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Dye Sensitized Solar Cells

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ECE 4833: Devices for Renewable Energy
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Motivation

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Efficient Solar Cells at a low cost

Motivation

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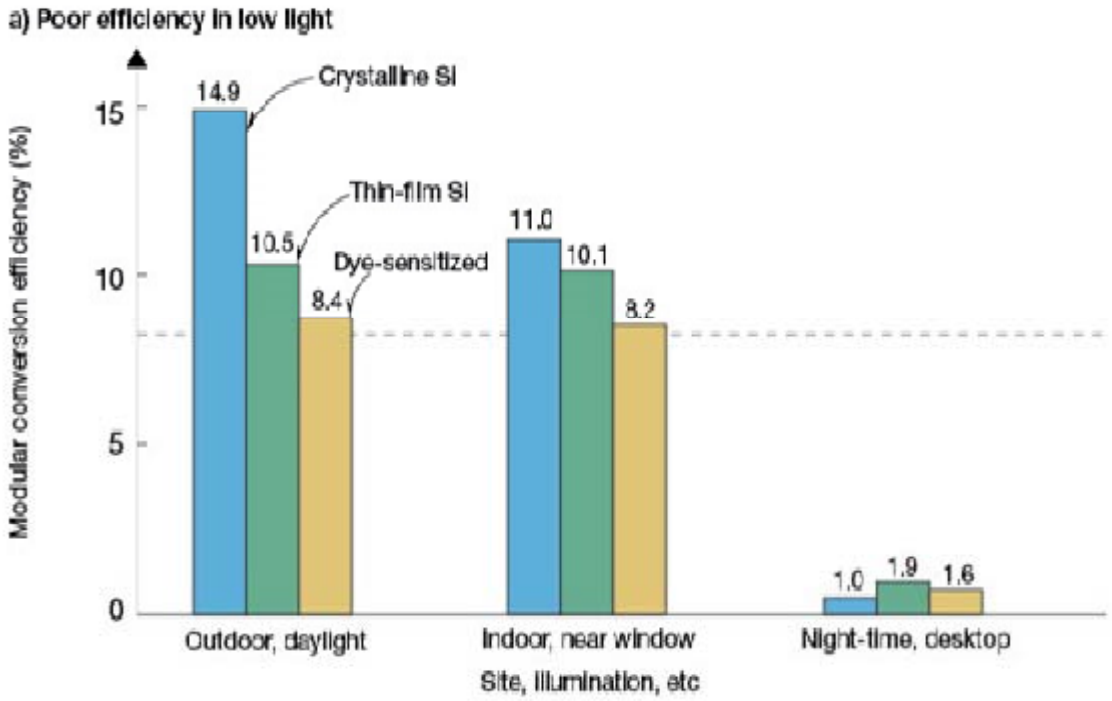
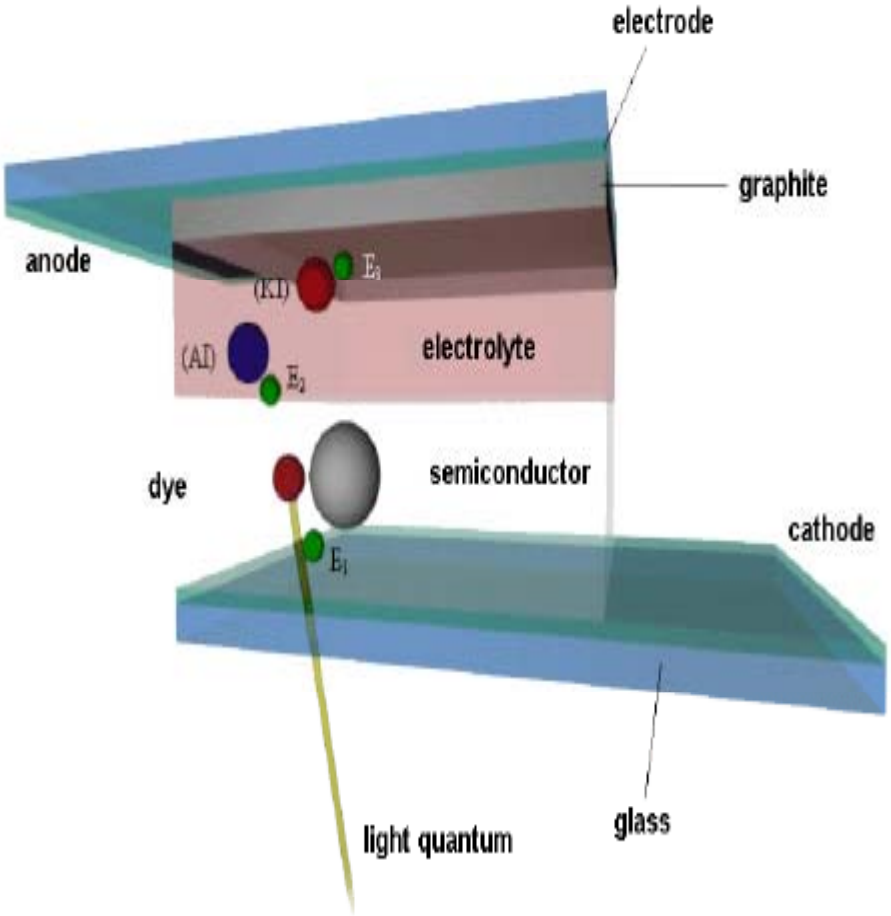
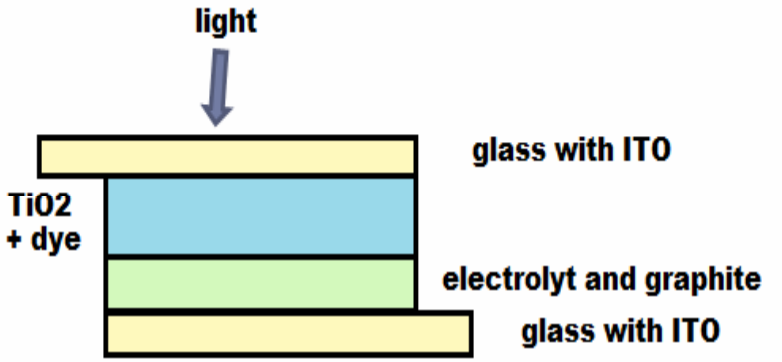
Commercially realistic energy conversion efficiency is key

- **Economic Viability**
- **Efficiency**
- **High surface area of porous film**
- **Mechanical Robustness**
- **Performance and Reliability depend on absorption of solar radiation**



Fabrication





Implementation

- 2 planar electrodes at a distance of 20- 40 μm
    1) Electrode 1: 5-10 μm thick TiO2 surface+ light sensitive dye
    2) layer of platinum(acts as catalyst)
- Inner surface of electrode consisting of fluorine doped tin oxide SnO2:F
- Region between filled with electrolyte that makes for redox reactions(e.g Iodine and KI solution)

Operation

1. $2\ dm + h\upsilon \rightarrow 2\ dm^*$

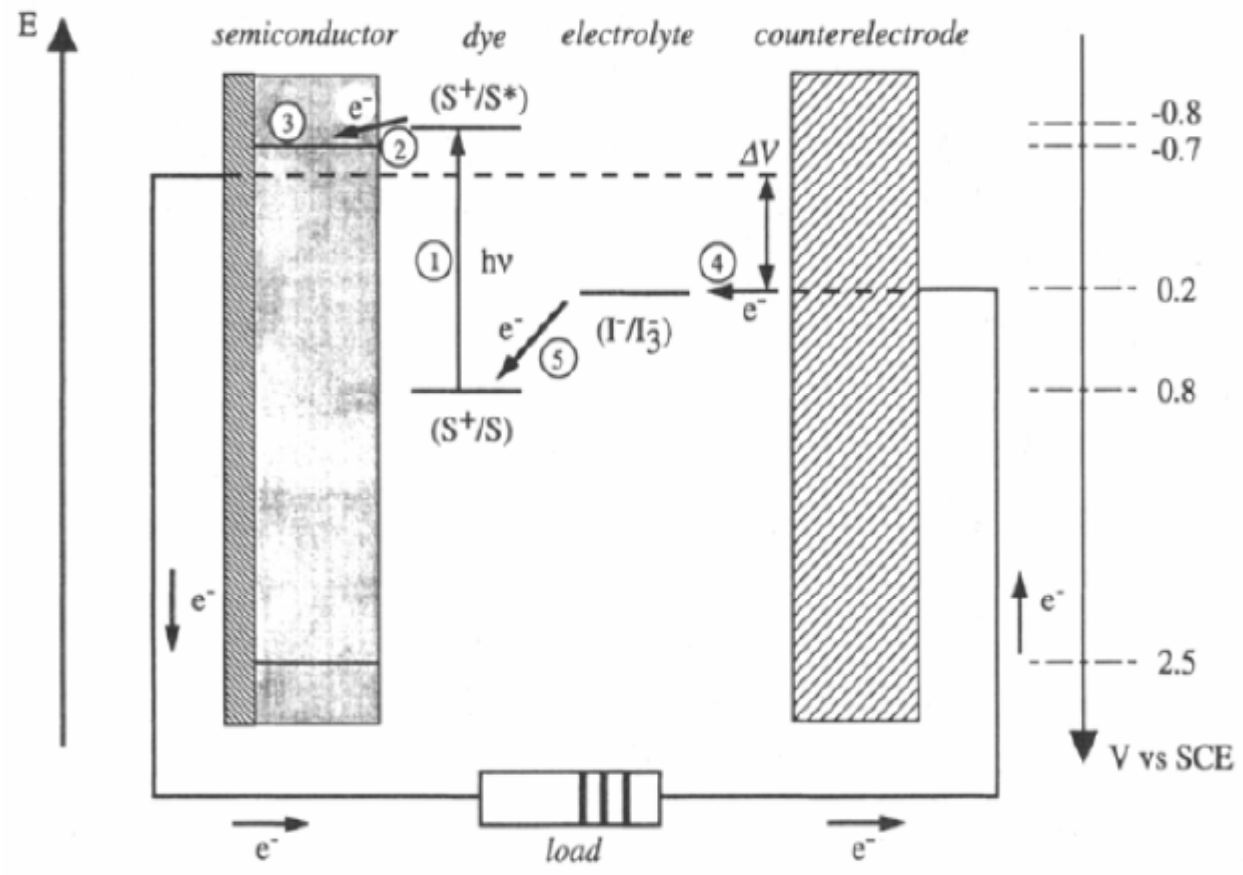
2. $2\ dm^* \rightarrow 2\ dm_{ox} + 2e^-$
   $2\ TiO_2 + 2\ e^- \rightarrow 2\ (TiO_2)^-$

3. $2\ dm_{ox} + 3\ I^- \rightarrow 2\ dm + I_3^-$

4. $I_3^- + 2\ e^- \rightarrow 3\ I^-$

dm = dye molecule

Operation


E
semiconductor
dye
electrolyte
counterelectrode
(S+/S*)
e-
3
2
ΔV
1
hν
4
e-
e-
5
(I-/I3-)
(S+/S)
e-
e-
-0.8
-0.7
0.2
0.8
2.5
V vs SCE
e-
load
e-

Operation

- **Step 1: Photosensitization**
  - sunlight falls on TiO2 surface
  - organic and coordination compounds in dye e.g. L6Ru2+

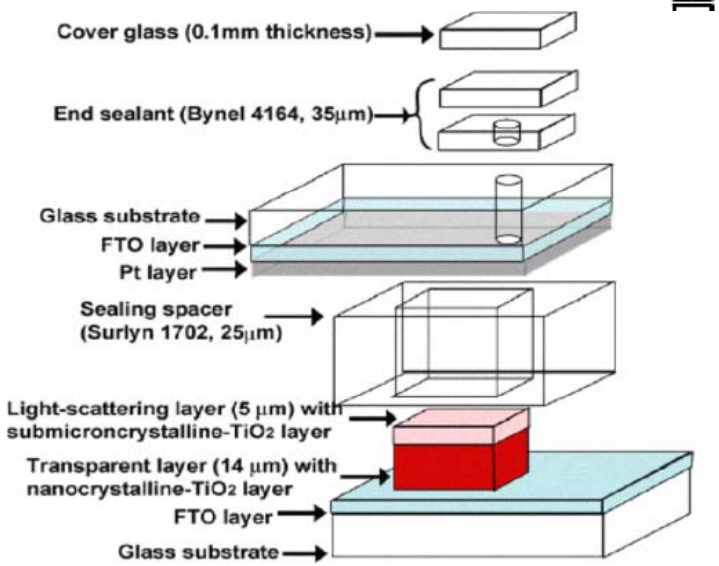
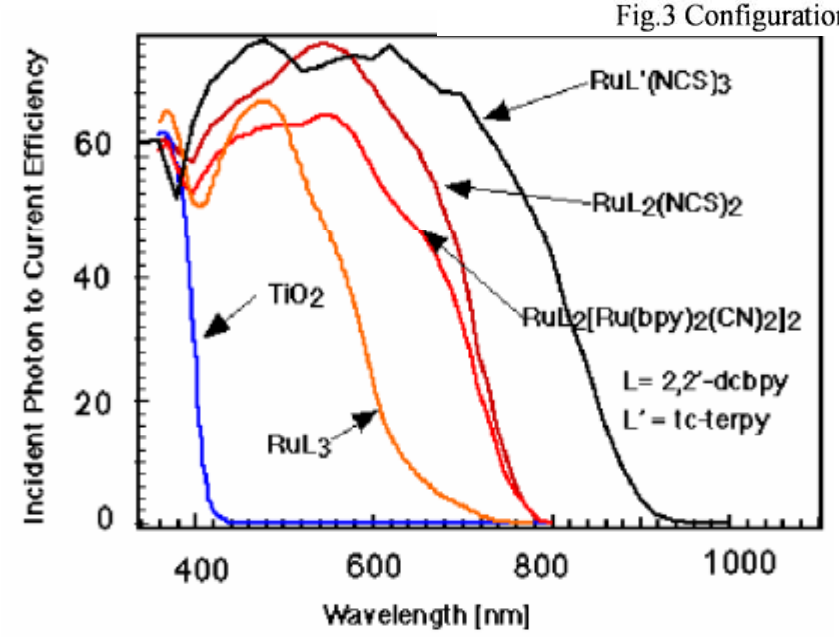


Fig.3 Configuration of DSSCs

- **Ru2+:**
  - Allows transitions at low energies
  - Exhibits Chelat effect that makes for high stability
  - Absorbs in the visible spectrum



Operation

- **Step 2: Charge "injection" into TiO2**
  - **absorbed photons go to excited state and**
  - **electron jumps to conduction band of Titanium**
- **Step 3: Separation of Charge**
  - **electron diffuses to counter electrode**
  - **lost dye electron is replaced by one in KI makes for high stability**
  - **Absorbs in the visible**

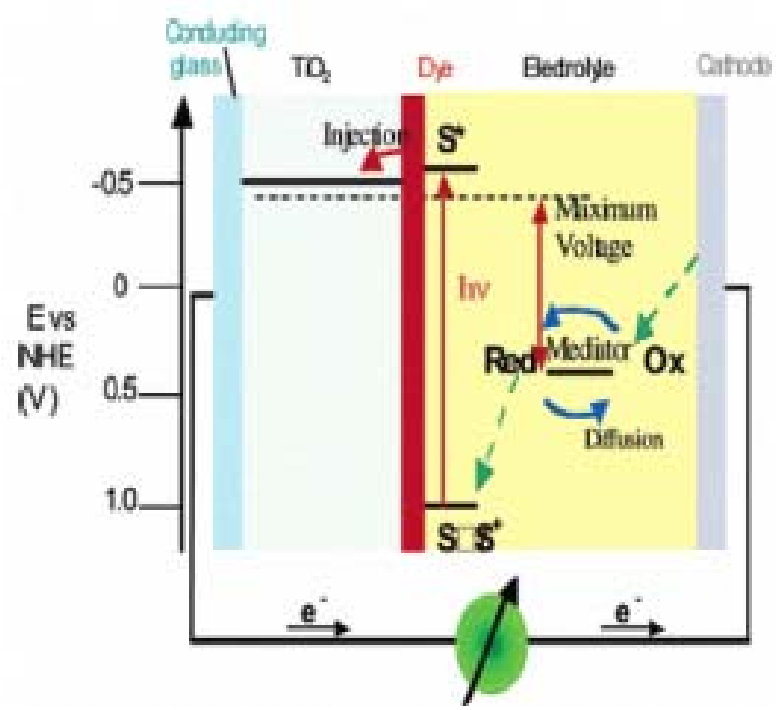


Fig.2 Principle of operation of DSSCs

negative electrode

$Ru^{3+} + I^- \rightarrow Ru^{2+} + I$

$2\,I \rightarrow I_2$

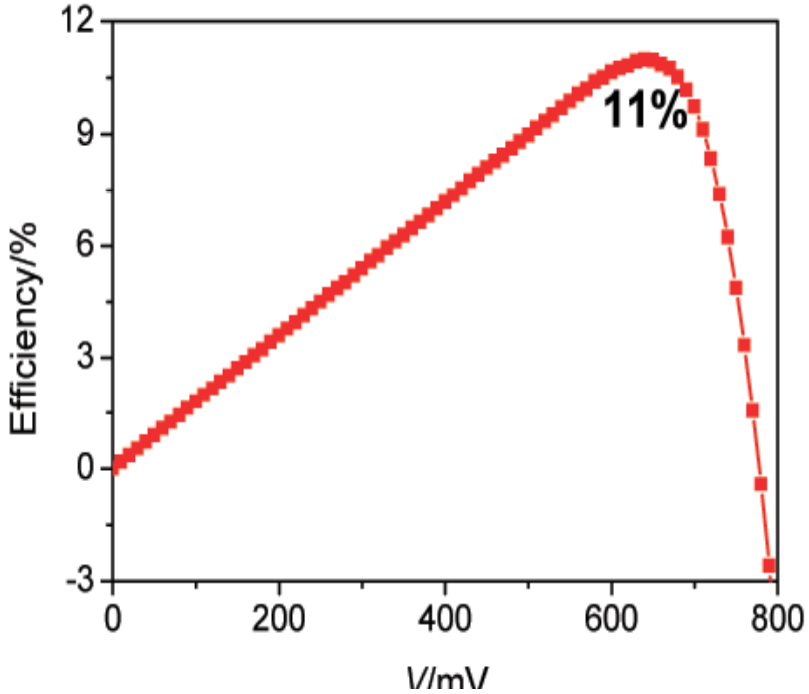
$I_2 + I^- \rightarrow 3\,I^-$

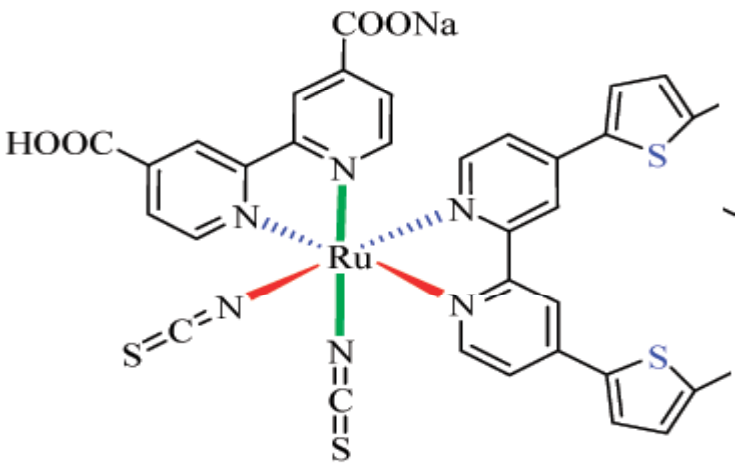
positive electrode

$I_3^- + 2\,e^- \rightarrow 3I^-$

Efficiency

- High Quantum Efficiency
  - Thick structure absorbs photons & efficiently converts to electrons
- Max Current produced 20 mA/cm2
  - Number of electrons absorbed is key
  - Depends on absorption of TiO2 layer and incoming solar spectrum
- Degrade when exposed to Ultra Violet Radiation
- Fill factor = 45% and overall peak power production efficiency= 11%





Comparison of features

Advantages

- Mechanically robust and light weight so used for rooftop solar panels
- Ability to operate in low light conditions due to combination of Slow recombination process and fast electron transfer
- Highly cost efficient

Disadvantages

- Not the best option for large scale applications where higher efficiency is required
- Liquid electrolyte can freeze at low temperatures and expand at high temperatures
- Efficiency lower than traditional solar cell

Comparison

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Dye Sensitized Solar Cells

- Longer absorption time
- Not as efficient as traditional Si solar cell
- Mechanically robust and light weight
- Flexibility leads to wide variety of applications
- Make use of chemical dye and redox reactions for operation

Traditional Si Solar Cells

- 6 times as expensive as Dye sensitized solar cells
- Not as lightweight as Gratzel Cells.
- More efficient than Gratzel Solar Cells
- Operation consists of electron transfer through drift and diffusion

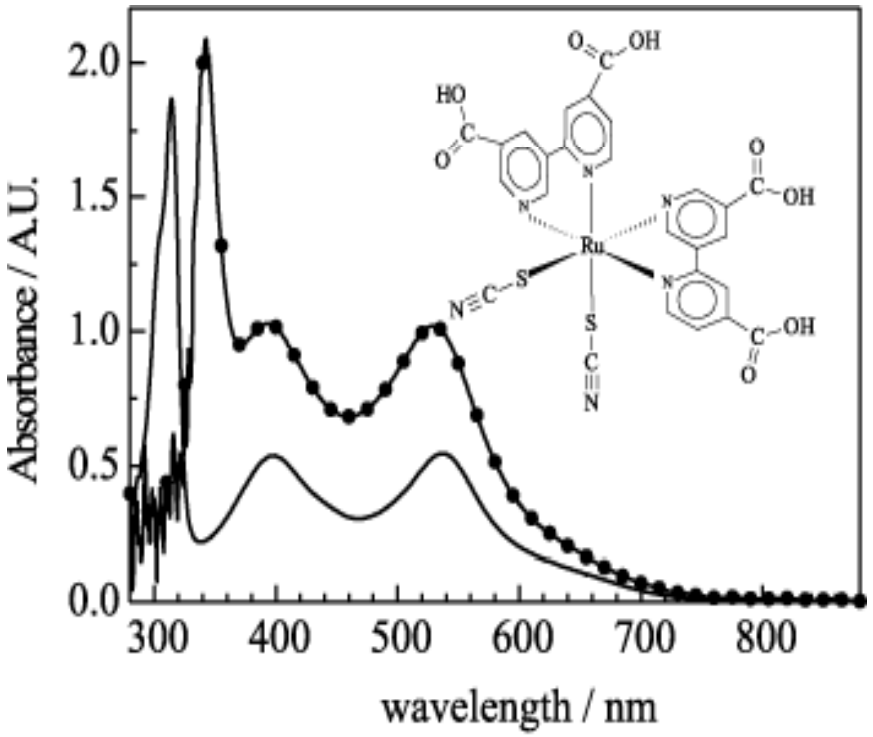
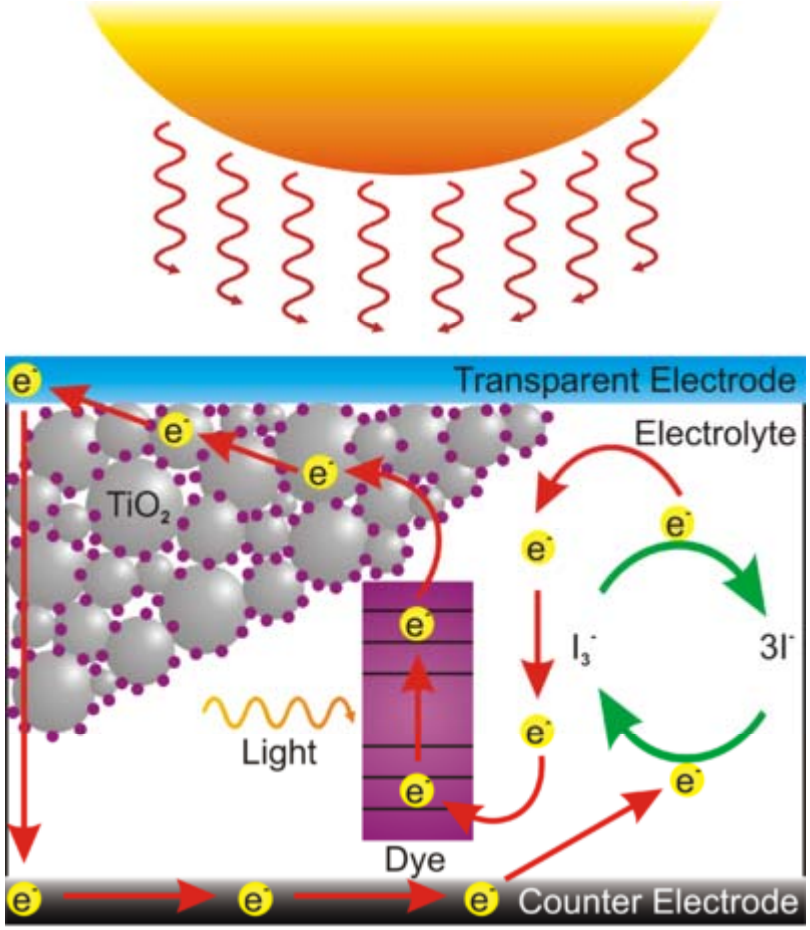


Figure 4. Absorption spectrum of the N3 dye in ethanol solution (—) and of a N3 dye-sensitized nanocrystalline TiO_2 electrode (-•-).



Challenges

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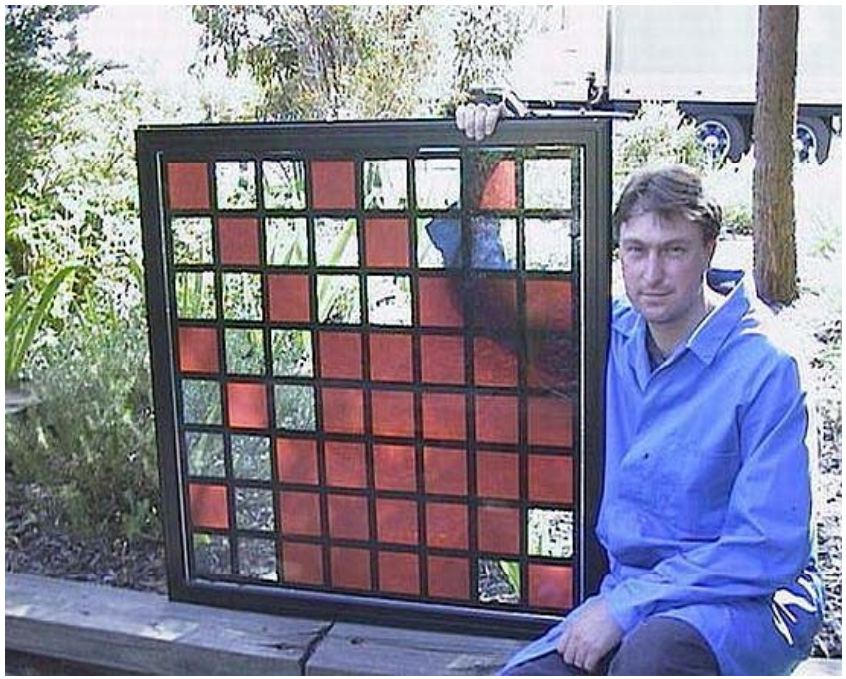
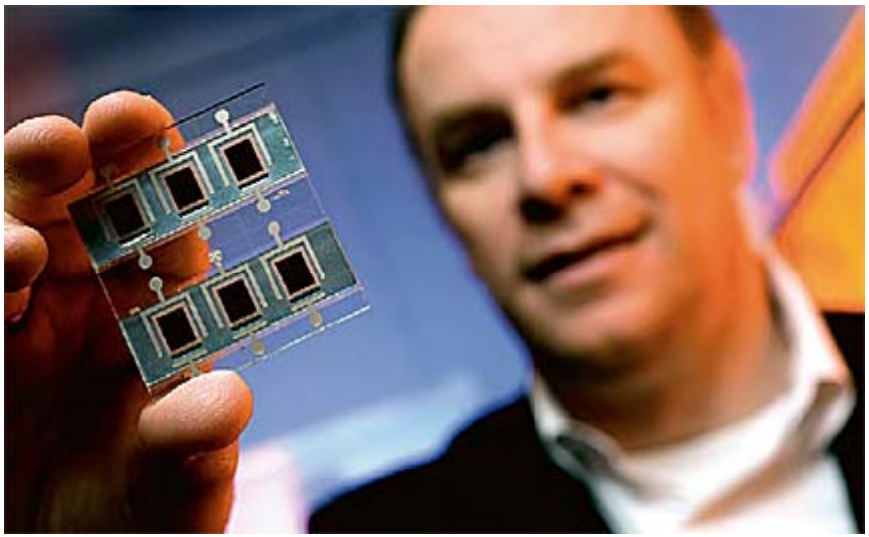
- **Higher Efficiency**
  - **Increase in surface area for absorption**
  - **Fill Factor**
  - **Expansion and freezing of Electrolyte**





Future Use

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References

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