

The Dye Sensitized Solar Cell

Behind the Scenes of “Sunny Memories”

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Filling in for:

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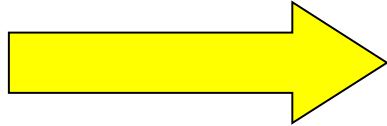
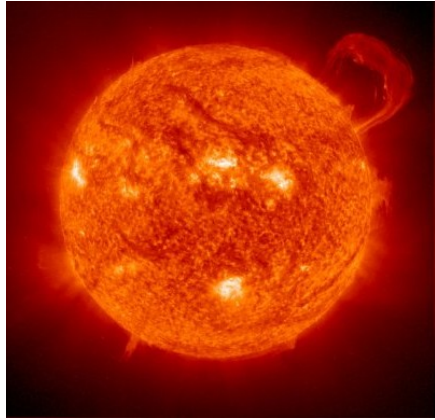
Ecole Polytechnique Fédérale de Lausanne (EPFL)

- EPFL is one of the premier Science and Engineering Universities in Europe
- 6,000 Students
- Over 100 Nationalities with 50% of the teachers coming from outside of Switzerland.
- Michael Grätzel is the most highly cited solar scientist in the world.



Grätzel lab is a five minute walk from Lac Léman and beach volleyball courts.

Dye-Sensitized Solar Cells are Photovoltaic Devices



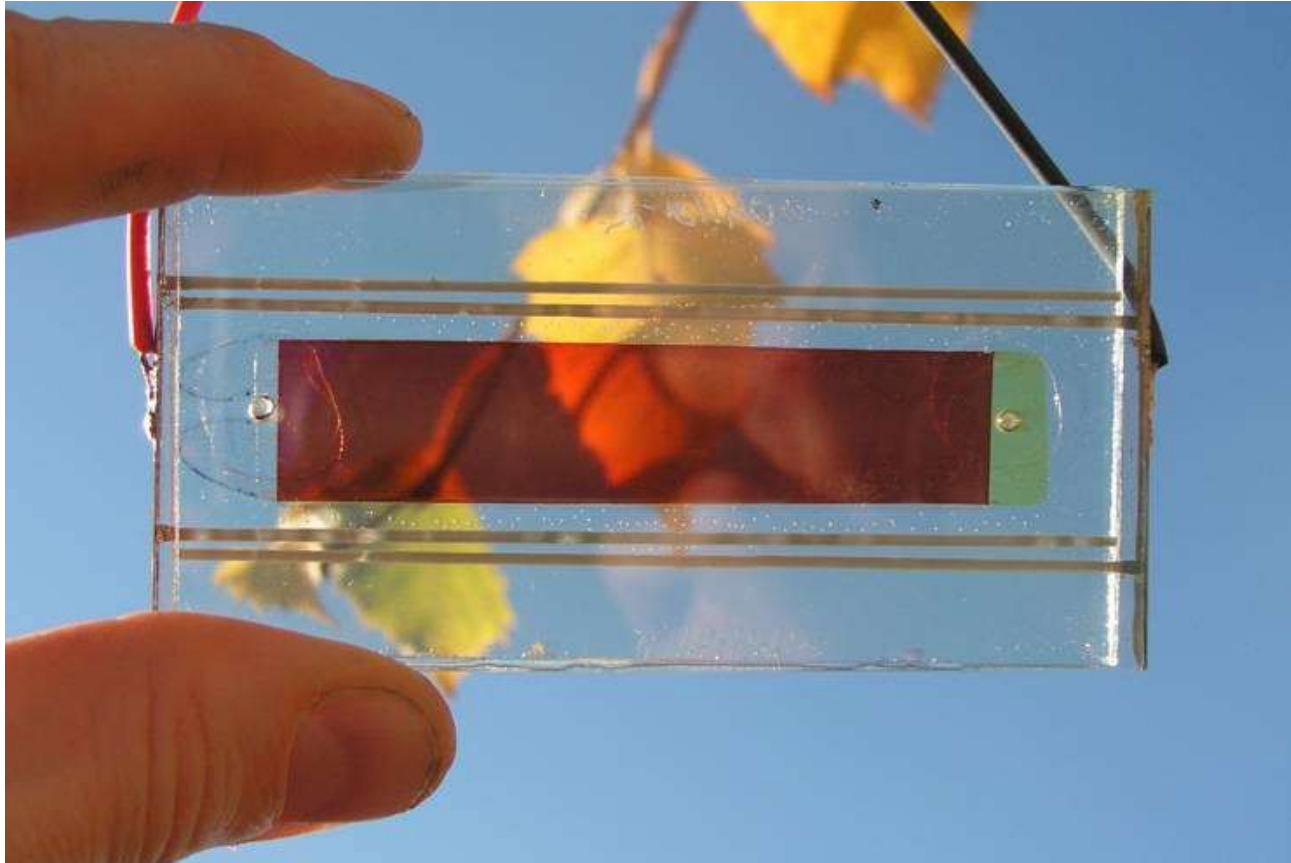
Power from Solar Cell: $P_{PV} = I_{mp} \times V_{mp}$

Power Conversion Efficiency: $\eta_{PV} = \frac{P_{PV}}{P_{sun}}$

On a sunny day, the power from the sun (P_{sun}) is one kilowatt per meter squared (1 kW/m^2).

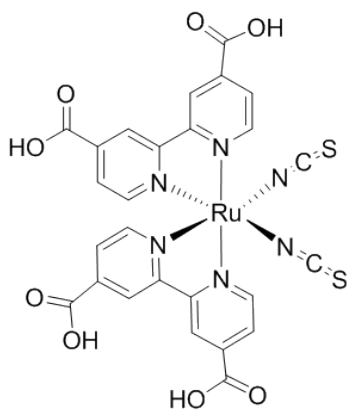
A new in paradigm in solar energy conversion

The Dye Sensitized solar cell:
Low to medium purity materials
Low cost processing
High Efficiency
High Stability



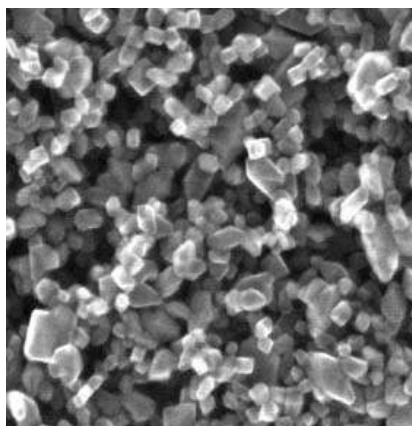
Dye-Sensitized Solar Cell Components

Sensitizing Dye



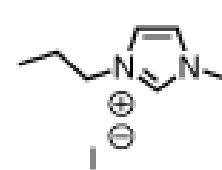
Chemical Structure of N3 Dye

Titania Nanoparticles



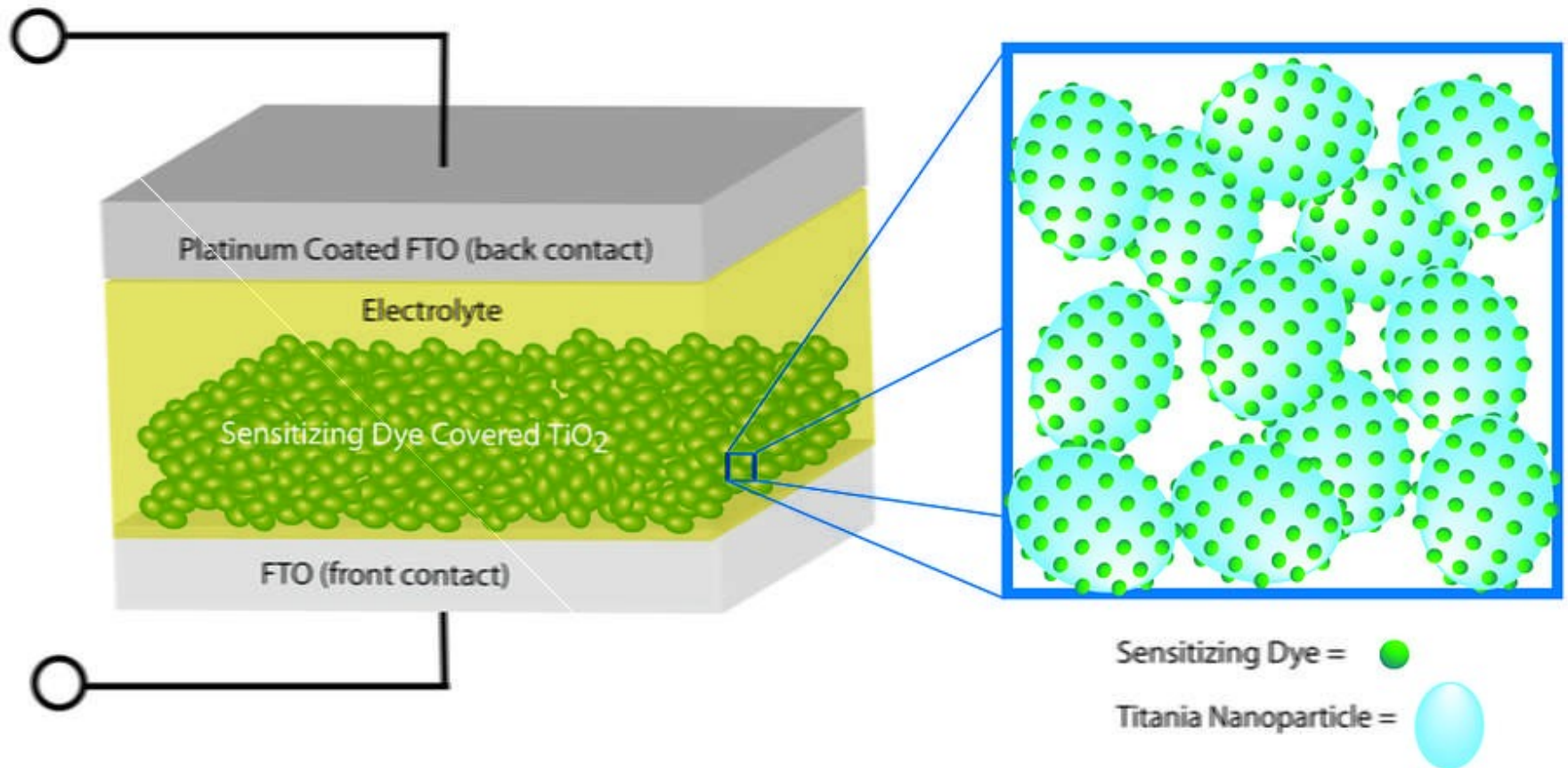
20 nm Titania nanoparticles

Electrolyte

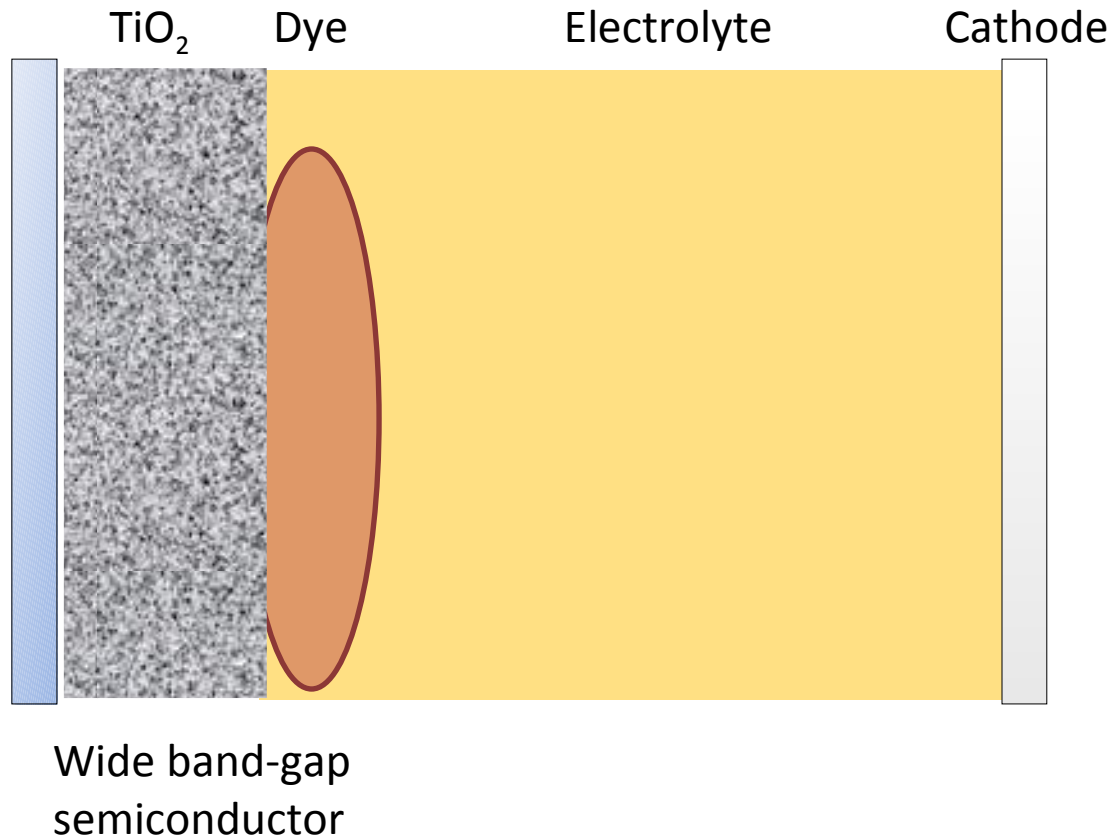


Iodide/Tri-iodide
Redox Couple

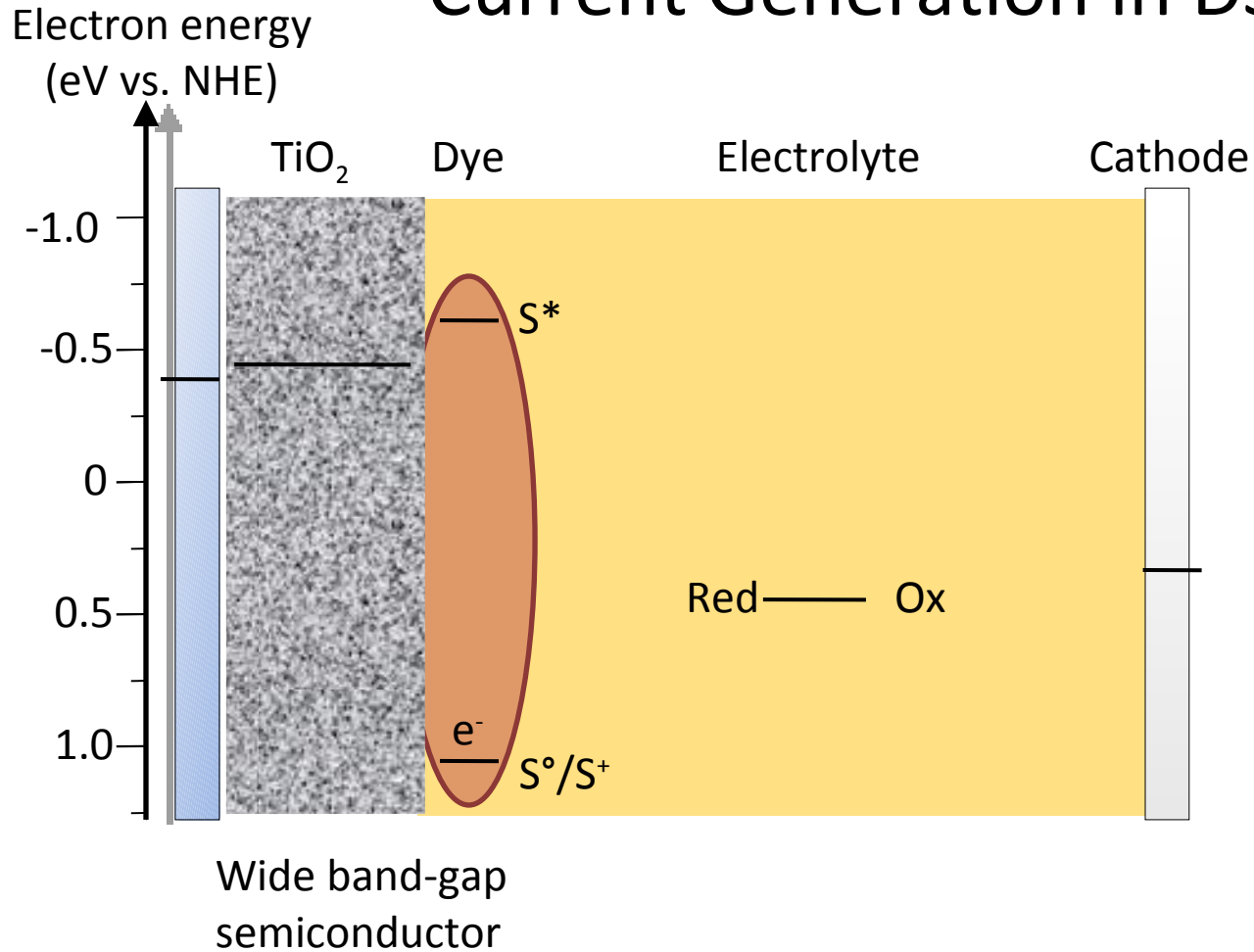
Dye-Sensitized Solar Cell Schematic



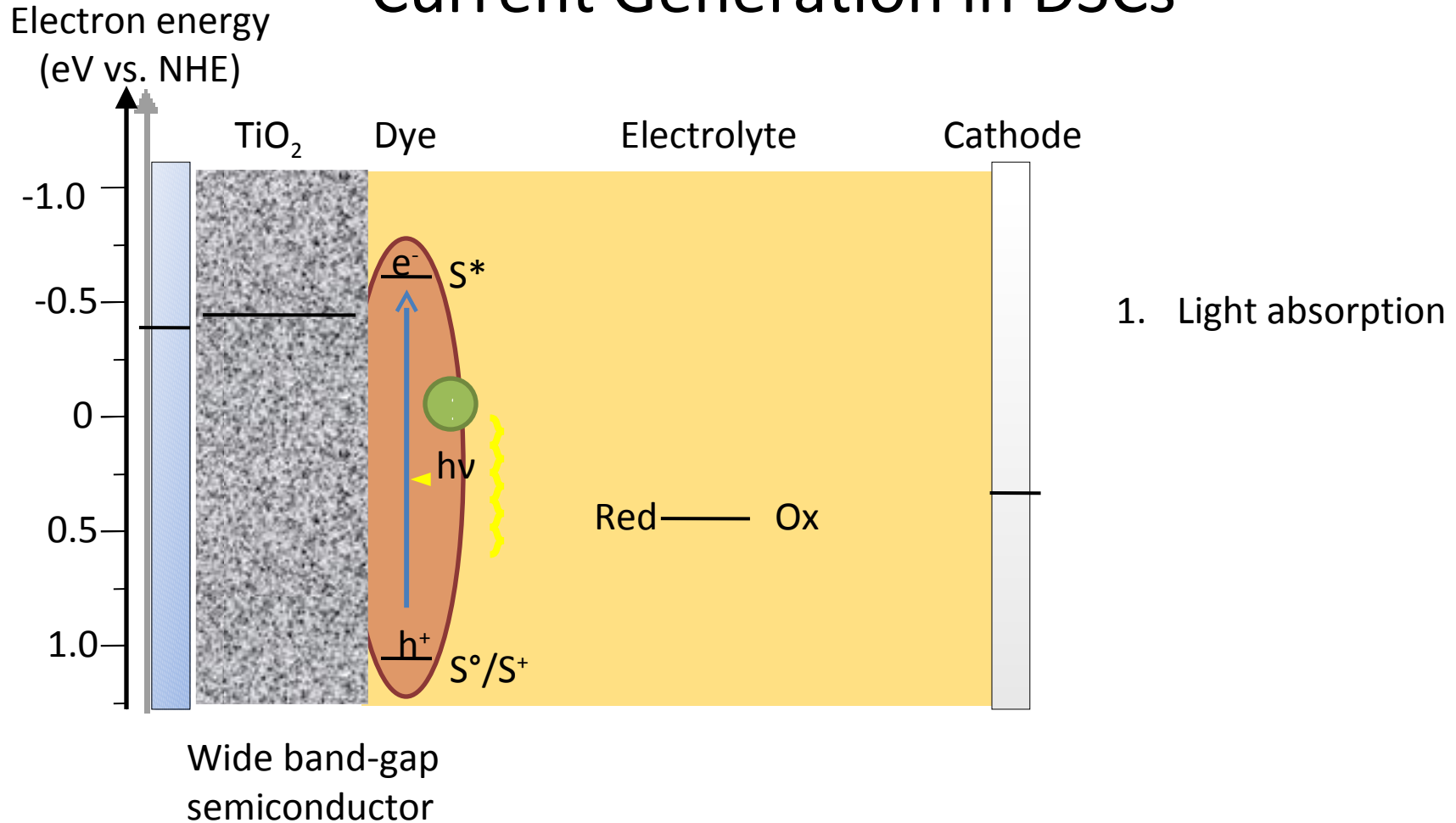
Current Generation in DSCs



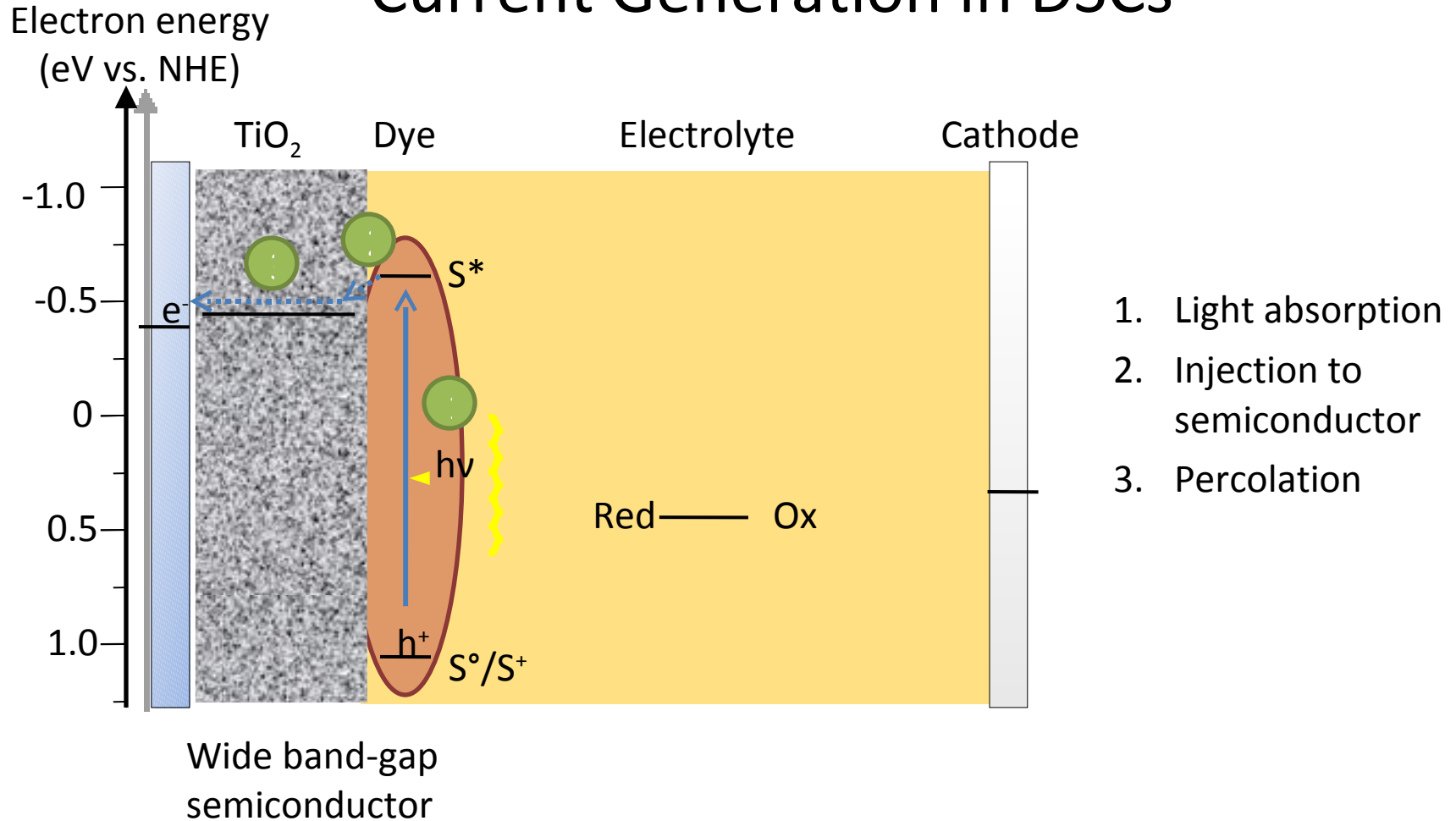
Current Generation in DSCs



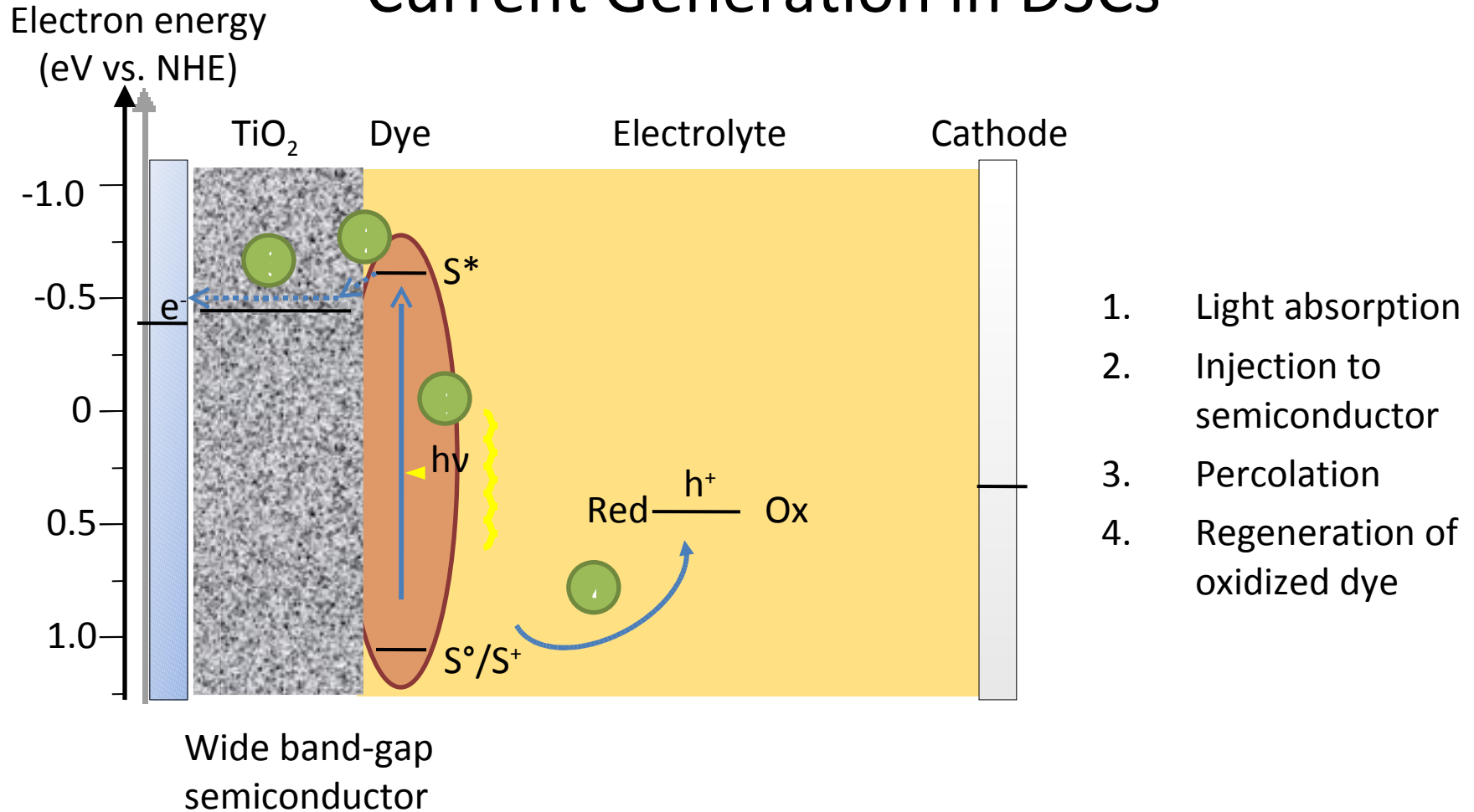
Current Generation in DSCs



Current Generation in DSCs

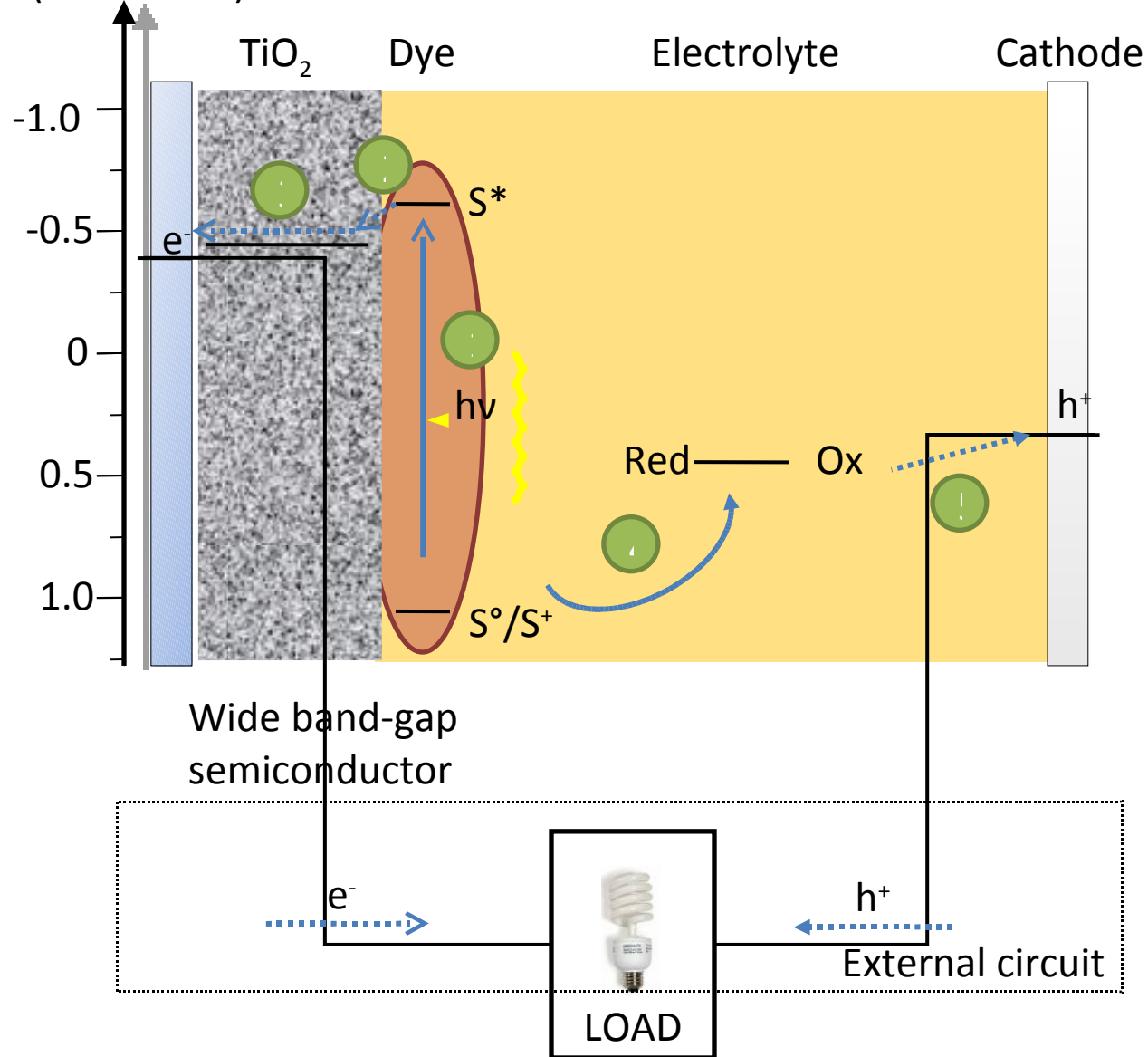


Current Generation in DSCs



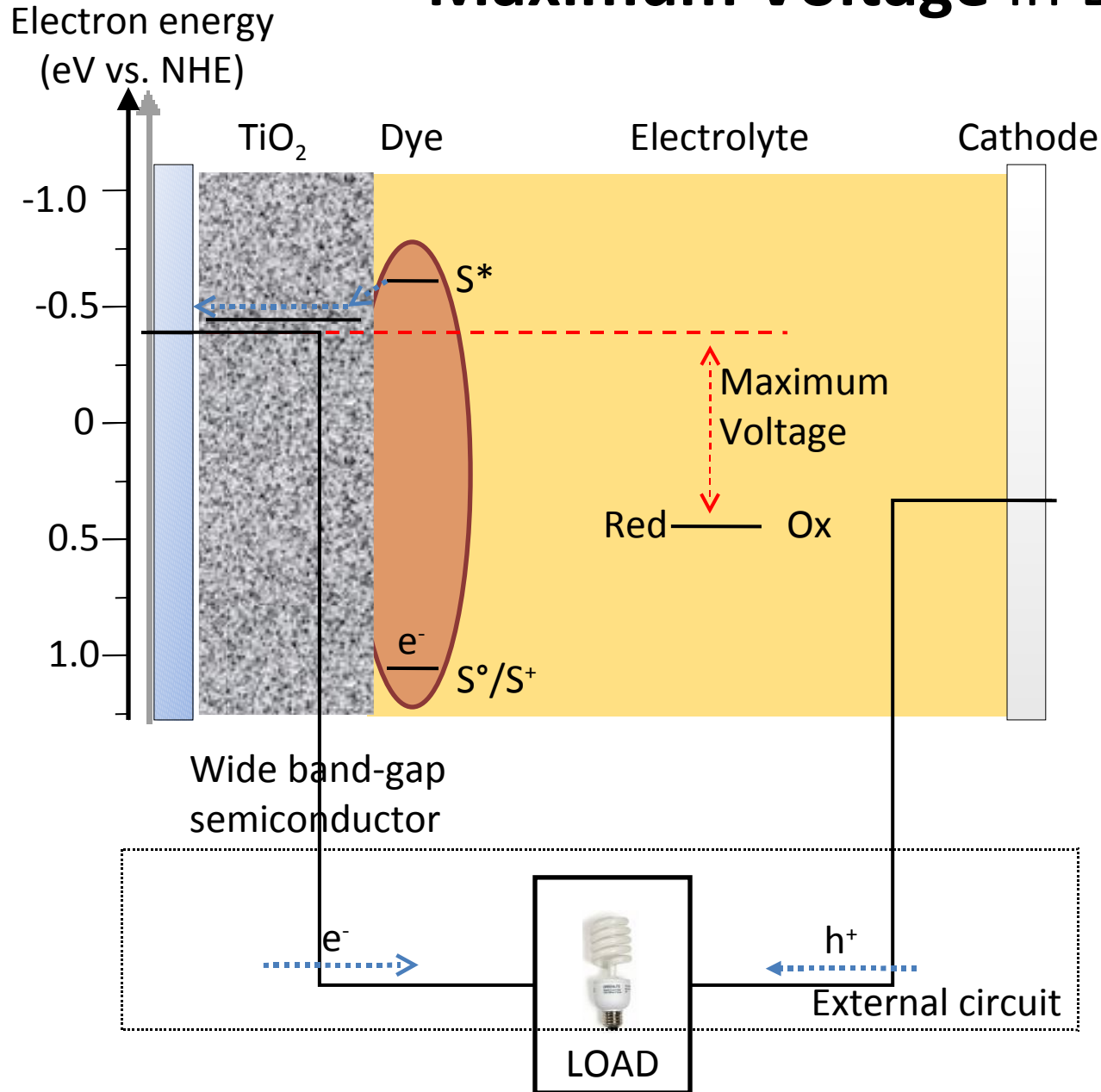
Current Generation in DSCs

Electron energy
(eV vs. NHE)



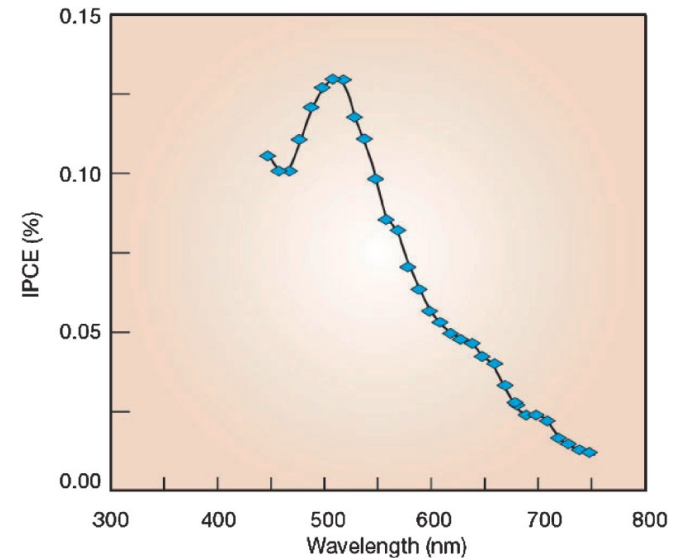
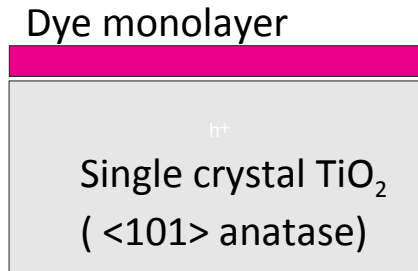
1. Light absorption
2. Injection to semiconductor
3. Percolation
4. Regeneration of oxidized dye
5. Regeneration of oxidized species

Maximum Voltage in DSCs

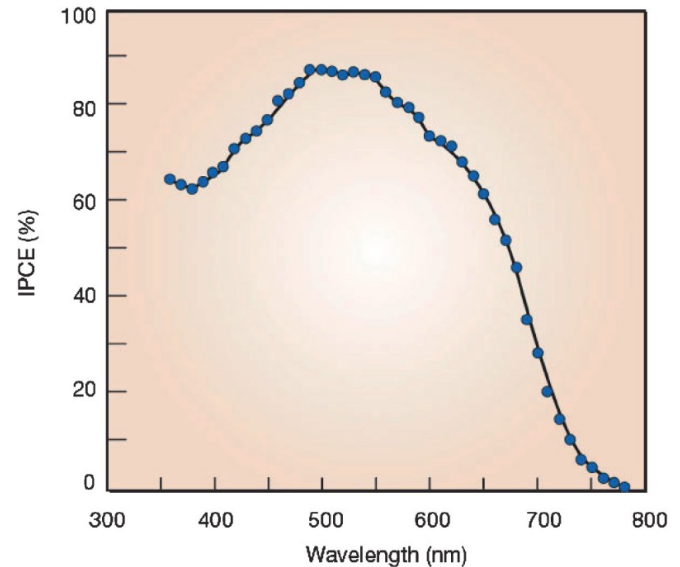
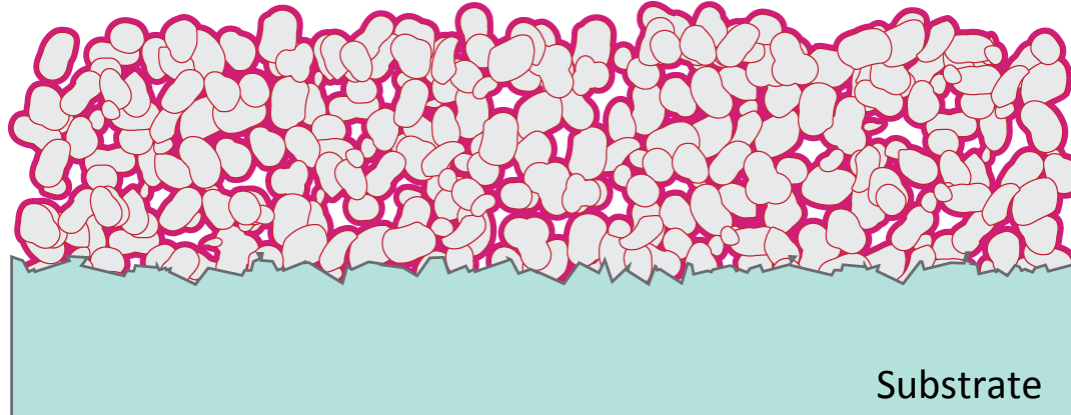


The voltage is determined mainly by the titania and redox couple in the electrolyte.

Why Dye-Sensitized Solar Cells are nicknamed the “Grätzel Cell”



Dye Sensitized Mesoporous anatase TiO_2

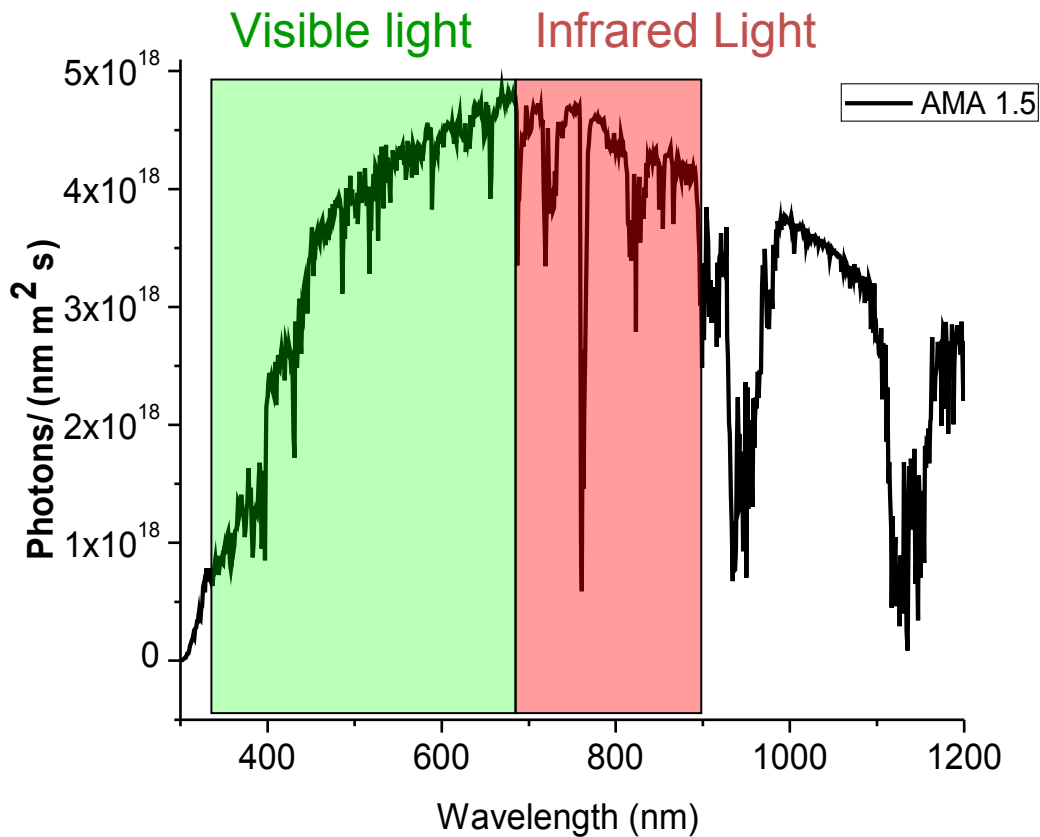


Dye-Sensitized Solar Cells are 12% Efficient. What can we do to make them better?

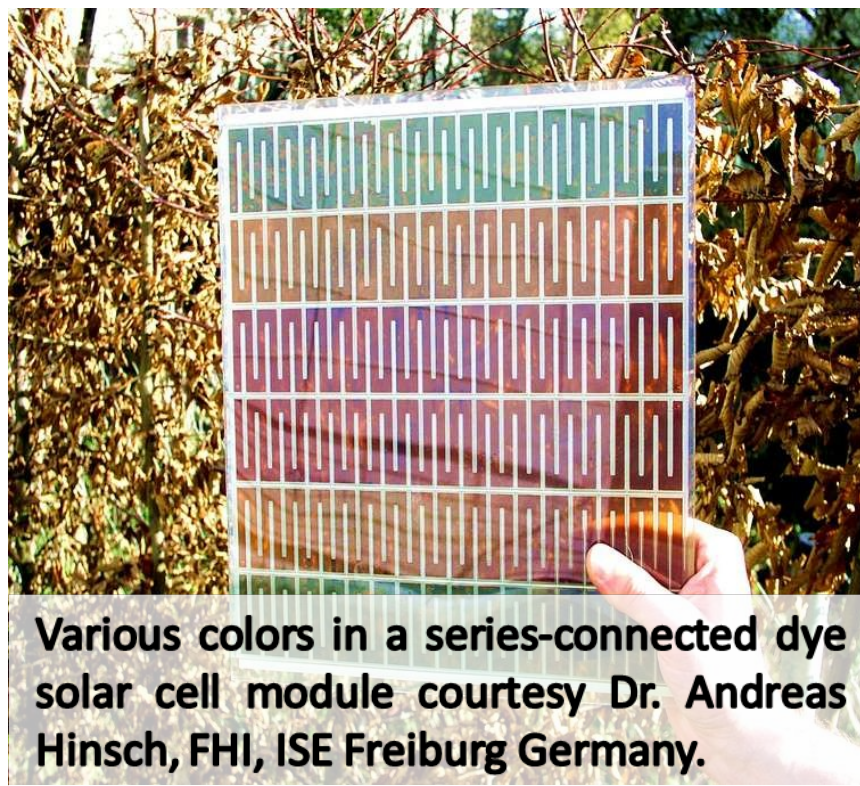
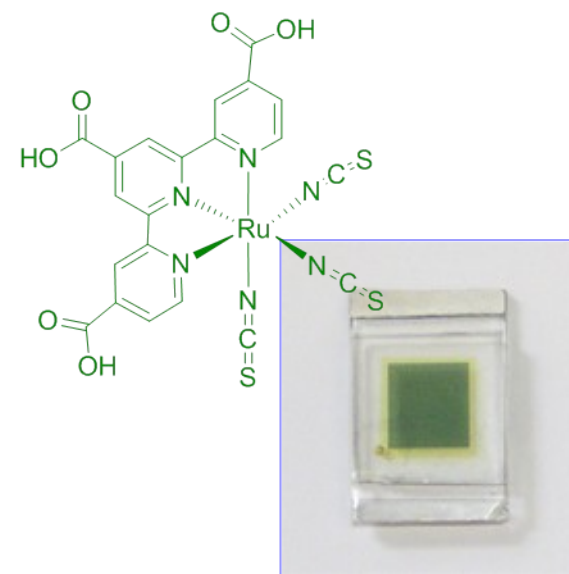
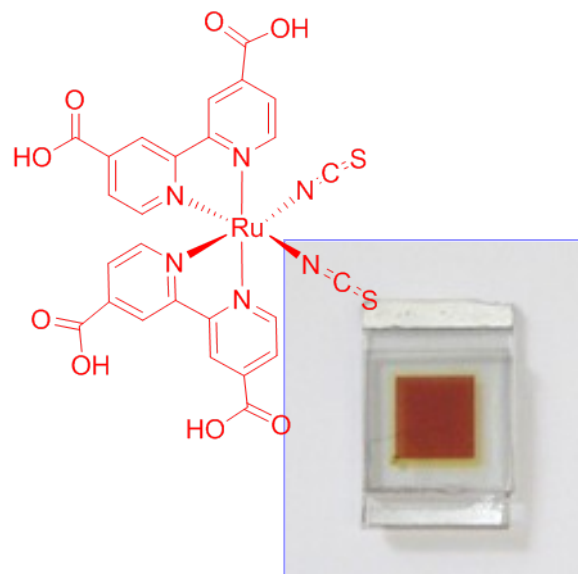
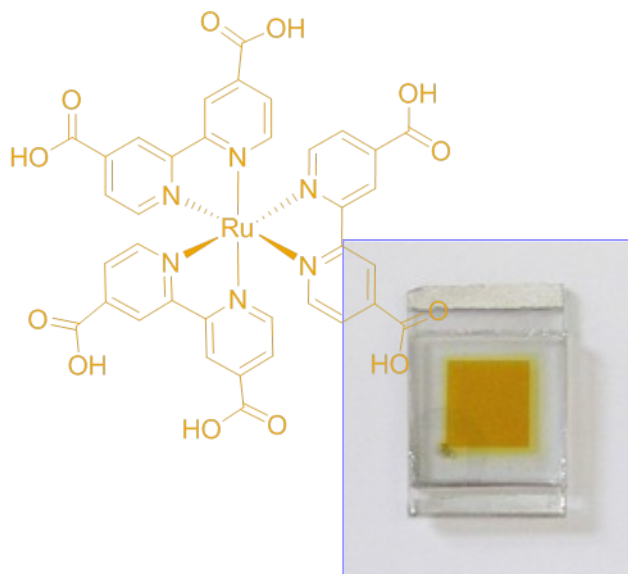
- **Develop dyes to absorb more photons**
- **Create new electrolytes that provide higher voltages.**
- **Develop Dye-Sensitized Solar Cells that can last for 30 years**

Where do we need to absorb the light?

Solar Spectrum

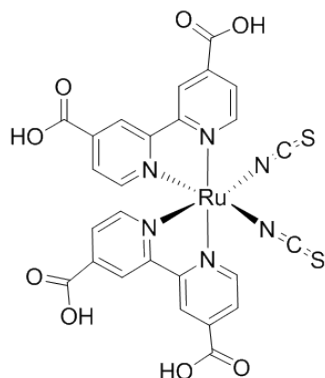


Dye-sensitized solar cells absorb >85% of visible light, but almost no light in the near-infrared.



Leaf-shaped transparent DSC with four colors courtesy AISIN SEIKI CO.,LTD.

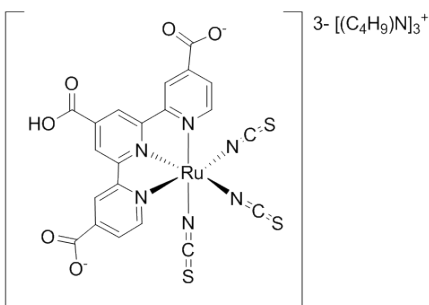
Design dyes that broadly absorb light



N3

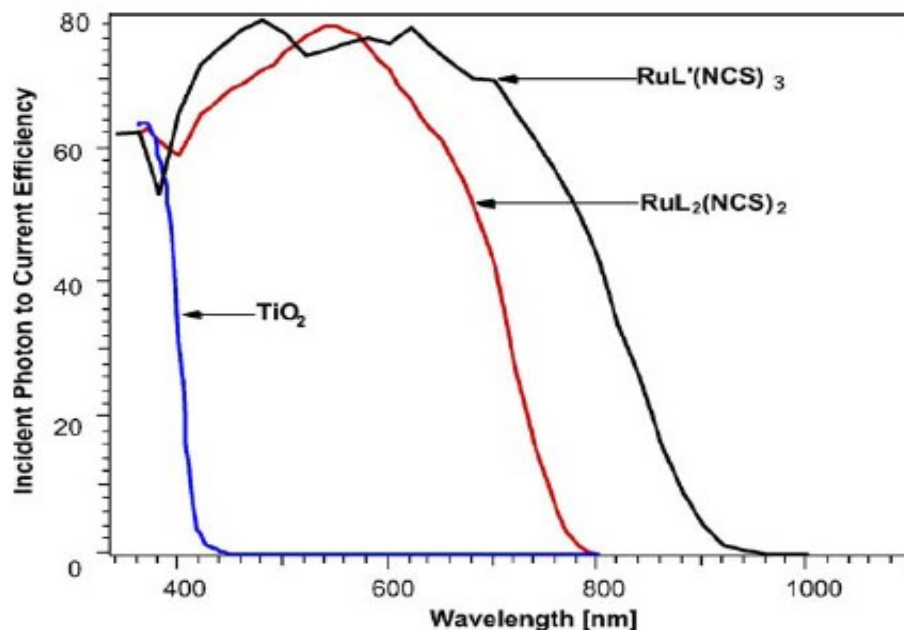
cis-Ru(SCN)₂L₂

(L = 2,2'-bipyridyl-4,4'-dicarboxylate)



N749

tri(cyanato)-2.22-terpyridyl-4,44-tricarboxylate)Ru(II)



L = 4,4'-COOH-2,2'-bipyridine

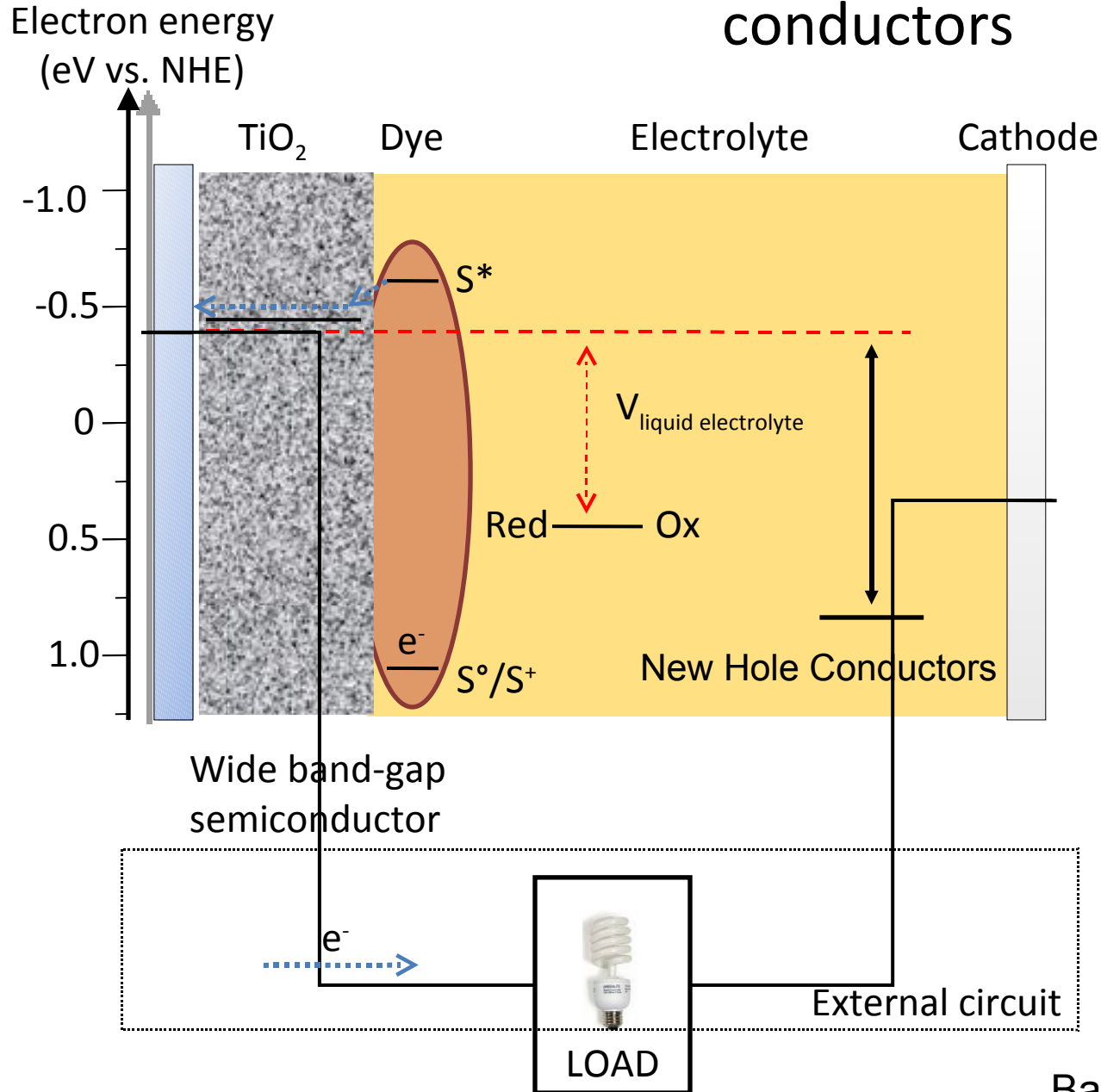
L' = 4,4',4''-COOH-2,2':6',2''-terpyridine

Design Near-Infrared Absorbing Dyes

- Can increase power conversion efficiency from 12% to 14% by absorbing light out to 900 nm.
- Probably can't make DSCs >14% using liquid electrolytes.



Increase the maximum voltage using plastic hole conductors



Potential to make >20% efficient devices by replacing liquid electrolyte with plastic “solid-state” hole conductors.

Current “solid-state” DSCs are only 6.5% efficient.

Very promising research area.

Aesthetic Advantages of Grätzel Cells versus conventional Solar Devices

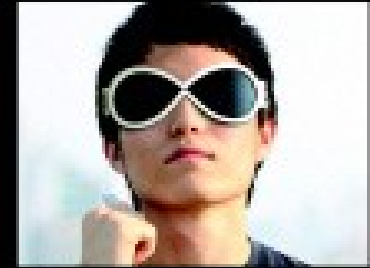
- Dyes determine the color of the device.
- Can be transparent
- Can be flexible
- Easy to make





Solar Powered Solar Panel Sun Glasses

The SIG, or “Self-Energy Converting Sunglasses” are quite simple. The lenses of the glasses have **dye solar cells**, collecting energy and making it able to power your small devices through the power jack at the back of the frame. “Infinite Energy: SIG”



Real Outdoor Test of DSC Modules



Module Unit



**Series connected
64 DSC cells**



Outdoor Test



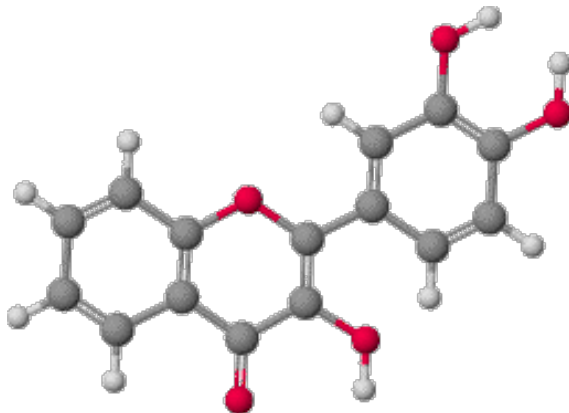
**Kariya City at lat. $35^{\circ}10'N$,
Asimuthal angle: 0°
Facing due south, Tilted at 30°**



High School Students make their own solar cell



anthocyanine dye from blackberries



Acknowledgement Present LPI Members (Director: Prof. Michael Graetzel)

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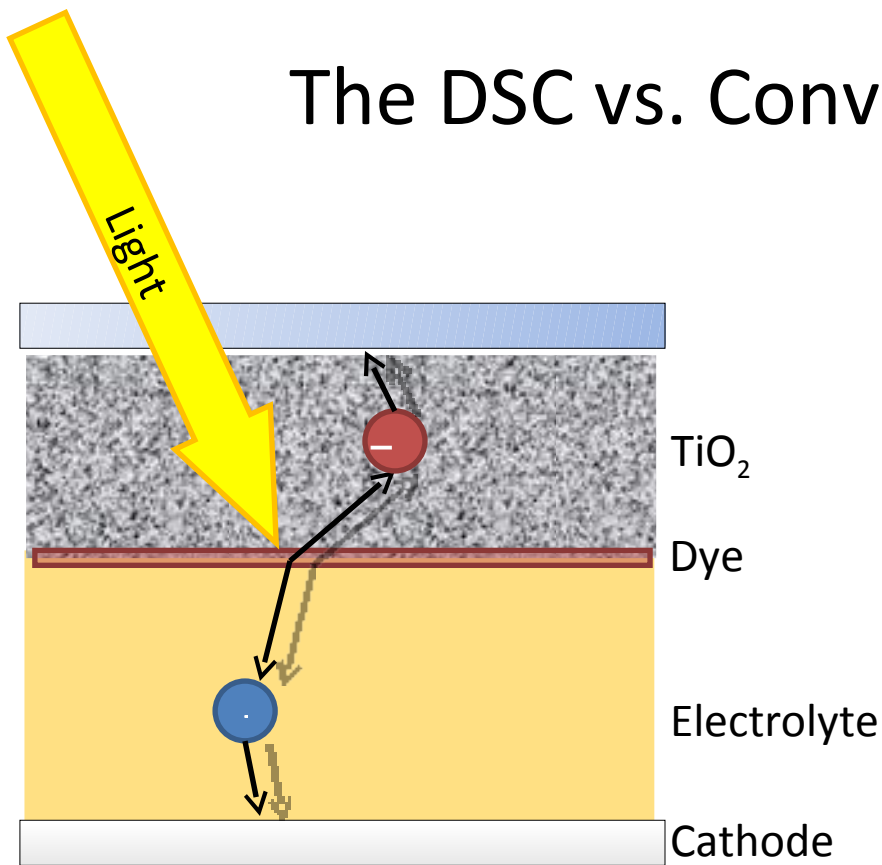
European Research Council, Adv. Res. Grant.

GRL Korea (with KRICT)

Industrial Partners,

*** DSC-Robust project coordinated by ECN Patten , This proposal received highest rating (15/15) of all proposals in energy field during first EU-FP7 call.**

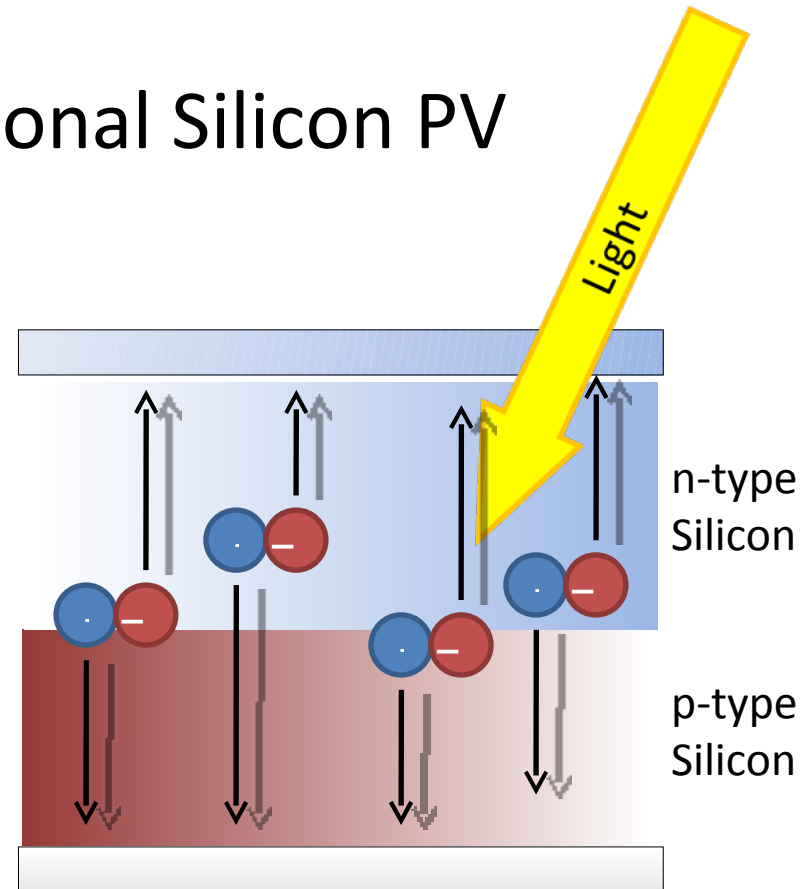
The DSC vs. Conventional Silicon PV



Light absorption and charge transport are **decoupled**

Relaxed constraints on individual components (each can be separately tuned)

Chemical synthesis of dye on TiO_2



Charge carriers (excited electrons) are produced throughout the semiconductor

Semiconductor considerations:

- Precise doping
- High purity
- High crystallinity

Solar Cell Efficiencies



Silicon Solar Cell Efficiencies:

Theoretical Maximum: 26%

Best in Lab: 25% (Green, UNSW)

Modules: 15-22%

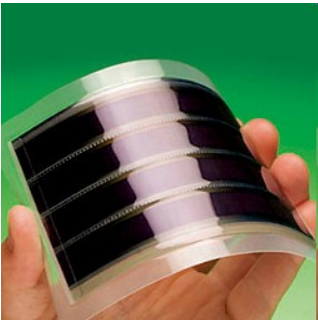


Thin Film Solar Cell Efficiencies:

Theoretical Maximum: >22%

Best in Lab: 20% (Noufi, NREL)

Modules: 9-12%



Dye-Sensitized Solar Cell Efficiencies:

Theoretical Maximum: 14-20%

Best in Lab: 12% (Grätzel, EPFL)

Modules: 6-9%