



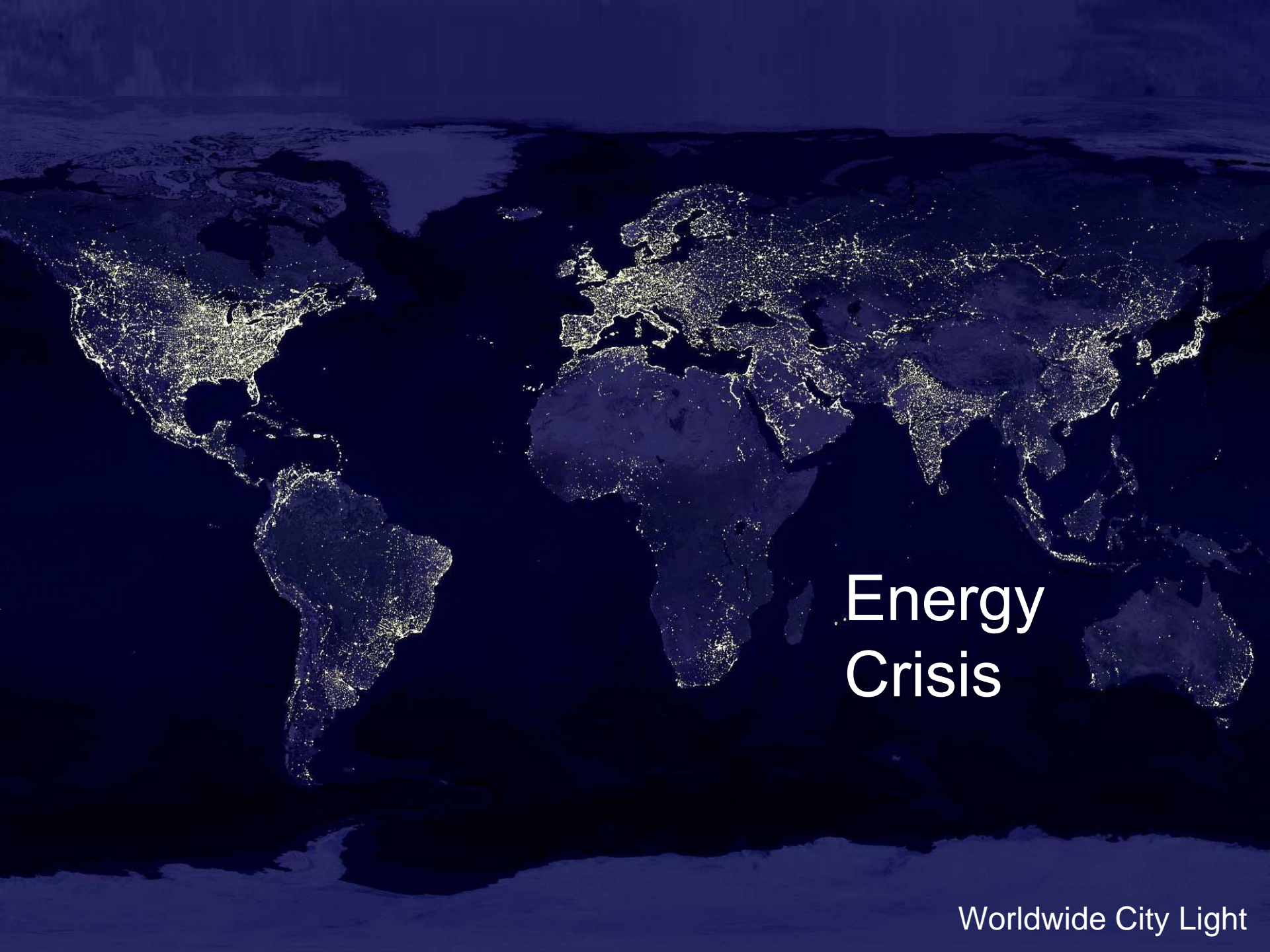
Dye Sensitized Solar Cells (DSSCs): Materials and Perspectives

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27th Nov. 2015

¹Technische Universität München

²Ludwig-Maximilians-Universität München
LMU



Energy Crisis

Worldwide City Light



Global Consensus

Photosynthesis
principle



New Type Third Generation Dye-sensitized Solar Cells

Environmental Friendly



15%
Reduction in
Manufacturing
Waste water



1
Toxic chemicals
Phased out
Of production



6%
Energy
consumption
Reduction
over 2 years

Outline...

I. Introductions

- a. Historical Review
- b. Principle of DSSC

II. Materials

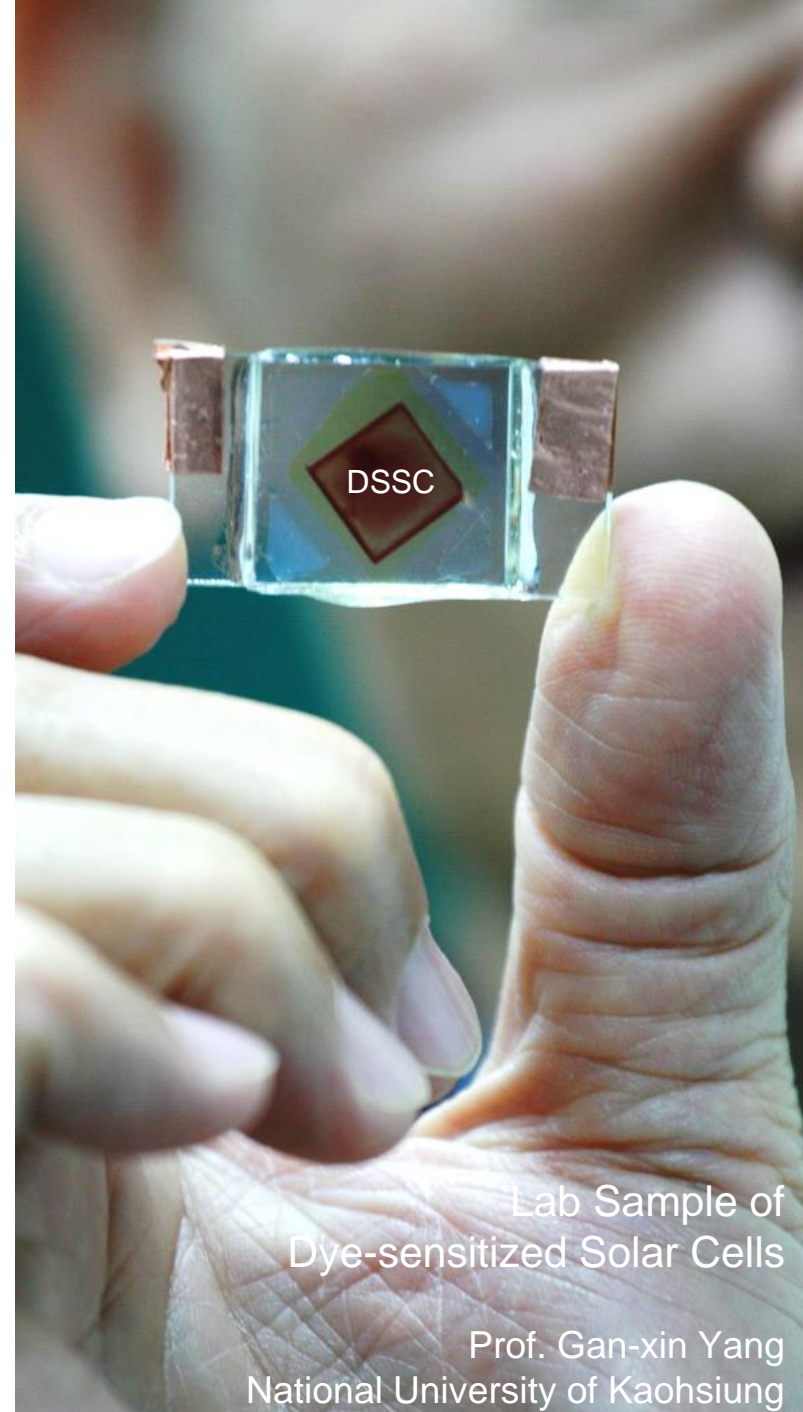
- a. Anode
- b. Cathode
- c. Dye
- d. Electrolyte

III. Specific Example

- a. Bachelor Thesis

IV. Summary and Outlook

- a. Summary of DSSC
- b. Promising Application



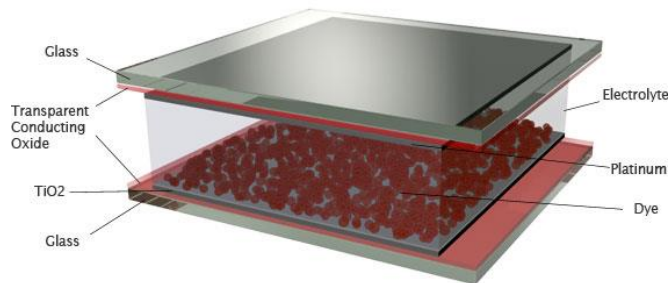
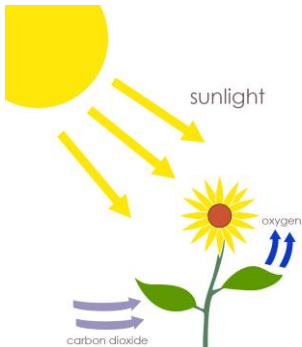
Lab Sample of
Dye-sensitized Solar Cells

Prof. Gan-xin Yang
National University of Kaohsiung

1.

Introductions

Historical Review & Principle



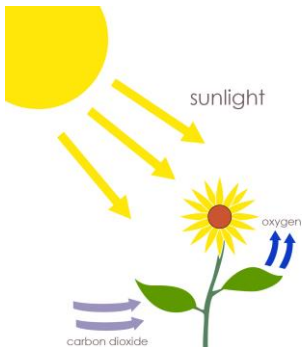


Historical Review of DSSC

1. Pre-concept

1960 - 1972

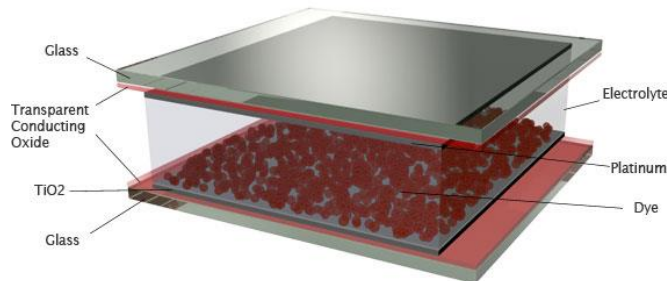
- At UC Berkeley
- Demonstrated
- Instability Problem
- Prototype of DSSC



2. Grätzel cell

1988 - 1991

- UC Berkeley & EPFL
- First publication of high efficiency DSSC
- M. Grätzel was awarded Millennium Tech Prize in 2010 for this invention



3. Modified DSSC

1991-2015

- Enhanced Anode, Cathode
- New Dyes and Electrolytes
- Greatly Improved Efficiency
- Large Area



4. Future DSSC

2016-2050

- Integration
- Flexibility
- Manufacturing
- Commercialization





Prof. Michael Grätzel
Lab of Photonics And Interfaces
EPFL, Switzerland

What is the Dye sensitized Solar Cells?

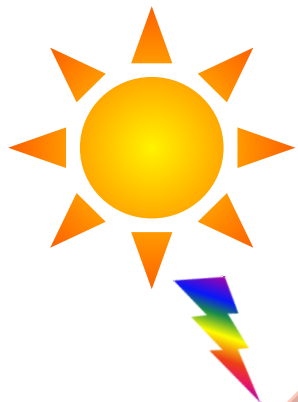
Definition and Principle



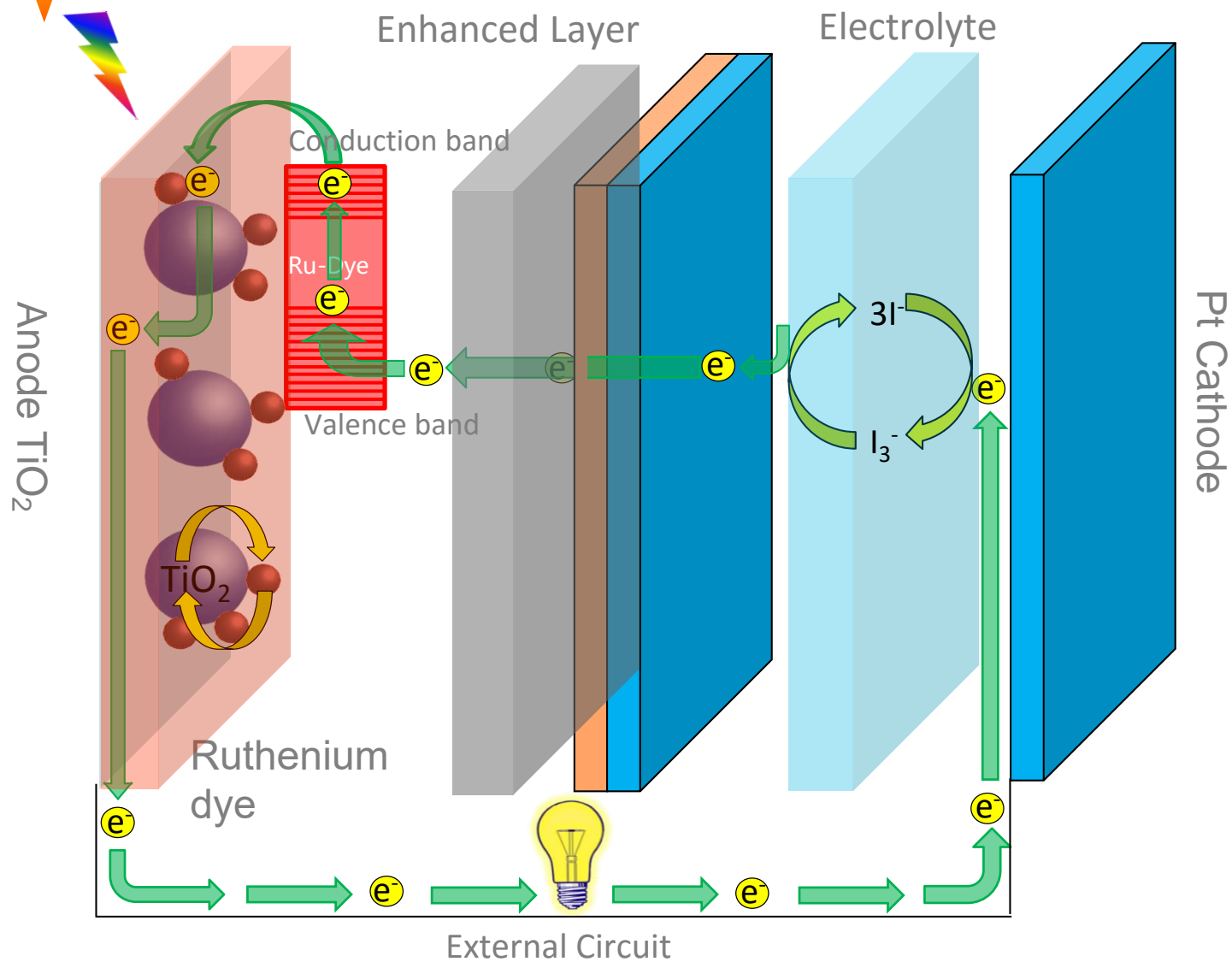


”

“Dye-sensitized solar cells are a special kind of a low-cost thin films solar cell that efficiently converts visible light into electrical energy.”



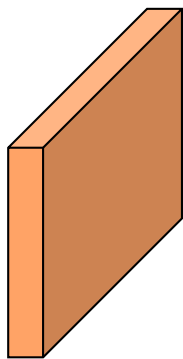
SCHEMATIC OF PRINCIPLE



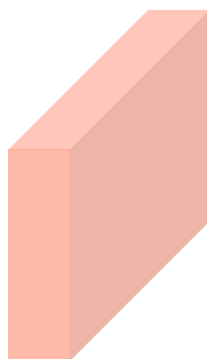
2.

Materials

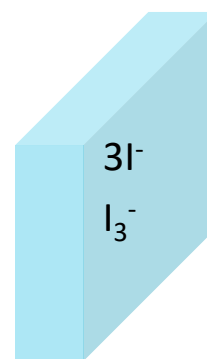
Anode, Cathode, Dye and Electrolyte



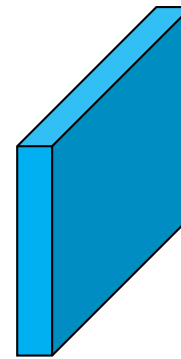
Anode



Dye

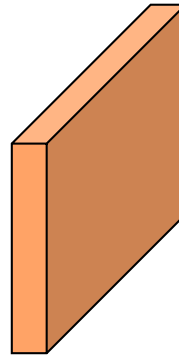


Electrolyte



Cathode

Anode



Materials

Nanoparticles, wires

$\text{TiO}_2/\text{SnO}_2/\text{ZnO}/\text{Nb}_2\text{O}_5$

Specific Surface Area

Nanocomposites

$\text{TiO}_2/\text{SnO}_2/\text{ZnO}/\text{Ag}\dots$

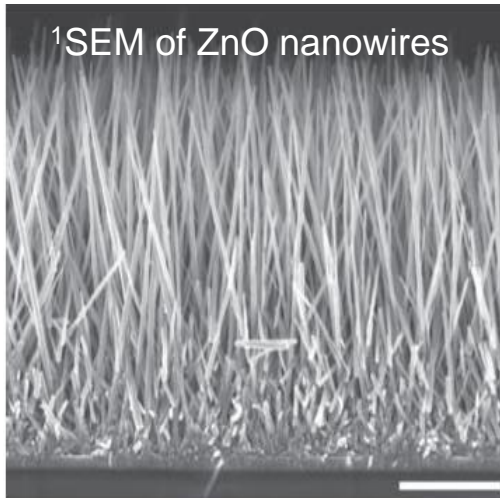
Specific Surface Area

Multi-layers Anode

$\text{TiO}_2/\text{SnO}_2$; Opal

Reflectivity and Absorption

¹SEM of ZnO nanowires



Semiconductors

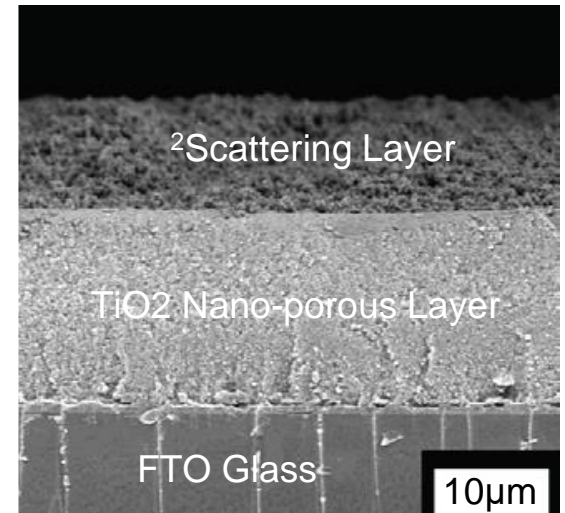
$\text{TiO}_2/\text{SnO}_2/\text{ZnO}/\text{Nb}_2\text{O}_5$

Electron transfer

²Scattering Layer

TiO_2 Nano-porous Layer

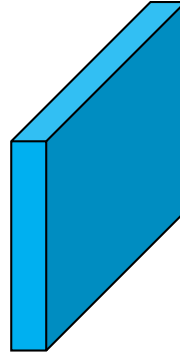
FTO Glass



¹<http://www.chem.umass.edu/~rbmetz/CHEM891/Energy3.pdf>

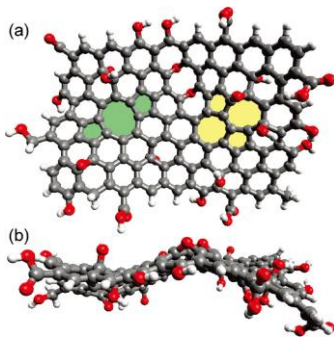
²Fan-Tai Kong et al. Advances in OptoElectronics [J] Volume 2007, doi:10.1155/2007/75384

Cathode

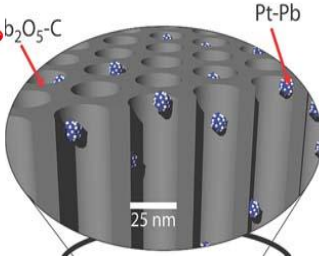


Carbon-based

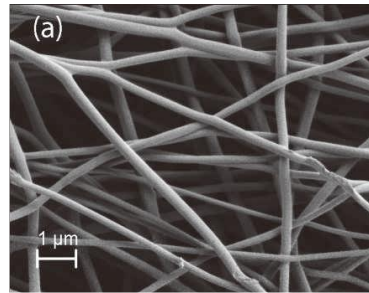
Graphene (Catalyst)



Carbon Composites



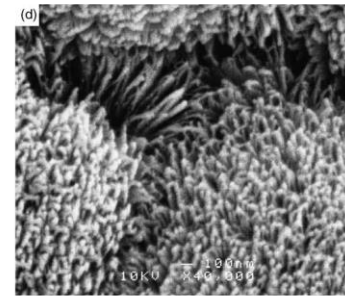
Carbon Nanotubes



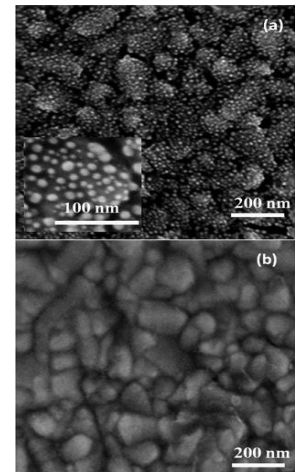
Materials

Copper

Copper Oxides



Platinum



Dye

Materials

Dye
Sensitizers

Inorganic

Metal Polypyridyl
complexes of Ru & Os

Metal Porphyrin

Phthalocyanine

Quantum Dots

High

Thermal
Stability

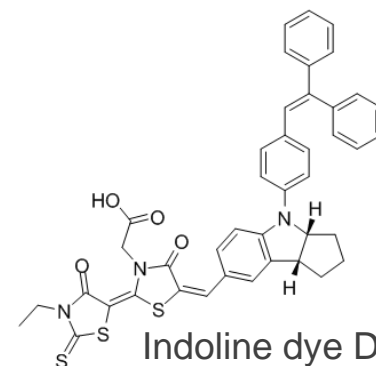
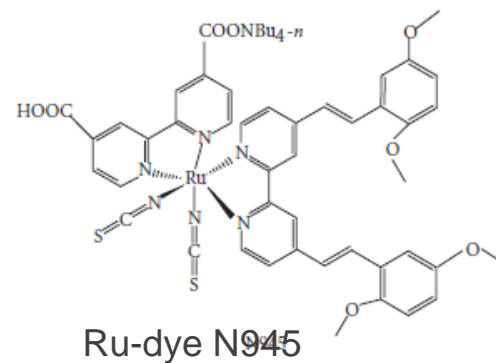
Chemical
Stability

Organic

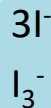
Natural Organics

Synthetical Organics

Easy
Design



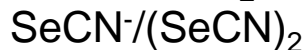
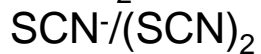
Electrolyte



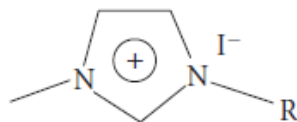
Liquid State

Organic Solvent

Redox Couples:



Ionic Liquid



1-methyl-3-alkylimidazolium iodide

R = C₃–C₉ alkyl.

$\eta_a/\text{mPa}\cdot\text{s}$: C₃, 865, C₄, 963, C₅, 1362

C₆, 1439, C₇, 1792, C₈, 1976, C₉, 2099

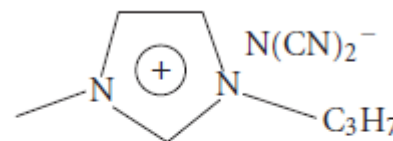
Leakage and Vaporization Problems

Materials

Quasi-solid State

Solid State

Stabilization

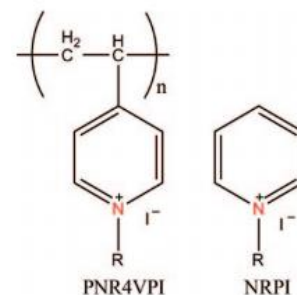


MPIDCN
 $\eta_a/\text{mPa}\cdot\text{s}$: 18

+

Framework Materials:

- Polymer
- Low-molecular-weight gelator
- Silica nanoparticles

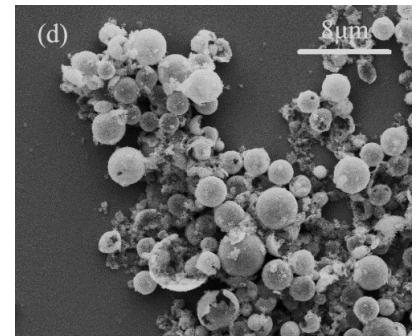
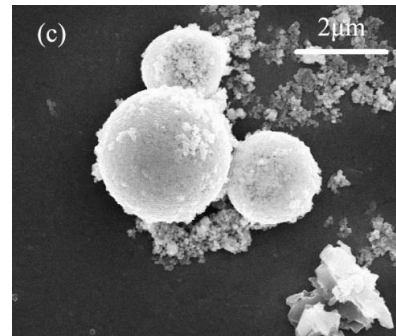
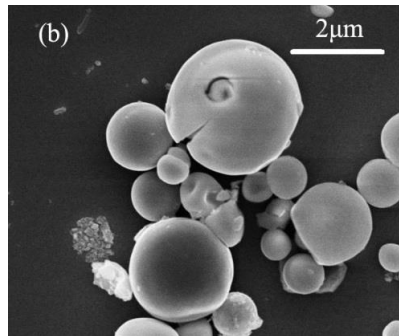
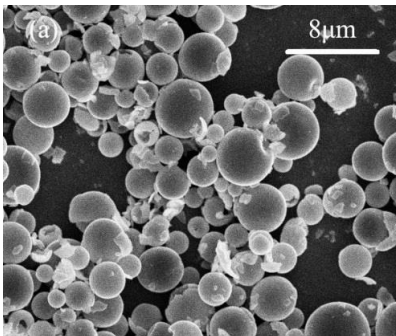


All solid

3.

Specific Examples

My Bachelor Thesis



Synthesis of Mesoporous SnO₂ and its application in DSSCs

Bachelor Thesis, 2013, Beijing

Mesoporous SnO₂
Microsphere

Advantages

Bandgap	Mesoporous	Reflectivity	Surface Area
3.5-4.0eV	2-50nm	>2.0	46.92m ² /g

▲

Mesoporous SnO ₂	Commercial P25 TiO ₂
Commercial P25 TiO ₂	Commercial P25 TiO ₂
FTO Conductive Glass	FTO Conductive Glass

Synthesis

Prepared by Atomization reaction with calcination at different temperature

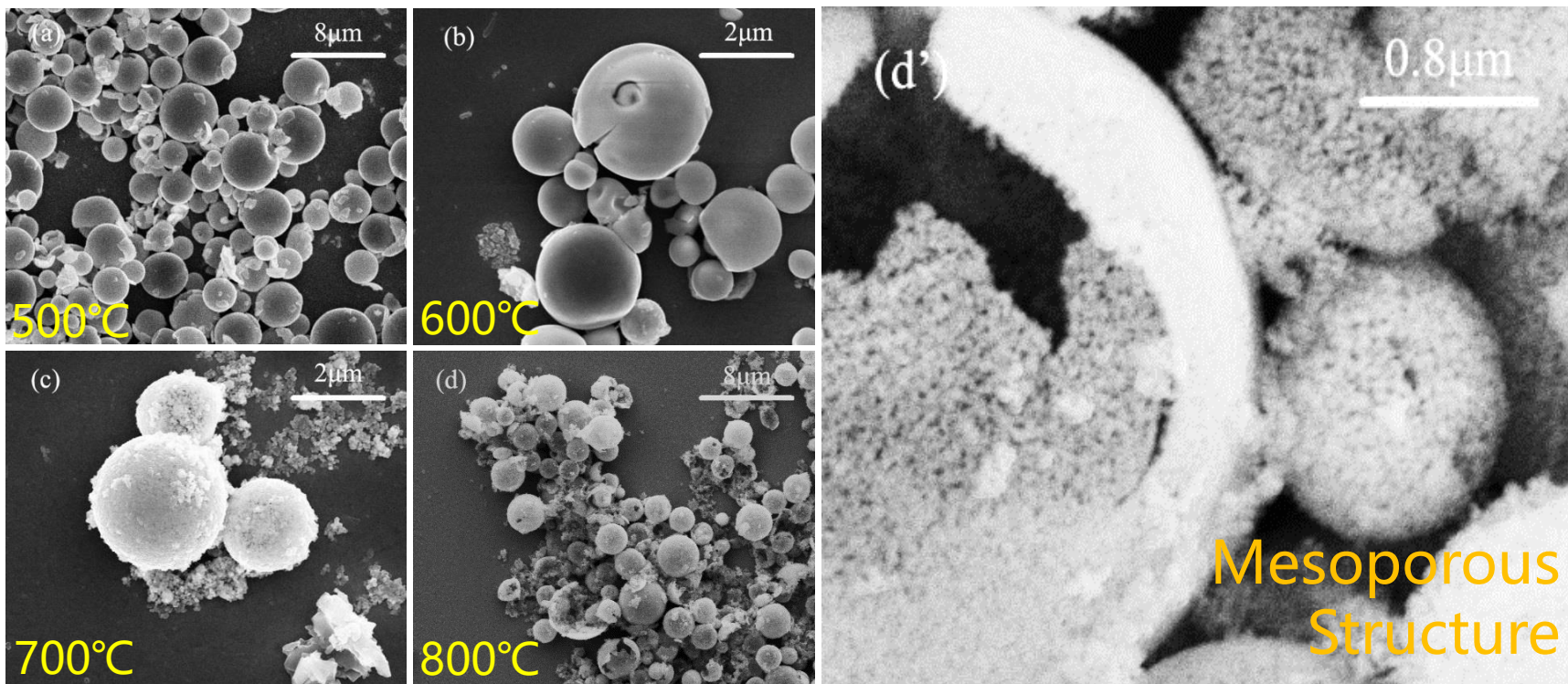
DSSC

Using mesoporous SnO₂ as the reflective layer of TiO₂ anode.

Doctor blade method
Screen printing method

Synthesis of Mesoporous SnO₂ and its application in DSSCs

Morphology of mesoporous SnO₂, SEM pictures



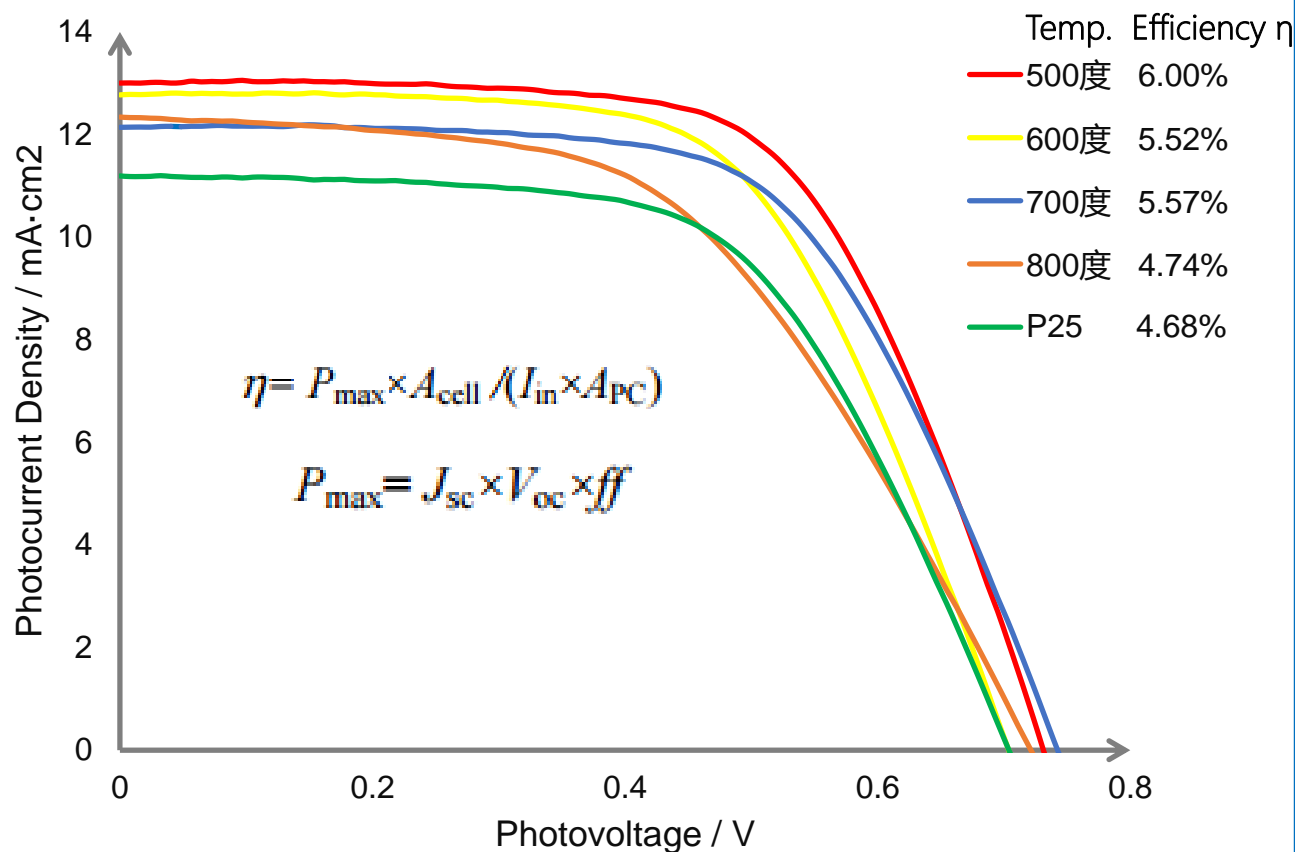
Calcination Temp. (°C)	500	600	700	800
Average Crystal Size (nm)	5.3	10.6	22.3	12.8

Synthesis of Mesoporous SnO₂ and its application in DSSCs

I-V Curve Test of DSSC Samples

DSSC I-V Curve

Influence of SnO₂ calcination Temp. on η of SnO₂/TiO₂

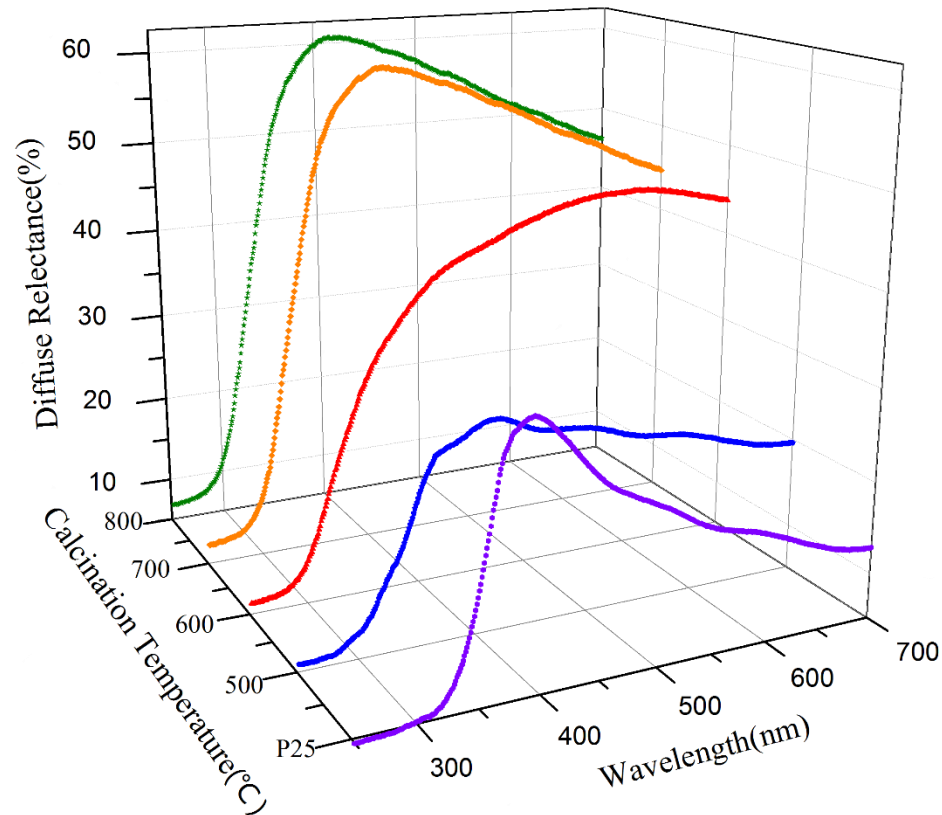


Synthesis of Mesoporous SnO₂ and its application in DSSCs

Light Scattering Test of DSSC Samples

DSSC
UV Spec.

Influence of SnO₂ calcination Temp. on η SnO₂ reflectivity

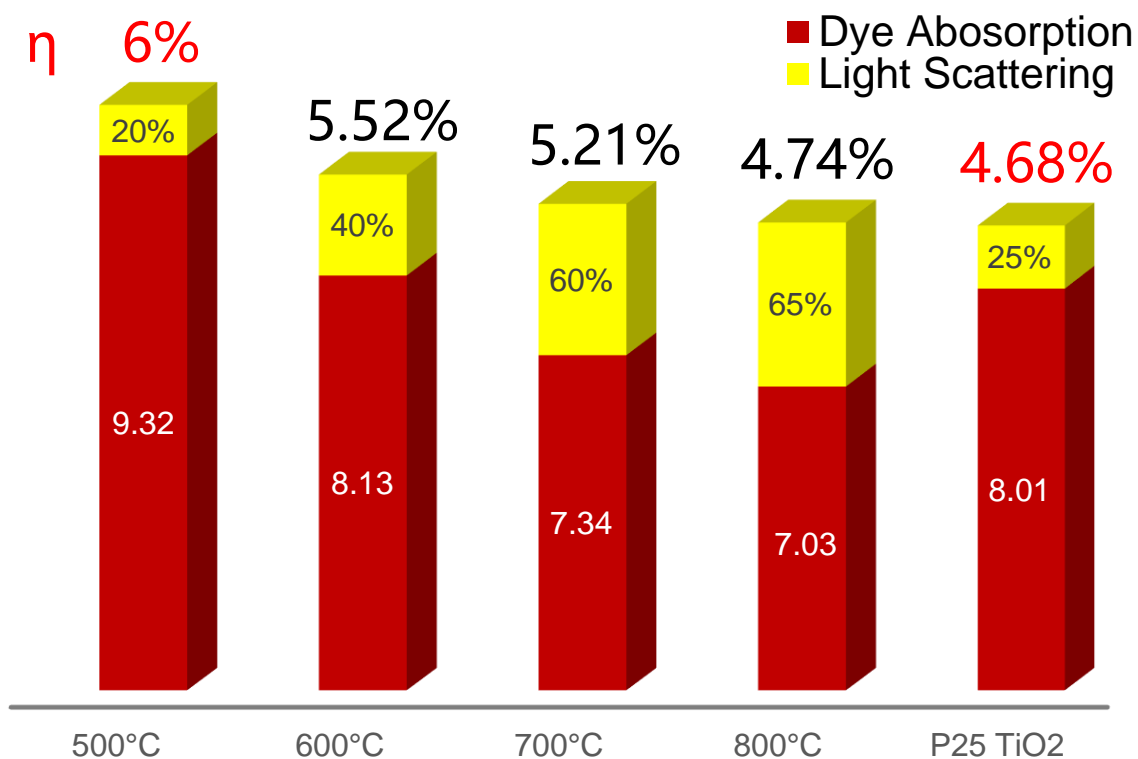


Synthesis of Mesoporous SnO₂ and its application in DSSCs

Efficiency of DSSC Samples

DSSC
Efficiency

Influence of SnO₂ calcination Temp. on η SnO₂/TiO₂



4. Summary and Outlook

Summary of DSSC & Applications





highest 11%

Photo Conversion Efficiency of DSSC, 2014
Achieved by M. Grätzel Group at EPFL

Published on Nature Chemistry 6, 242–247 (2014)
[doi:10.1038/nchem.1861](https://doi.org/10.1038/nchem.1861)



25%

Silicon Solar Cells



20.5%

Perovskite Solar Cells



12%

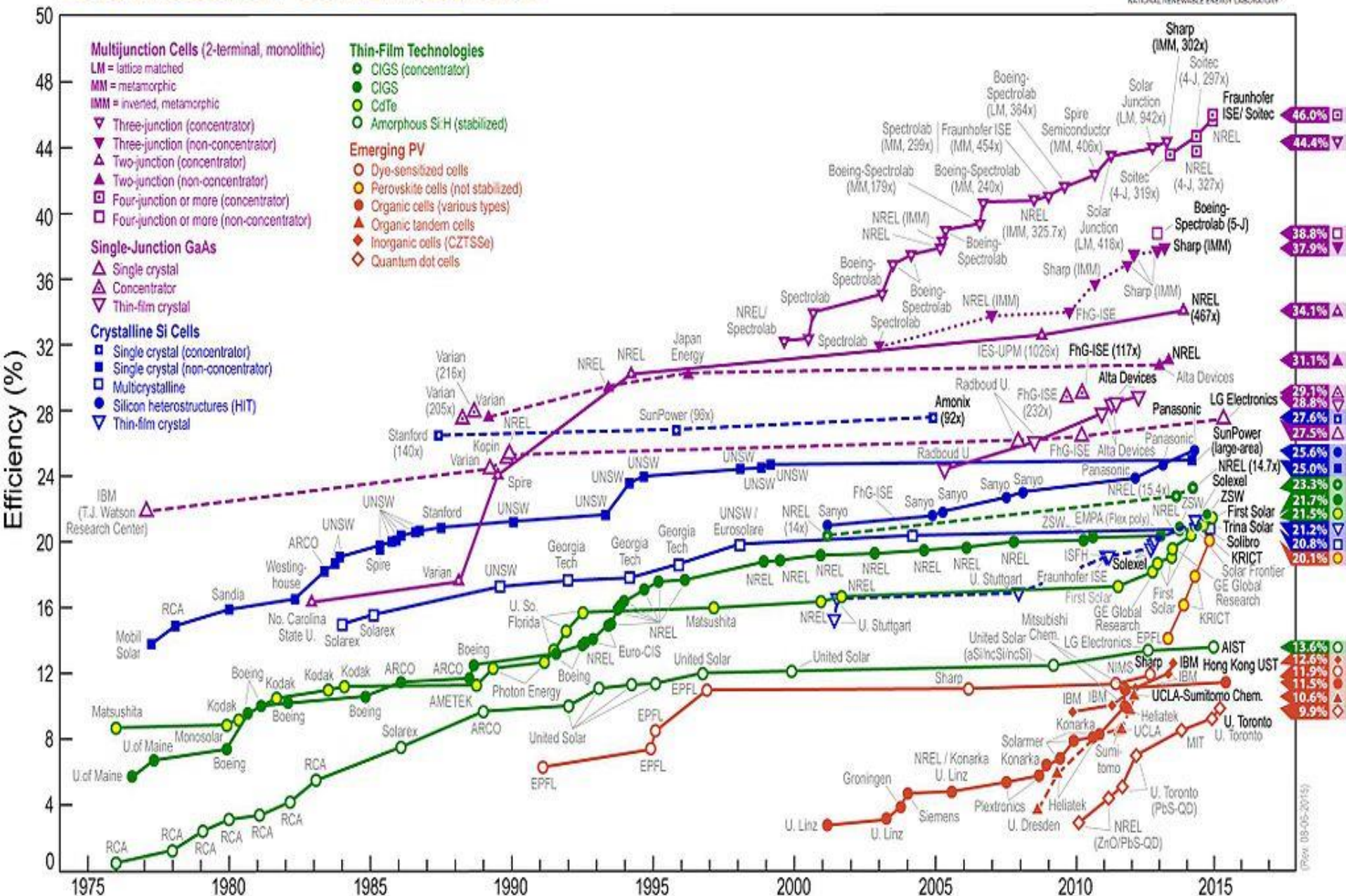
Organic Thin Film Solar Cells



11%

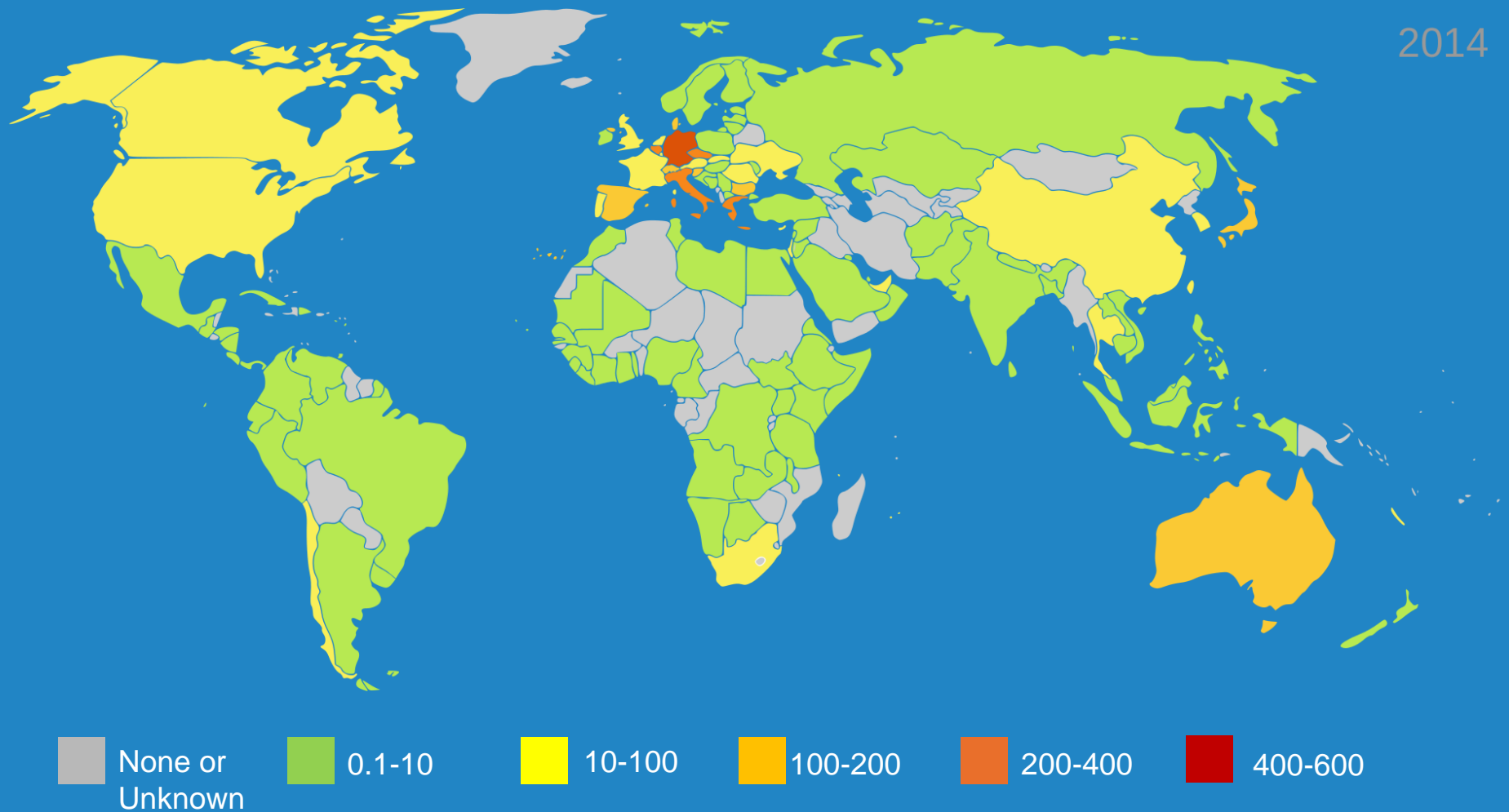
Dye Sensitized Solar Cells

Best Research-Cell Efficiencies



Worldwide installed photovoltaic capacity

Estimated figures for year 2014



Consumer electronics



Smart watch



eReader

[read more](#)


Bluetooth
Keyboard

[read more](#)


Remote
Control



Tablet
Accessories

[read more](#)

Sensors & Actuators



Actuators



Smoke
Detectors

[read more](#)


Motorized
Blinds



Wireless
Sensors



Location
Sensors

[read more](#)

Retail



Electronic
Price Labels



POS Shelf
talkers

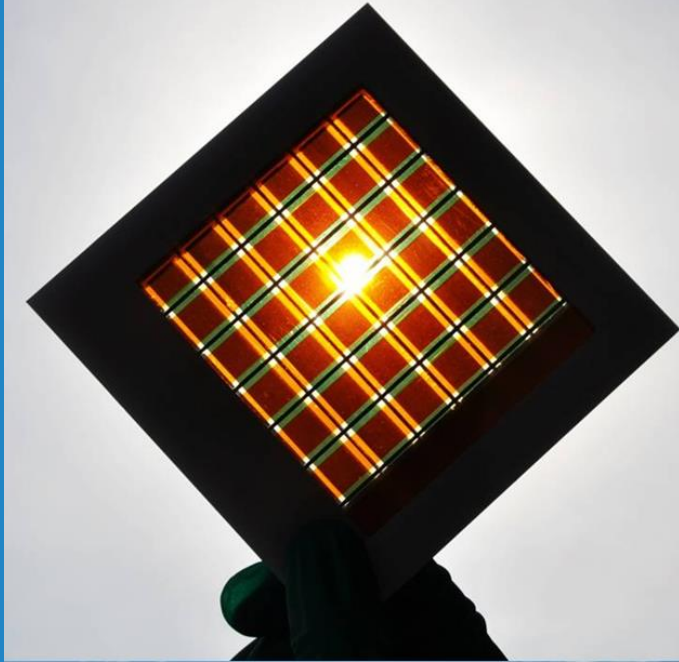


Powered
Smart Cards



RFID Tags





Outlook Applications



Thank you for your Appreciation...
Any QUESTIONS?



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Dye Sensitized Solar Cells (DSSCs): Materials and Perspectives

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27th Nov. 2015

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