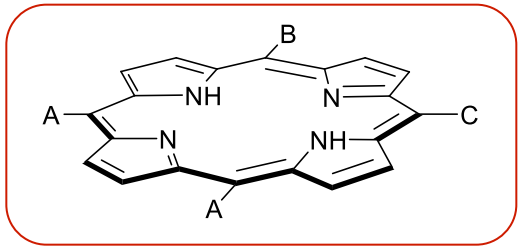
***trans*-AB-Porphyrin**



***trans*-A_2B_2-Porphyrin**

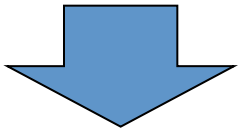


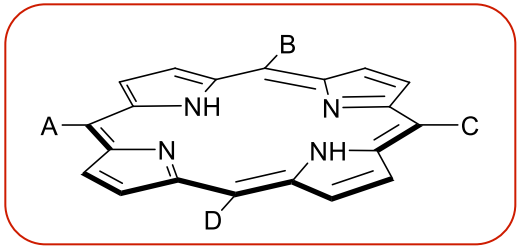
***cis*-A_2B_2-Porphyrin**



***cis*-A_2BC-Porphyrin**

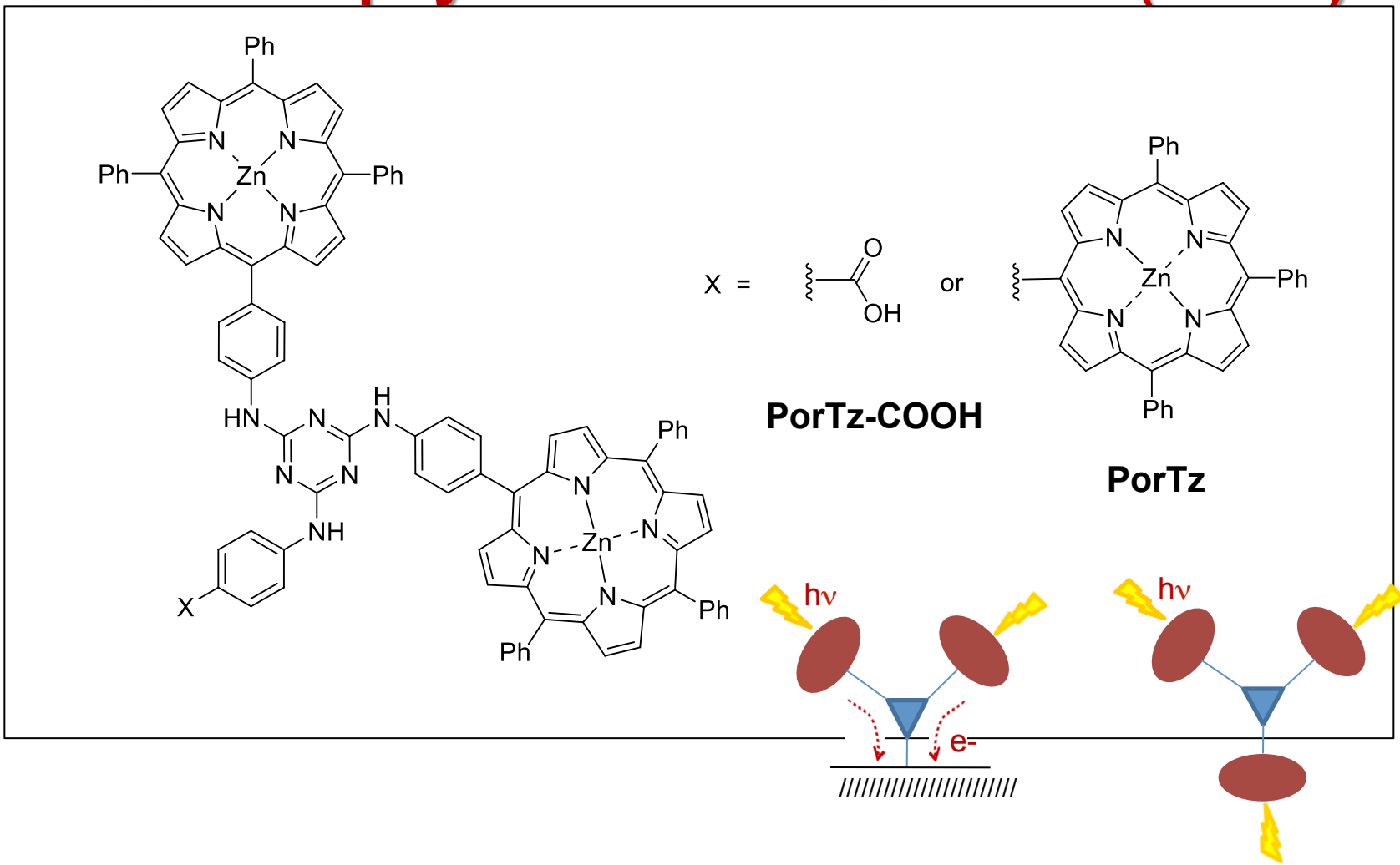
….., etc.





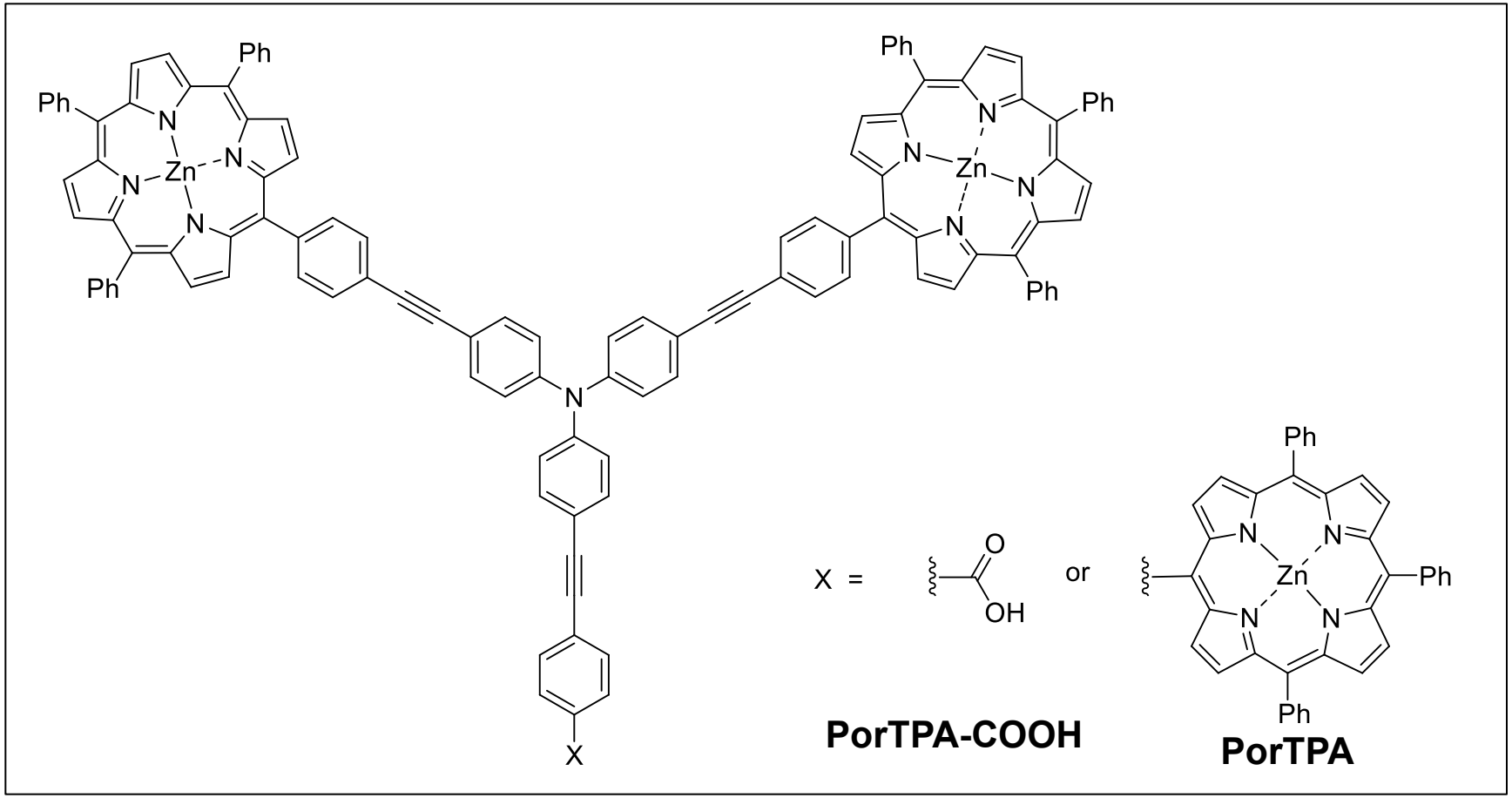
ABCD-Porphyrin

Series 1: Porphyrin-Triazine Derivative (PorTz)



Luechai, A.; Petsom, A.; Gasiorowski, J.; Neugebauer, H.; Sariciftci, N. S.; Thamyongkit, P. *J. Mater. Chem*. **2012**, *22*, 23030–23037.
Luechai, A.; Pootrakulchote, N.; Kengthanomma, T.; Vanalabhpatana, P.; Thamyongkit, P. *J. Organomet. Chem.* **2014**, *753*, 27–33.

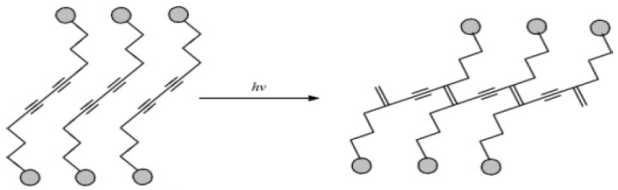
Series 2: Porphyrin-Triphenylamine Derivatives (PorTPA)



Kengthanomma, T.; Gasiorowski, J.; Ramil, A. M.; Sariciftci, N. S.; Thamyongkit, P. J. Mater. Chem. A. 2013, 1, 10524–10531.
Luechai, A.; Pootrakulchote, N.; Kengthanomma, T.; Vanalabhpatana, P.; Thamyongkit, P. *J. Organomet. Chem.* **2014**, *753*, 27–33.

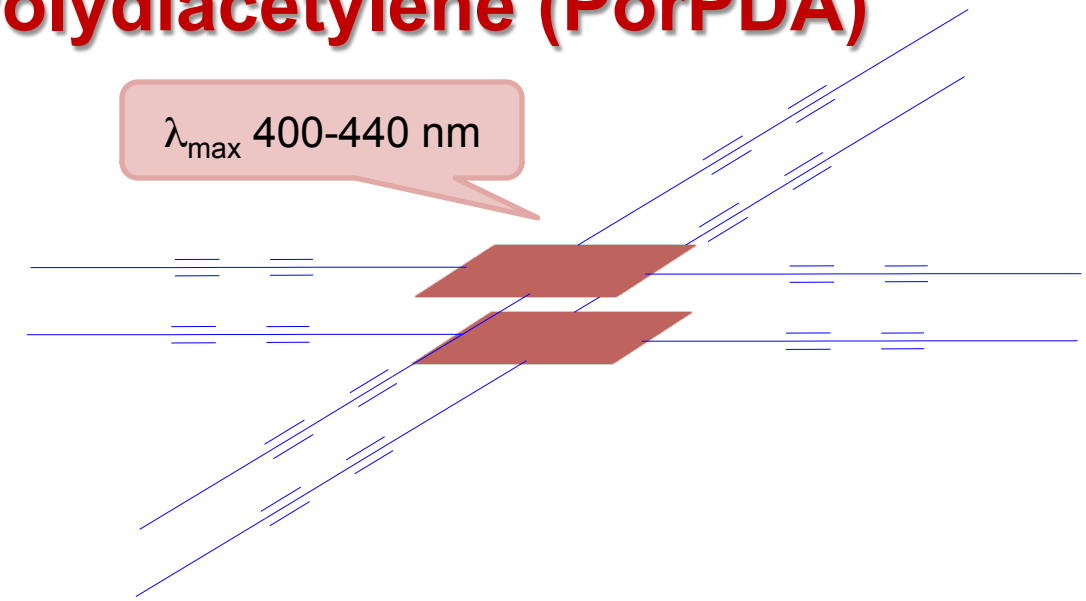
Series 3: Porphyrin-Polydiacetylene (PorPDA)

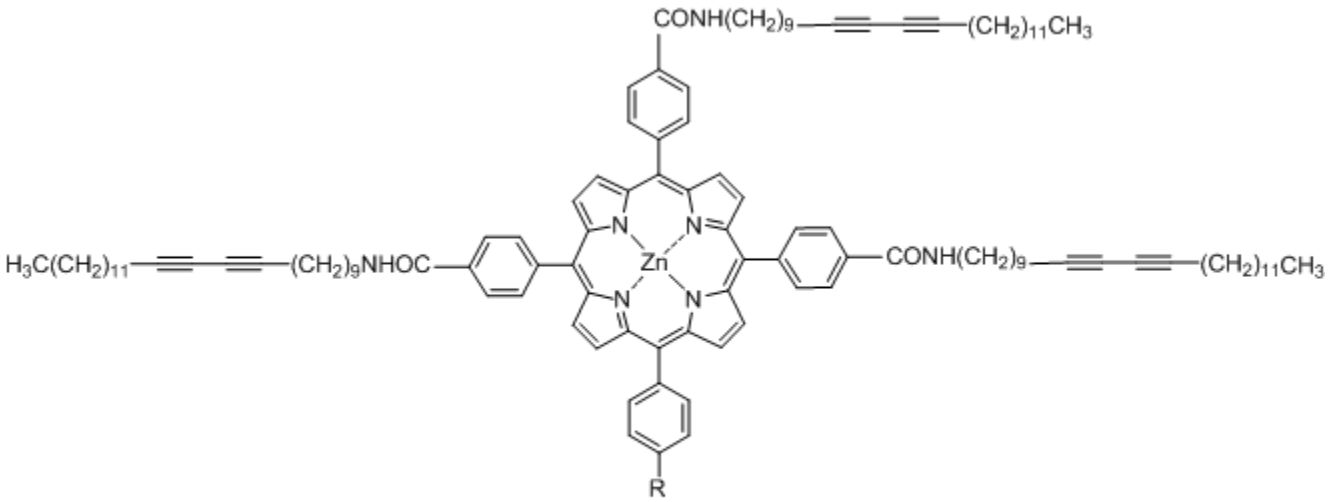
λ_{max} 600-650 nm



Diacetylene (DA) Polydiacetylene (PDA)

λ_{max} 400-440 nm



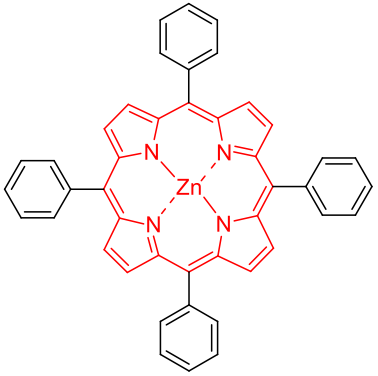


PorDA: R = - $CONH(CH_2)_9$ $(CH_2)_{11}CH_3$

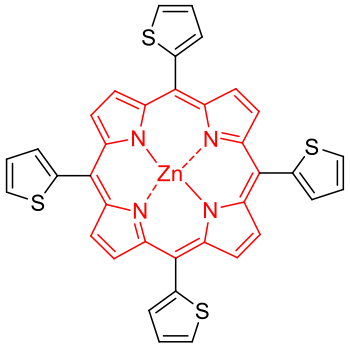
PorDA-COOH: R = -COOH

Reanprayoon, C.; Gasiorowski, J.; Sukwattanasinitt, M.; Sariciftci, N. S.; Thamyongkit, P. *RSC Adv.* **2014**, *4*, 3045–3050.

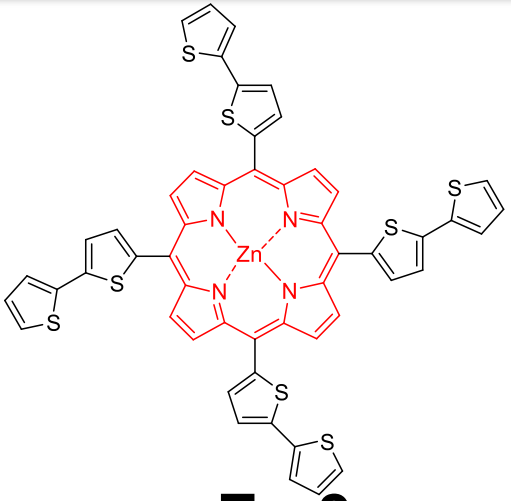
Series 4: Porphyrin-thiophene Conjugates for BHJ-Scs



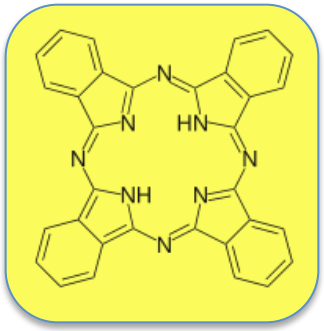
Zn-1

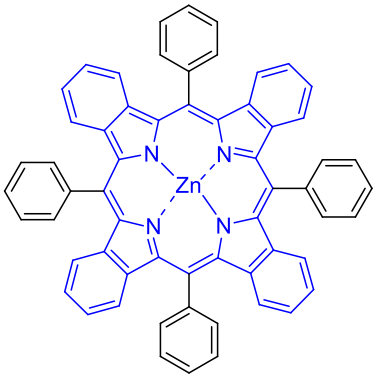


Zn-2

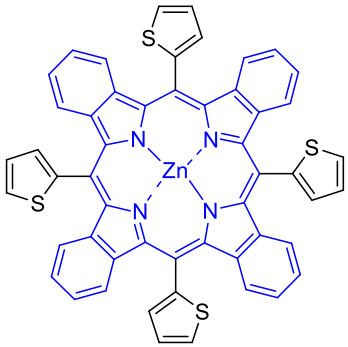


Zn-3

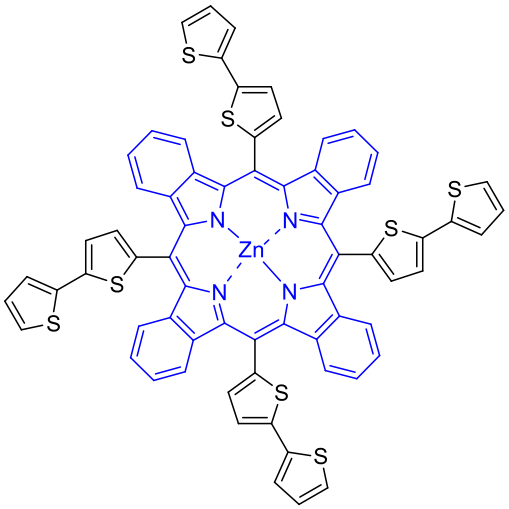




Zn-4

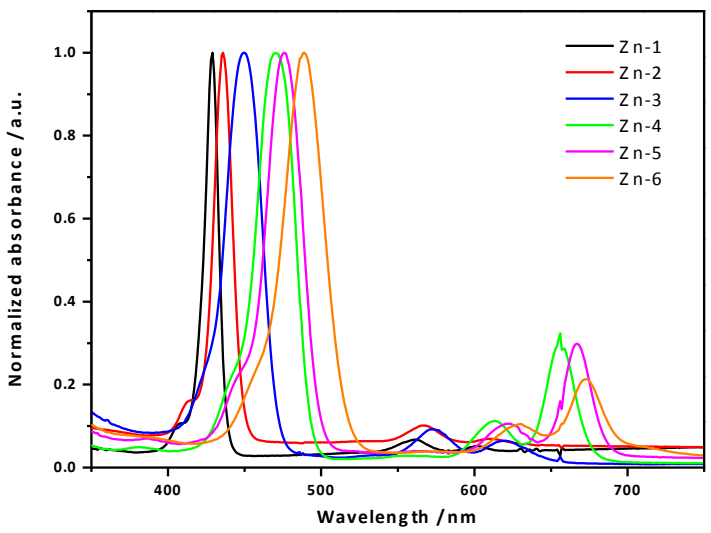


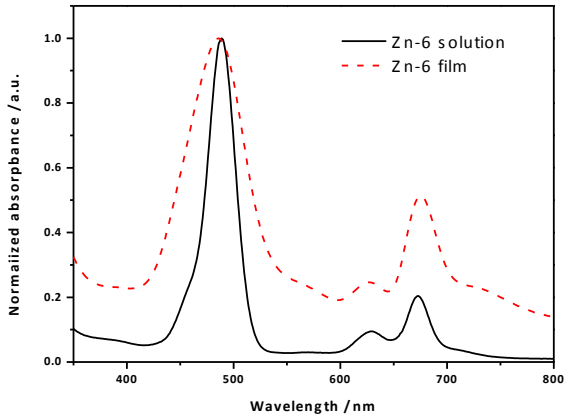
Zn-5



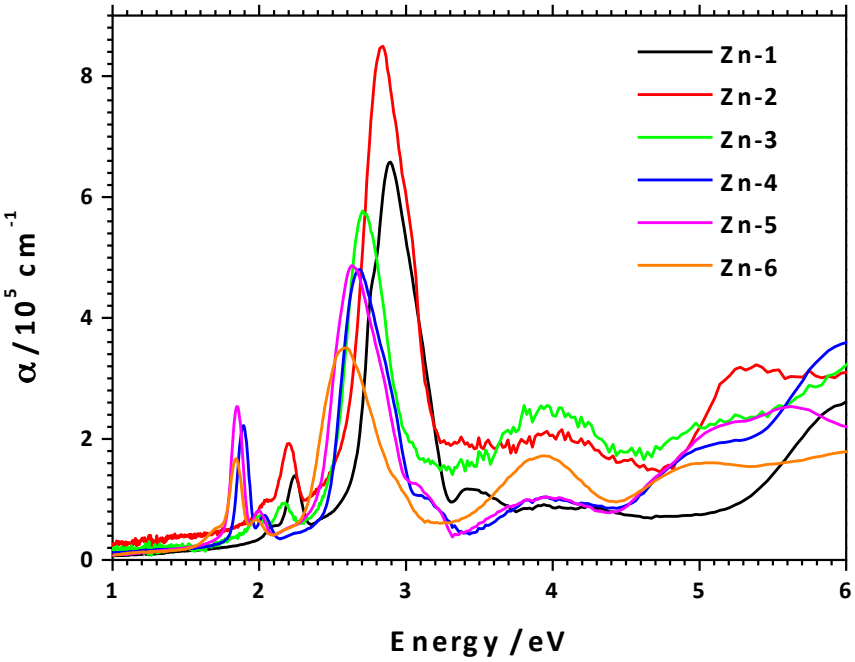
Zn-6

UV-Vis spectrophotometry





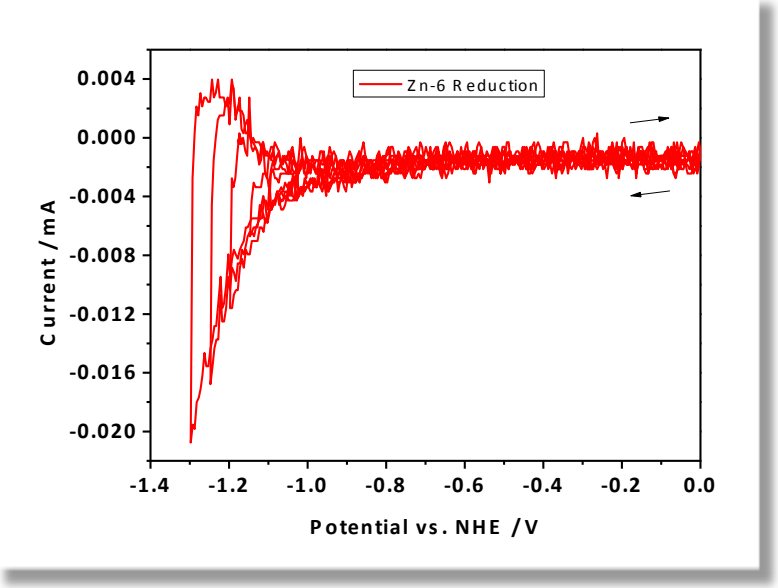
Ellipsometry measurement

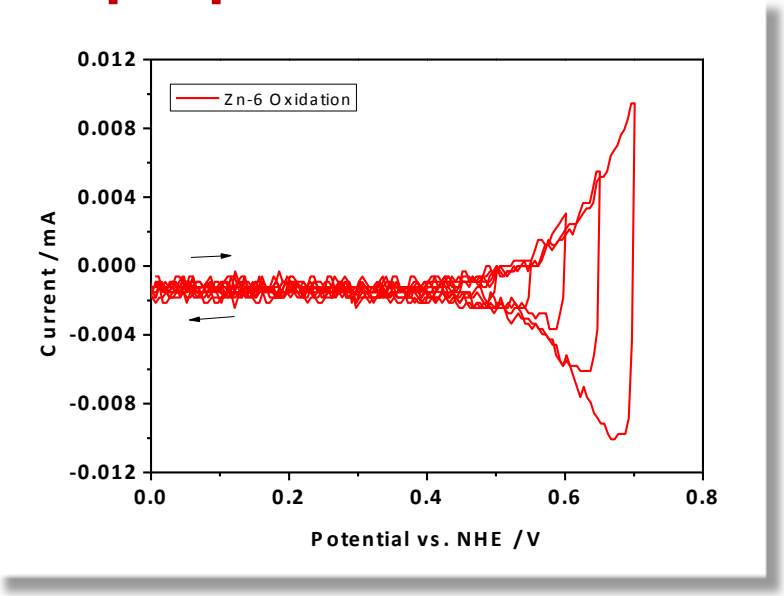


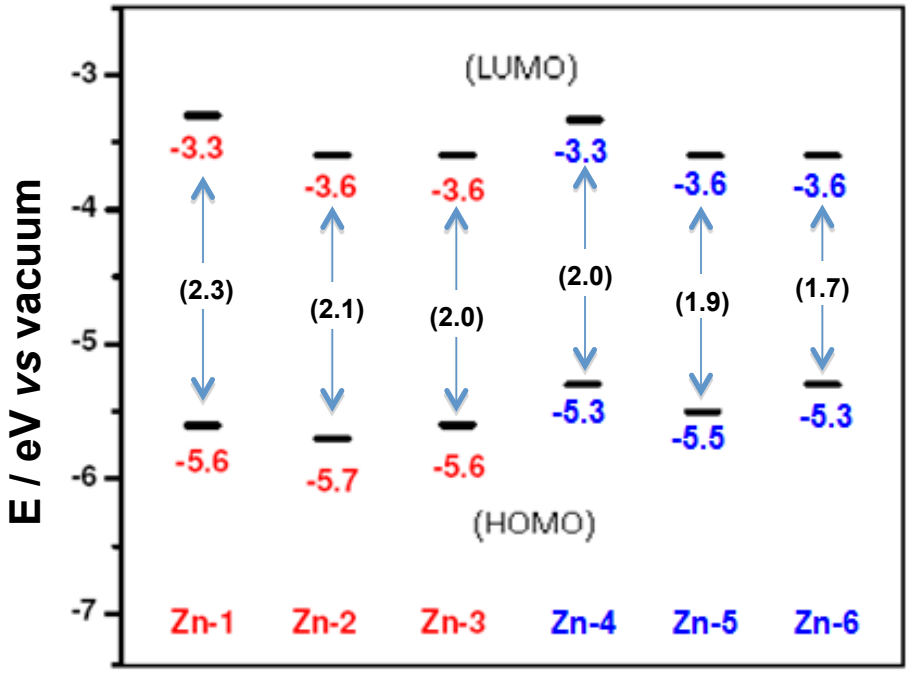
Compound	Soret / Q-band (nm) (ε, 10^5 M^{-1} cm^{-1})[a]
Zn-1	429 (5.7) / 561, 600
Zn-2	436 (4.4) / 567, 610
Zn-3	450 (3.5) / 574, 620
Zn-4	470 (1.9) / 613, 656
Zn-5	476 (2.0) / 622, 667
Zn-6	487 (2.5) / 630, 673

Diskin-Posner Y. *et. al. Acta Crystallographica Section E.* **2001**, *57*, m346-m348.

Electrochemical properties





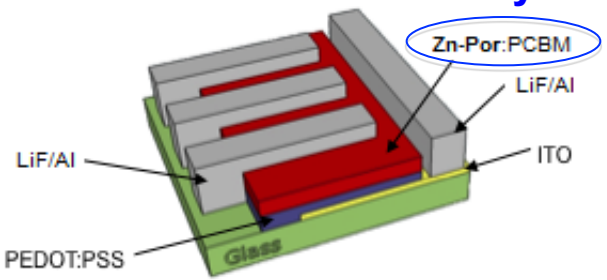


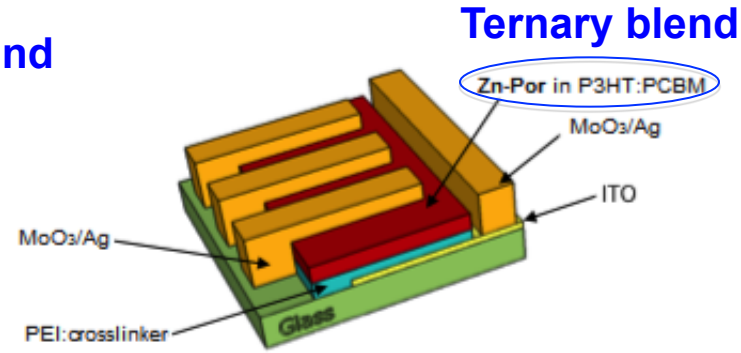
$E_g = E_{ox} - E_{red}$;

$E_{HOMO} = -(E_{ox} + 4.75)$ (eV);

$E_{LUMO} = -(E_{red} + 4.75)$ (eV)

Device studies





Conventional cell

Inverted cell

Reference cell

J_{sc} (mA/cm^2)	2.0 – 2.4	6.8	8.1 – 8.2
V_{oc} (V)	0.42 – 0.56	0.60	0.61
%FF	32 – 35	70	68 – 70
%η	0.32 – 0.39	3.55	4.23 – 4.33

Acknowledgement

Linz Institute for Organic Solar Cells (LIOS)
Johannes-Kepler University Linz, Austria

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- Assist. Prof. DI Dr. Markus Scharber
- Dr. Jacek Gasiorowski
- Patrick Denk

All LIOS and Thamyongkit's group members




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Thank you!