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# 610-280 Environmental Chemistry

Rachel Caruso

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## Energy Tutorial

Questions to be completed before the  
tutorial will be placed on LMS.

- Thursday 14<sup>th</sup> August at 1 pm, Cuming  
Theatre
- Repeat on Friday 15<sup>th</sup> August at 2 pm,  
Senior Theatre

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# 610-280 Environmental Chemistry

Energy: Solar Energy

- Solar energy
- Crystallised silicon cell
- Dye-sensitized solar cell

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## References

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- Ullmann's Encyclopedia of Industrial Chemistry (electronic reference), John Wiley and sons, Fritz Pfisterer: Photovoltaic Cells
- Wright, J. Environmental Chemistry, 2003
- <http://www.sandia.gov/pv/>

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## Solar Energy

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- Direct
  - Solar thermal: Use sun's rays to heat air/water
  - Solar thermal electrical: Use sun's rays to heat water produce steam, generate electricity
  - Solar electrical: use sun's rays to produce electricity: photovoltaic cells
- Indirect
  - Burning of biomass produced by photosynthesis
  - Conversion of biomass to other fuels
  - Wind energy to drive turbines
  - Wave energy to drive turbines

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## Solar Energy

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### Solar Energy

- energy (light or heat) that comes from the sun
- used to

1. heat things called *solar thermal energy* or
2. to produce electricity called *photovoltaics*

*Sunlight* → *Electricity*

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## Overview

- Solar Energy
  - Huge potential

Organic solar cells  
<http://www.ipc.uni-linz.ac.at/publ/homecol.pdf>

- Photovoltaic Cells

	Technology	Market Acceptance (Predicted)
1 <sup>st</sup> Generation	Crystalline silicon	1970
2 <sup>nd</sup> Generation	Amorphous silicon, thin film silicon, CdTe, CIS etc	1983, 2001, 1995
3 <sup>rd</sup> Generation	DSSC, organic hybrid	2003, (2015)
4 <sup>th</sup> Generation	Biological	(2030)

Summarized from Sylvia Tulloch, Executive Director,  
 Sustainable Technologies International Pty. Ltd., see [www.sta.com.au](http://www.sta.com.au)

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## Crystalline silicon cells

- Silicon – 4 valence electrons
- Silicon crystal – Si forms covalent bonds with 4 other Si atoms

Dope silicon to create an electric field:

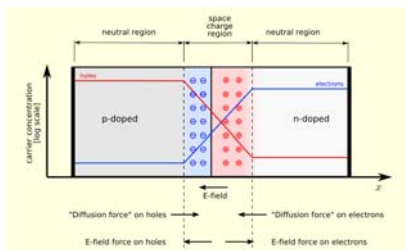
- Phosphorous → n-type semiconductor
- Boron → p-type semiconductor

[http://projectsol.aps.com/inside/inside\\_pv.asp](http://projectsol.aps.com/inside/inside_pv.asp)

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## p-n junction

- Placing the n-type and p-type semiconductors together produces an electric field (p-n junction):



## Band-gap energy

- Difference in energy between the valence band and the conduction band.

Require  $E_{\text{photon}} > E_{\text{band-gap}}$

$E_{\text{photon}} - E_{\text{band-gap}} \rightarrow \text{thermal E}$

$E_{\text{band-gap}} (\text{c-Si}) = 1.1 \text{ eV}$

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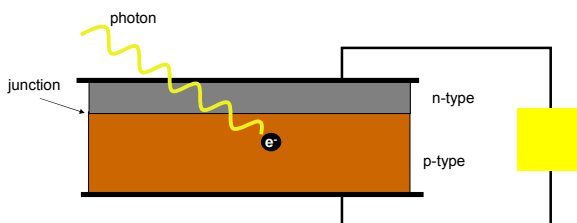
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## Crystalline silicon cells



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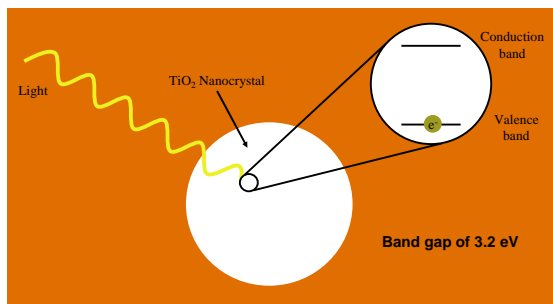
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## Titanium Dioxide



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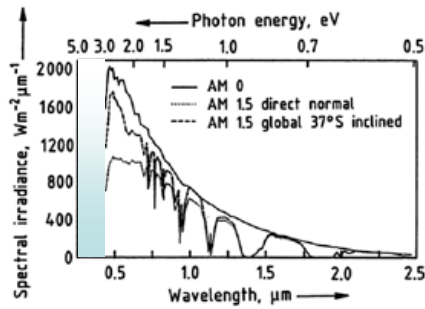
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## Solar spectrum



Ullmann's encyclopedia

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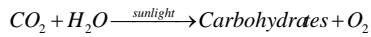
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## Dye Sensitized Solar Cells

- Prof. Michael Graetzel (1991), Switzerland
- Titanium dioxide on its own does not absorb enough sunlight
- Photosynthesis – chlorophyll



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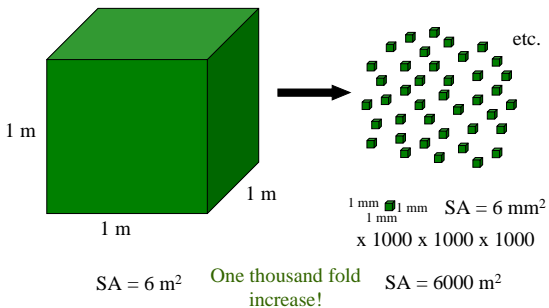
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## Surface Area Increase



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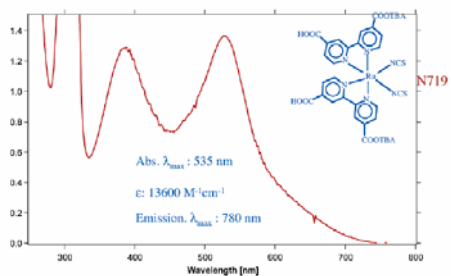
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## Absorbance of Dye



M. Grätzel, Inorganic Chemistry 2005, 44, 5841

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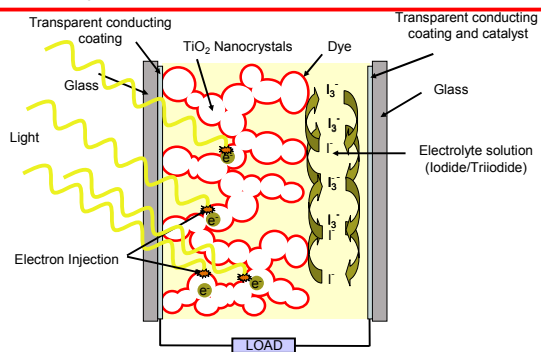
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## Dye Sensitized Solar Cells



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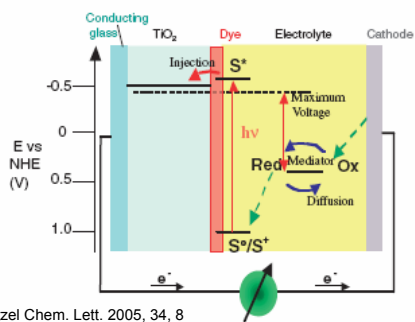
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## Operation of DSSC



M. Grätzel Chem. Lett. 2005, 34, 8

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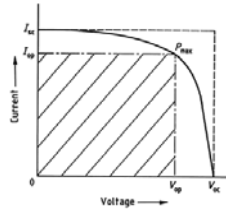
## Performance

- Fill factor (F.F.)

$$F.F. = \frac{P_{\max}}{I_{sc} \times V_{oc}}$$

- Conversion efficiency ( $\eta$ )

$$\eta = \frac{P_{\max}}{\text{Area} \times P_{in}}$$



Ullmann's Encyclopedia

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## Environmental impact

- No harmful emissions during operation.
- Production of panels produces greenhouse gas emission similar in quantity to nuclear power.
- Some components of older cell technologies are toxic – potential for release a concern.

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## In summary

### Energy: Solar Energy

- Solar energy to electricity conversion - photovoltaics
  - Working mechanism of the c-Si cell and DSSC
  - Calculation of efficiency
  - Environmental impact

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