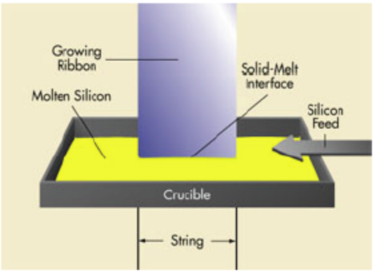
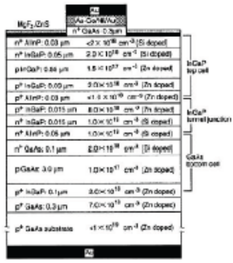
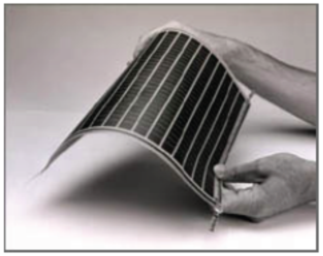
Technological Diversity



Kerfless Silicon


Multijunction Cells

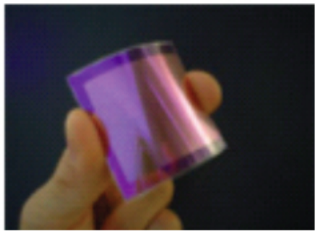
Copper Indium Gallium Diselenide (CIGS)


Amorphous Silicon

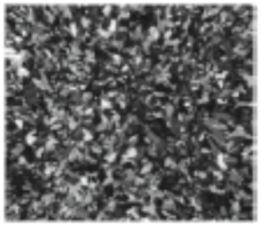

Dye-sensitized Cells


Silicon Sheet

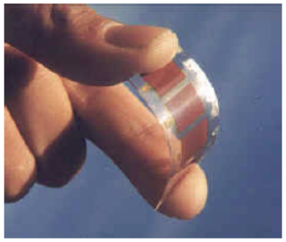

Cadmium Telluride


Hybrid (nano)


Monocrystalline Silicon


Multicrystalline Silicon

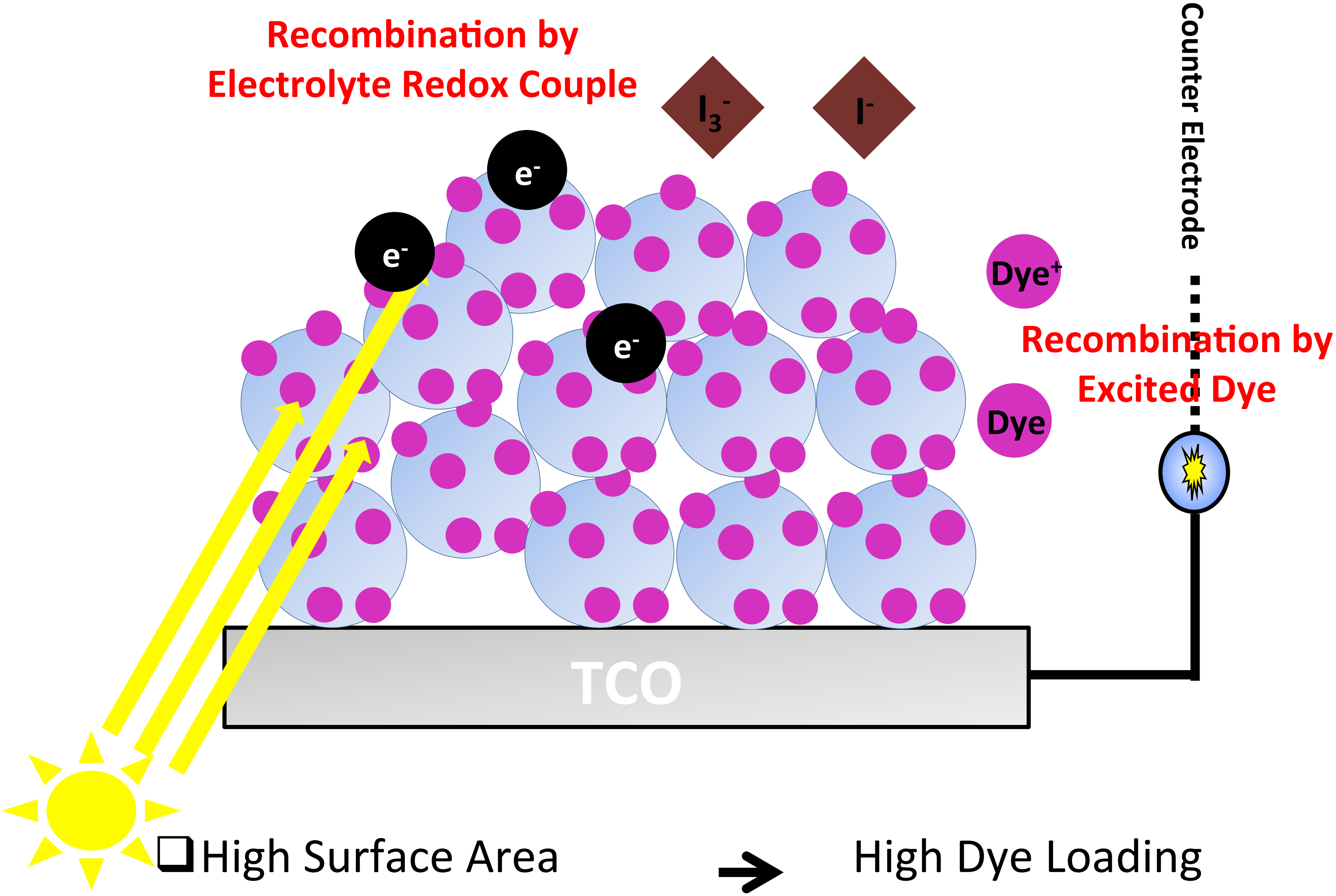

High-Efficiency silicon


Organics

Buonassisi (MIT) 2011

INTRODUCTION

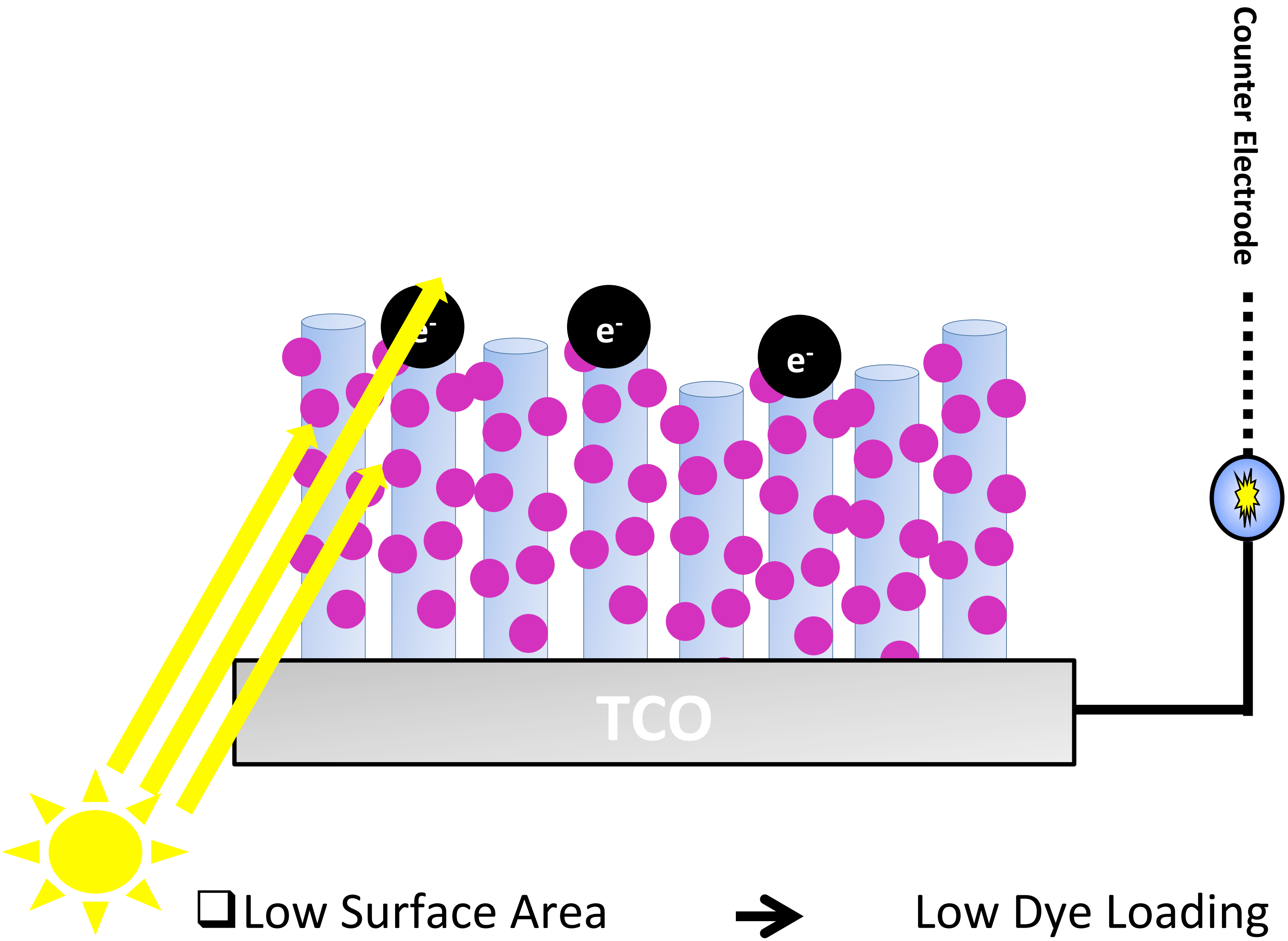
Nanoparticles TiO_2 Electrode



- ❑ High Surface Area → High Dye Loading
- ❑ Random Electron Pathway → Low Diffusion Length

INTRODUCTION

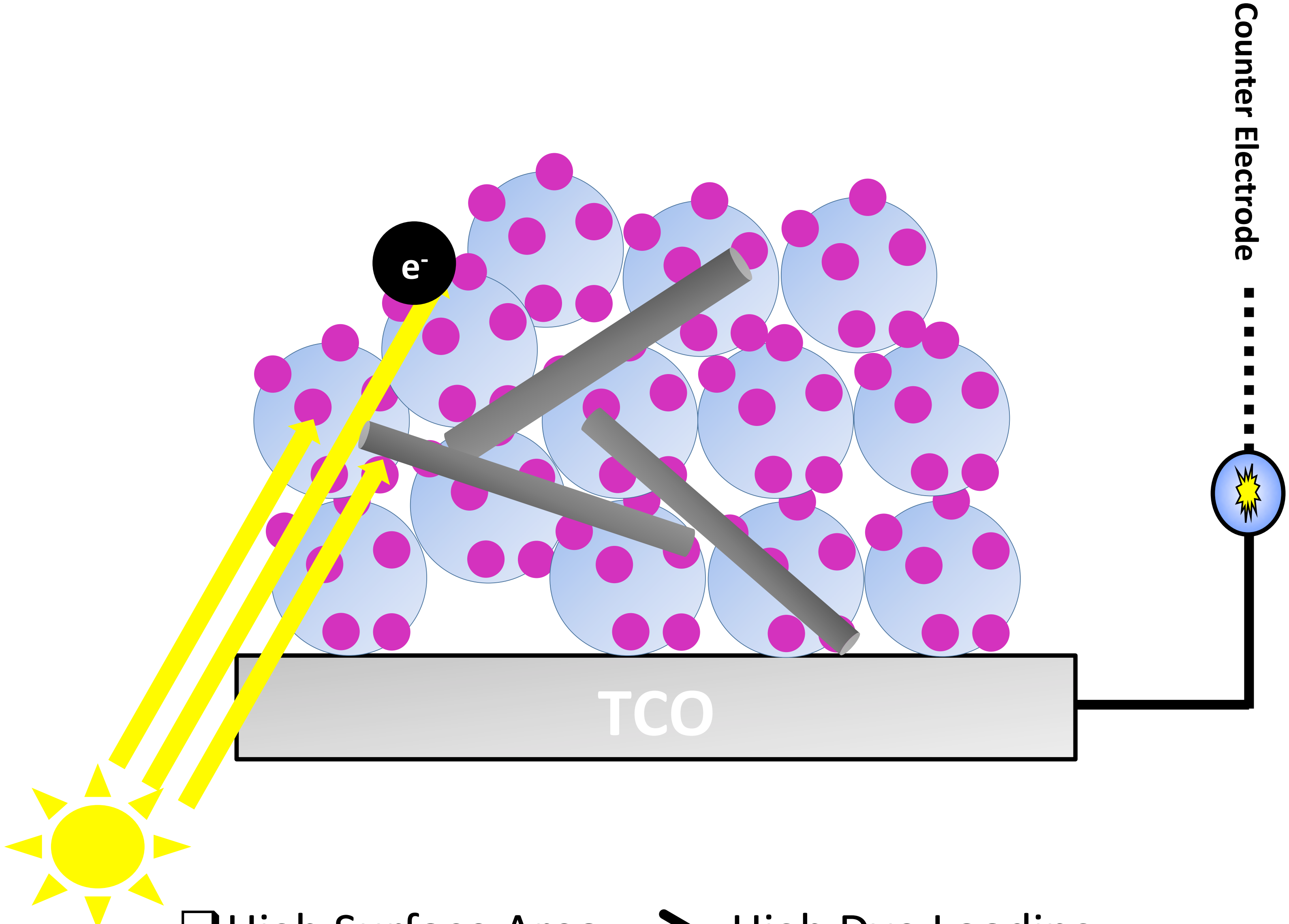
Vertical Nano-tube/rod TiO_2 Electrode



- ❑ Low Surface Area → Low Dye Loading
- ❑ Directional Electron Pathway → High Diffusion Length

INTRODUCTION

How Carbon Nanotube Helps DSSCs ?

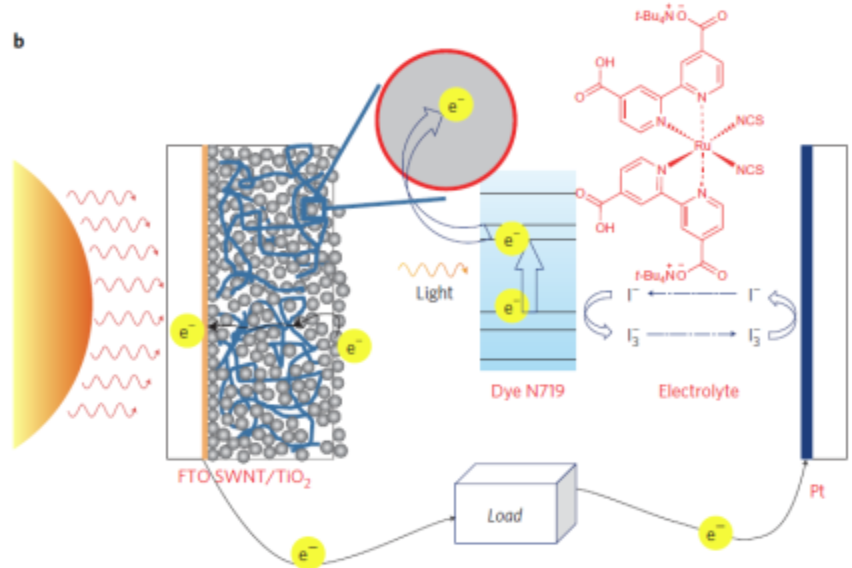


- ❑ High Surface Area → High Dye Loading
- ❑ Directional Electron Pathway → High Diffusion Length

Faster Transport and Thinner film

Faster transport

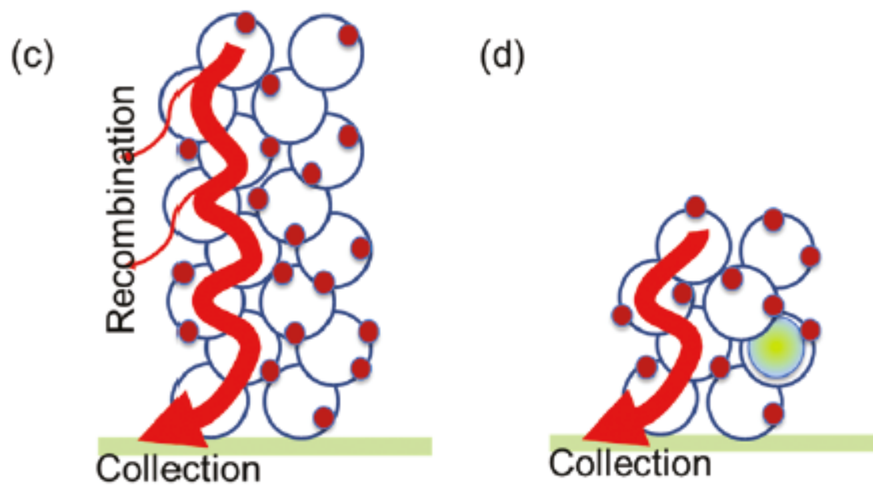
SWNT as electron pathway



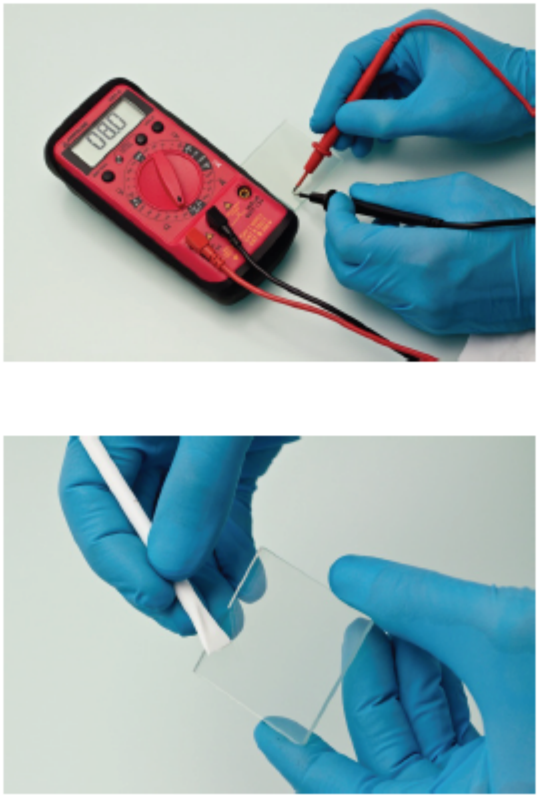
Nature Nanotechnology, 2011

Thinner film

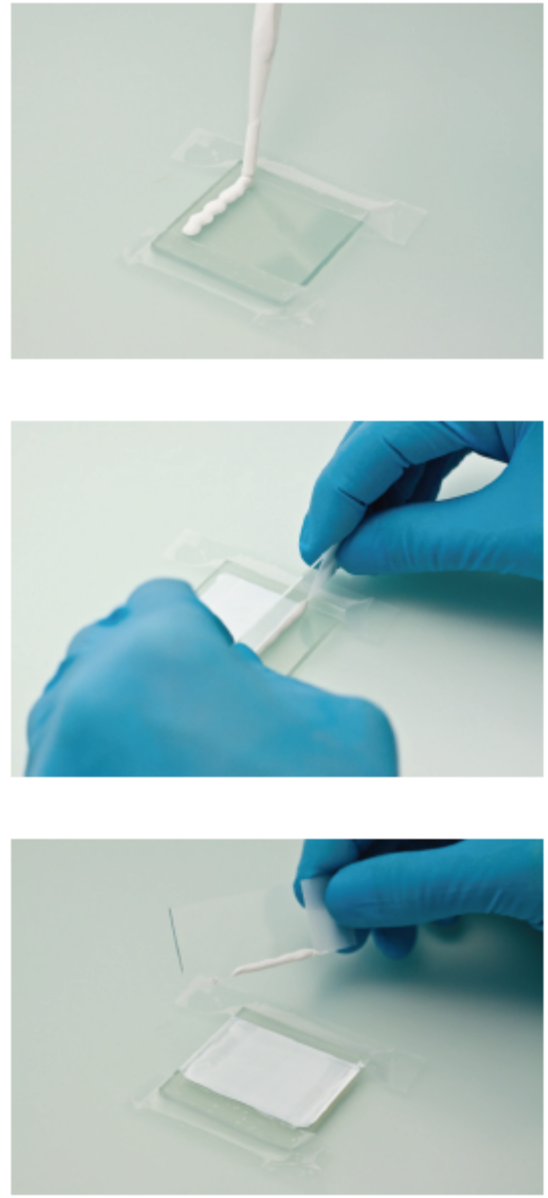
Less Absorption??
Plasmonics



ACS Nano, 2011

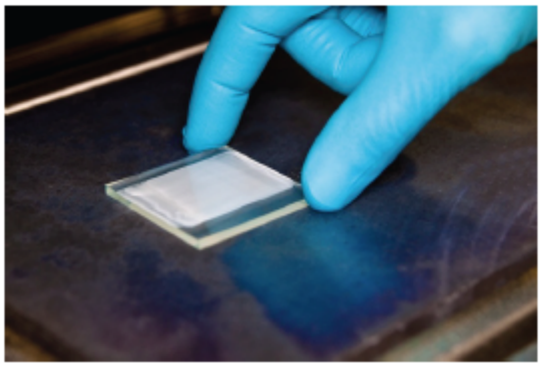


Identifying the conductive side of the TCO (transparent conductive oxide)

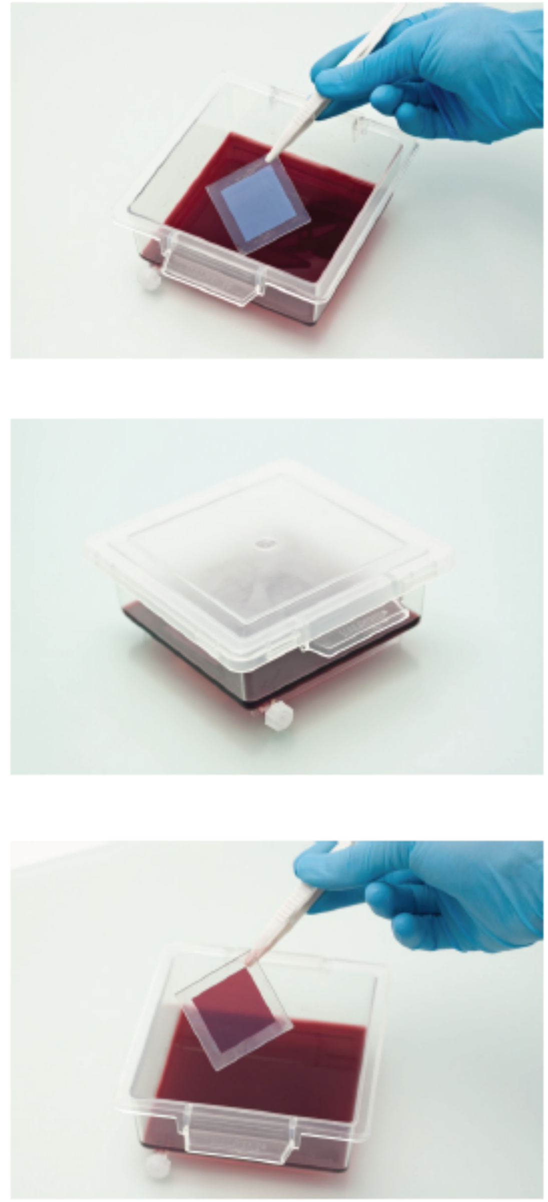


"Doctor-blading" the titania (TiO_2) paste

http://www.solaronix.com

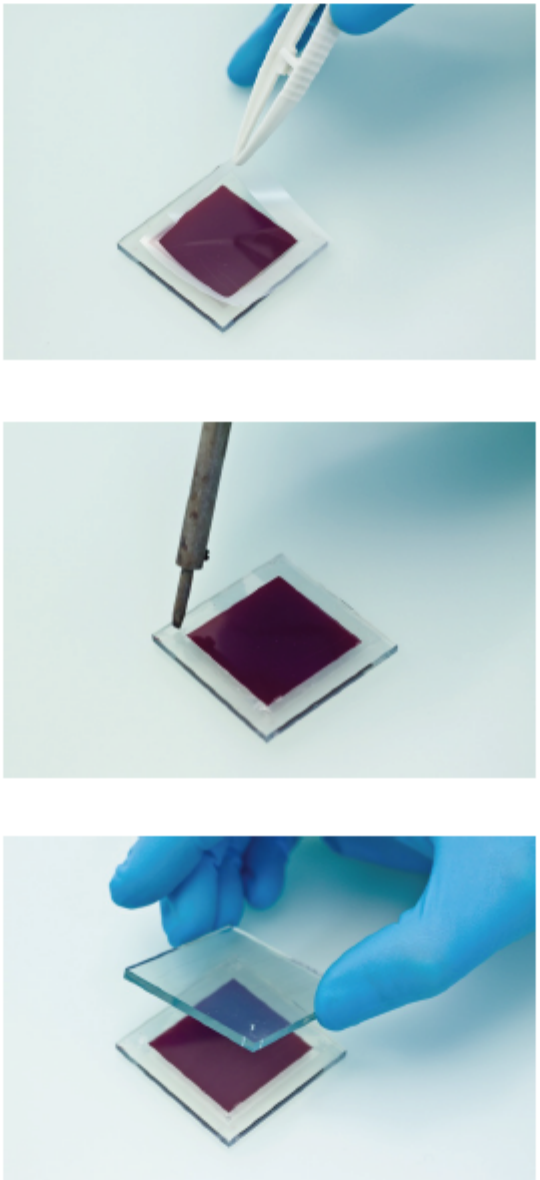


Sintering the film (heating)

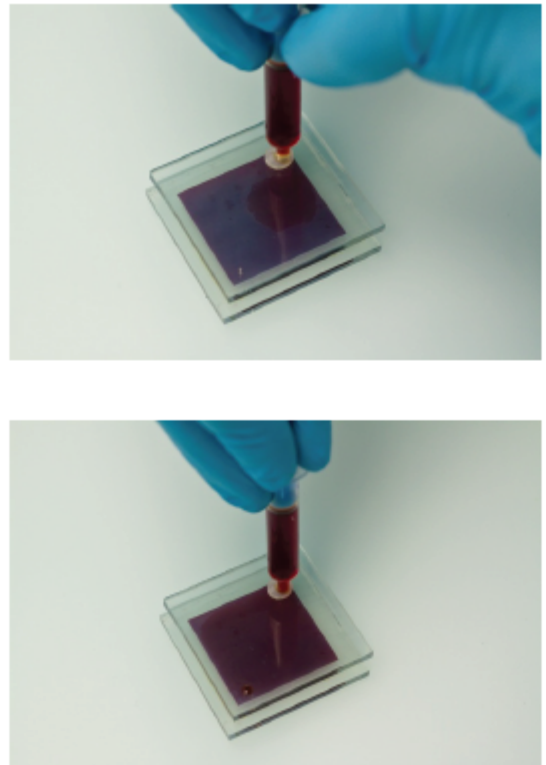


Dyeing the film

http://www.solaronix.com

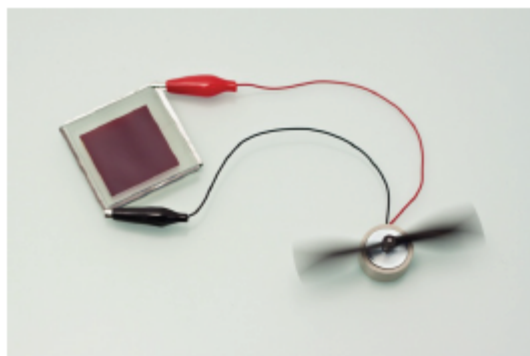


Assembling the device with another electrode



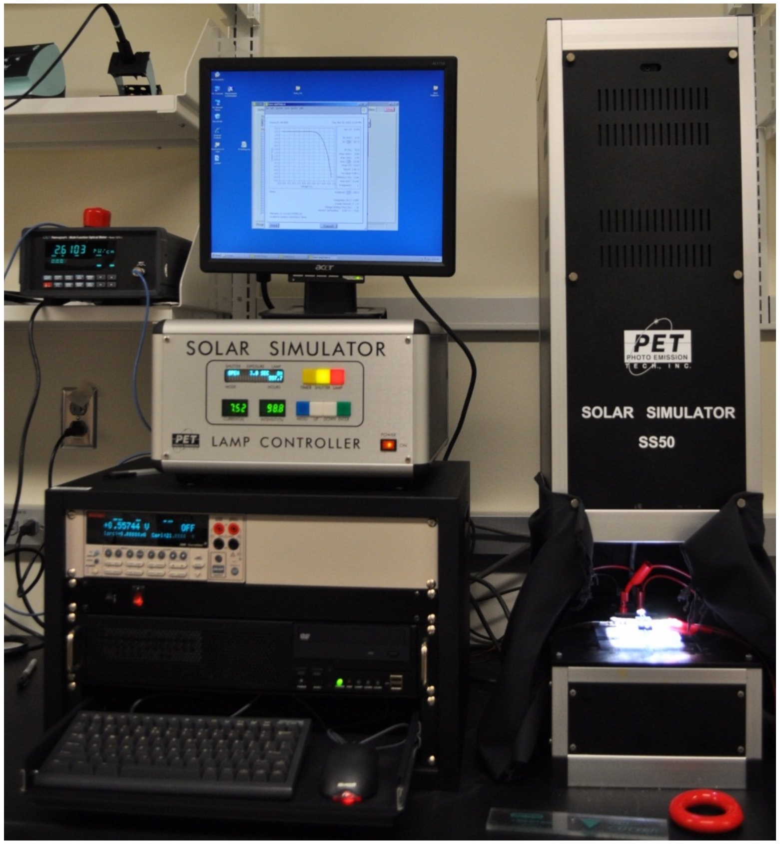
Filling the electrolyte

http://www.solaronix.com



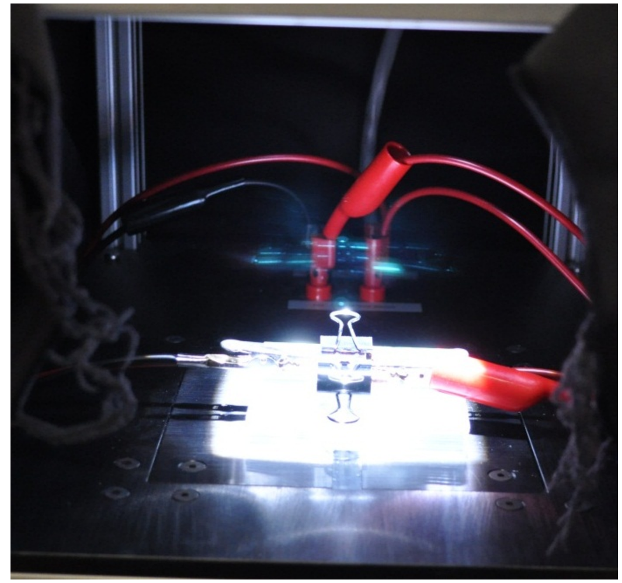
Testing the device

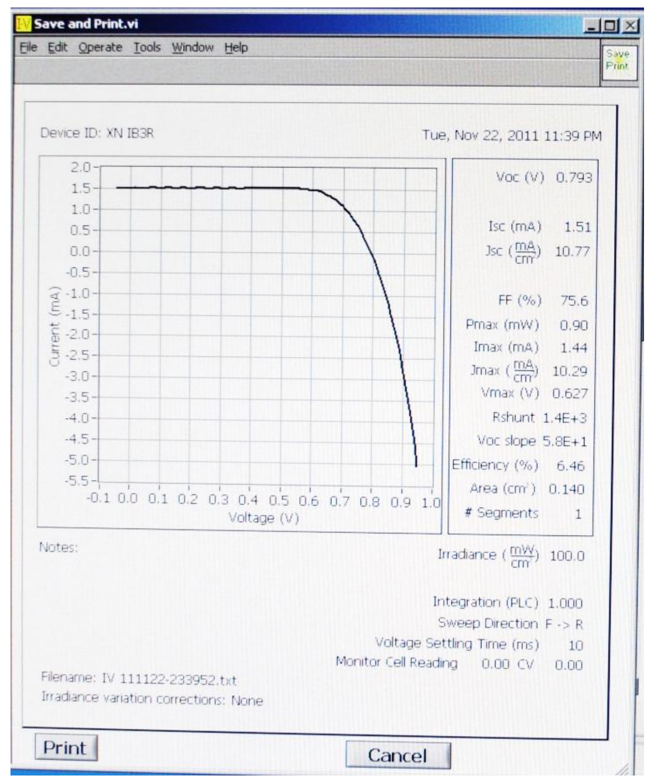
http://www.solaronix.com

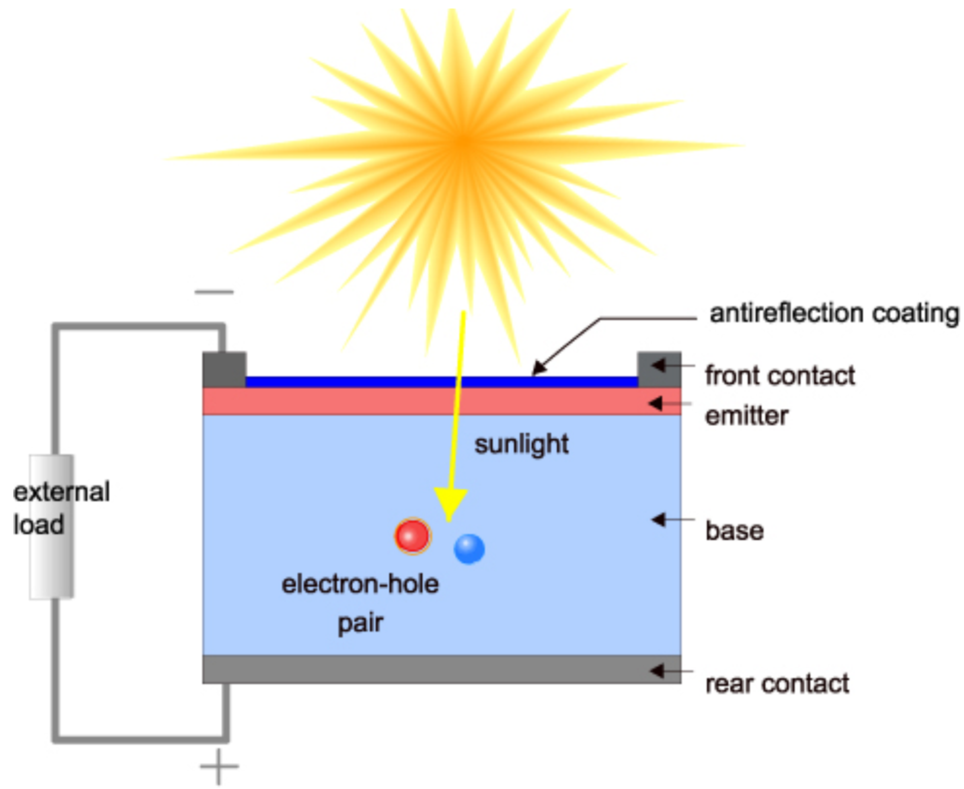


The Air Mass is the path length which light takes through the atmosphere normalized to the shortest possible path length. The reduction in the power of light as it passes through the atmosphere and is absorbed by air and dust.

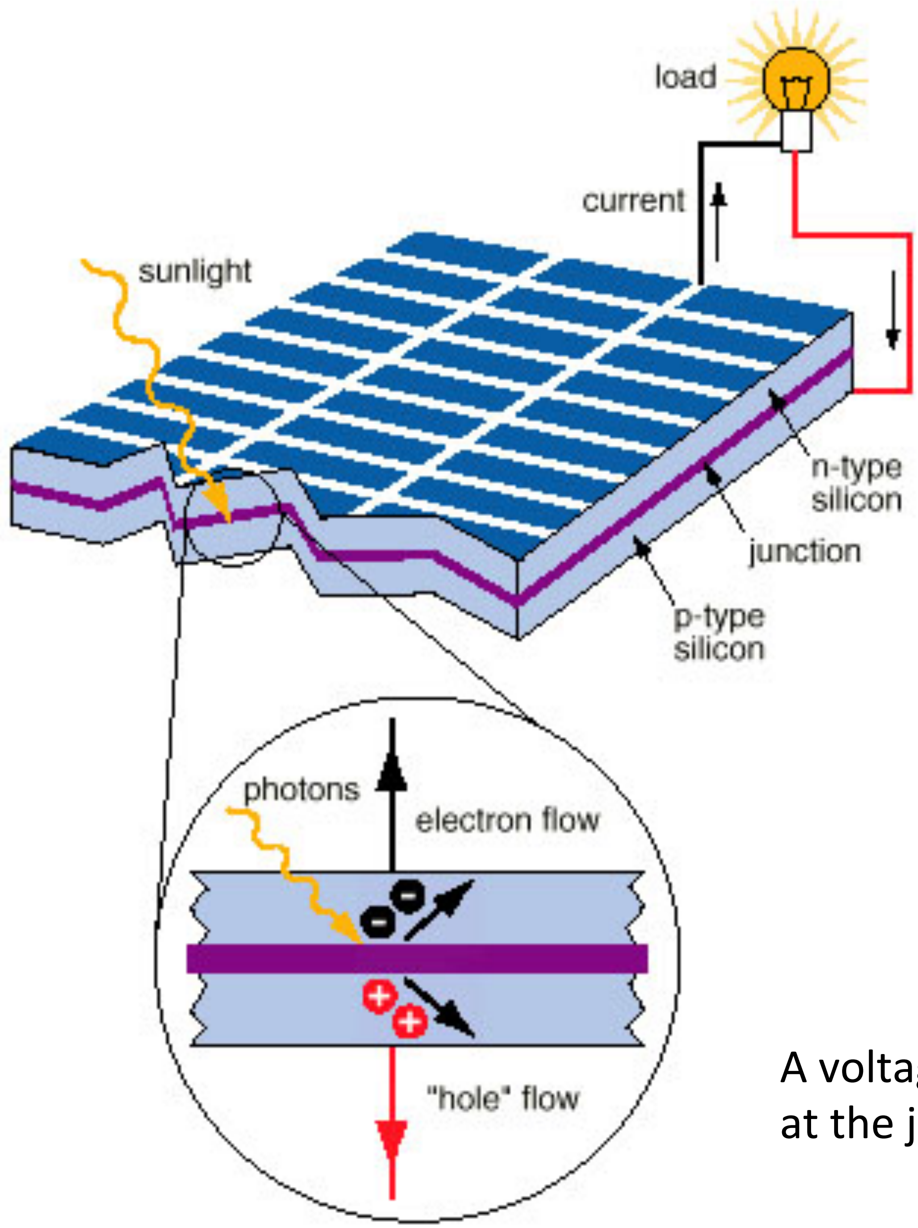
Instruments and data to be expected





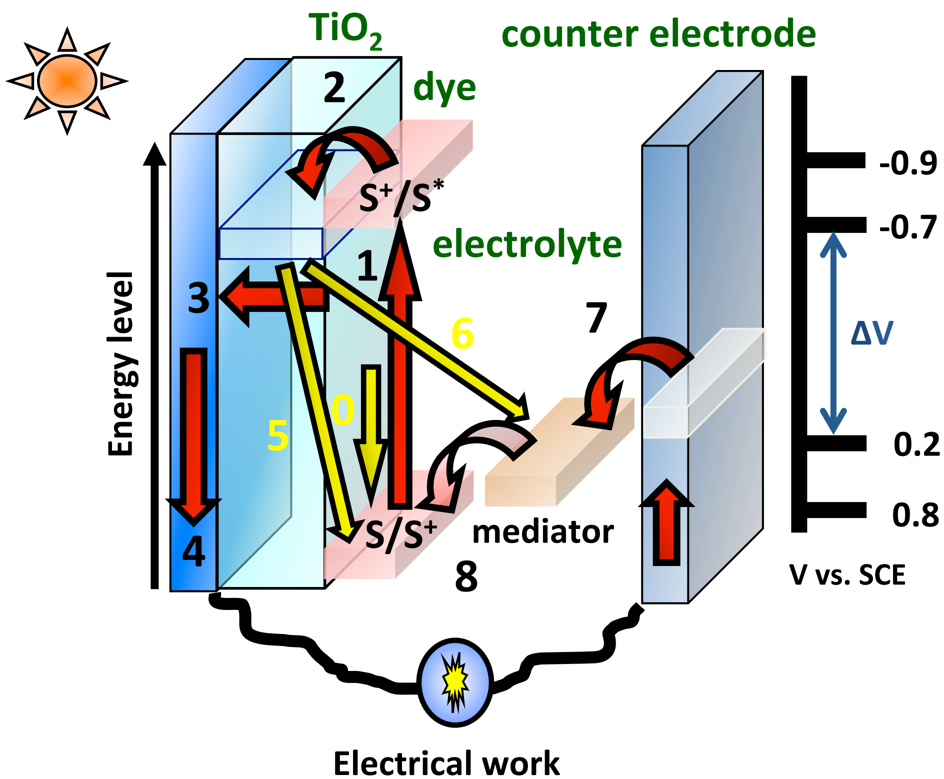


the generation of light-generated carriers
the collection of the light-generated carries to generate a current;
the generation of a large voltage across the solar cell; and
the dissipation of power in the load and in parasitic resistances.



A voltage results from the electric field formed at the junction

INTRODUCTION Mechanism of Dye-sensitized Solar Cell



Mechanism

Activation (1)

S|SC (Semiconductor) + hγ → S^*|SC

Electron injection (2)

S^*|SC → S^+|SC + e^-_{cb}(SC)

Electron collection (3)

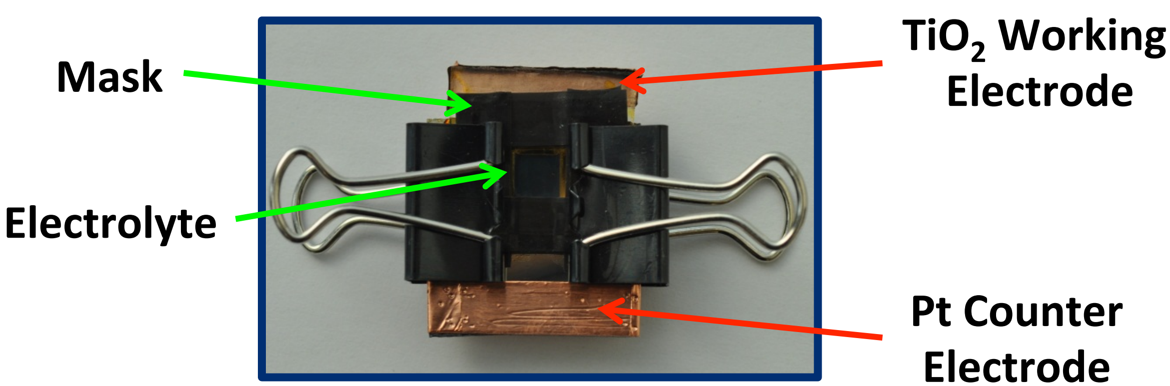
e^-_{cb}(SC) → e^-(FTO)

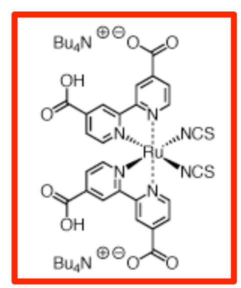
Electron reception (7)

I_3^- + e^-(Pt) → I^-

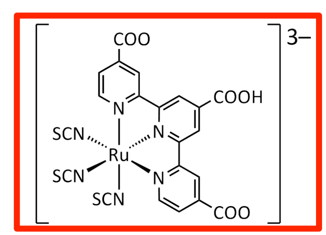
Interception (8)

S^+|SC + I^- → S|SC + I_3^-



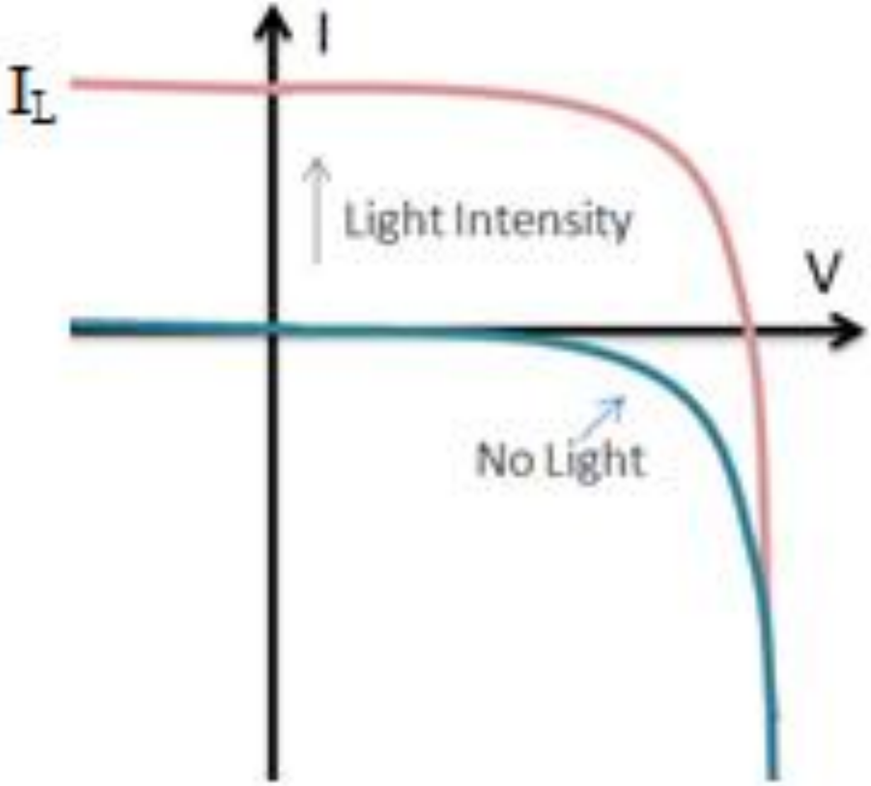


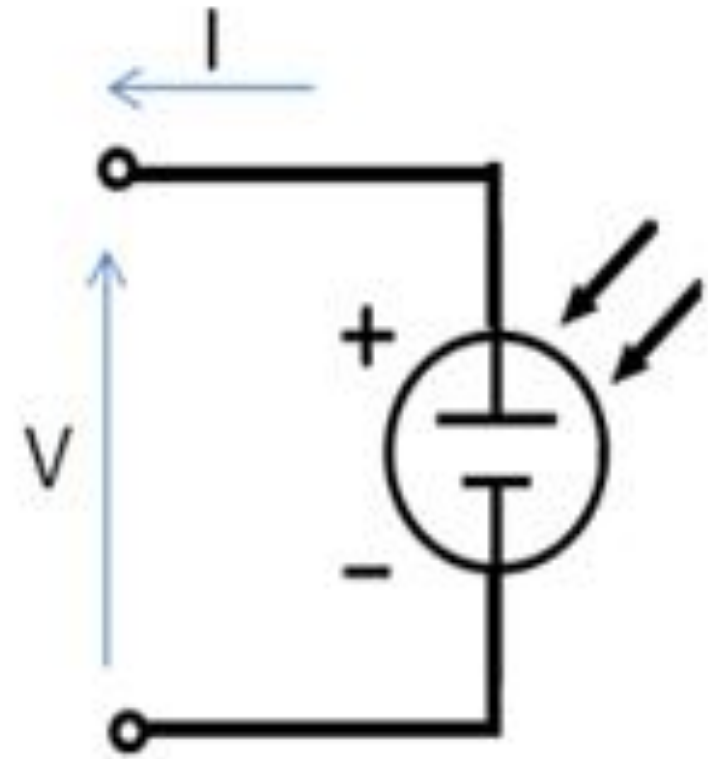
Red Dye (N719)



Black Dye (N749)

PARAMETERS I-V Curve



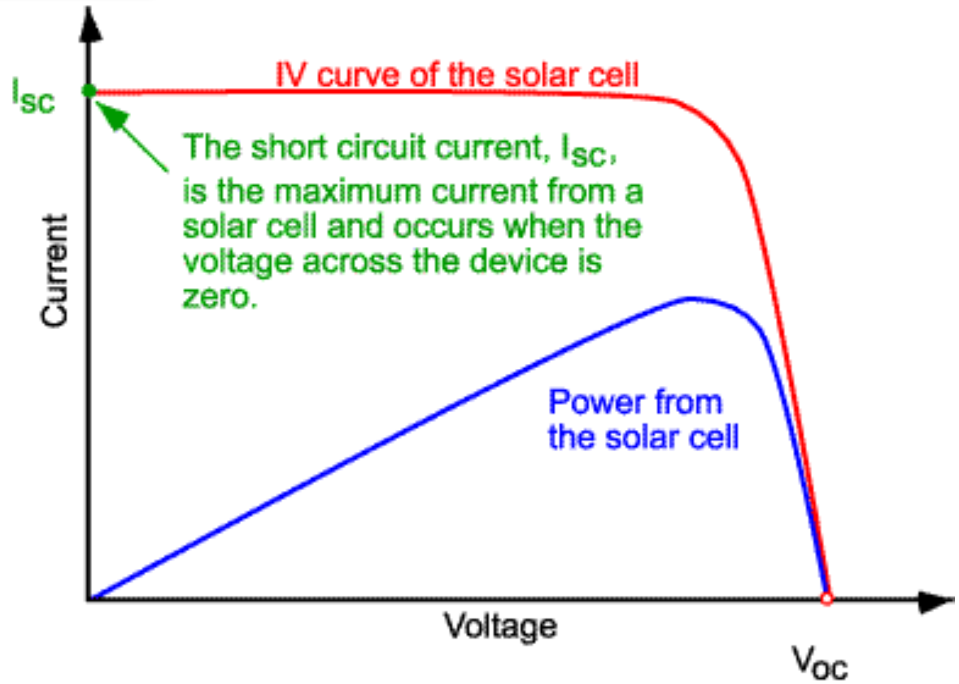


$$P_{max} = V_{OC} I_{SC} FF$$

$$\eta = \frac{V_{OC} I_{SC} FF}{P_{in}}$$

PARAMETERS

Short-Circuit Current (I_{SC})



The short-circuit current : the generation and collection of light-generated carriers

The area of the solar cell. To remove this use short-circuit current **density** (J_{sc} in mA/cm^2)

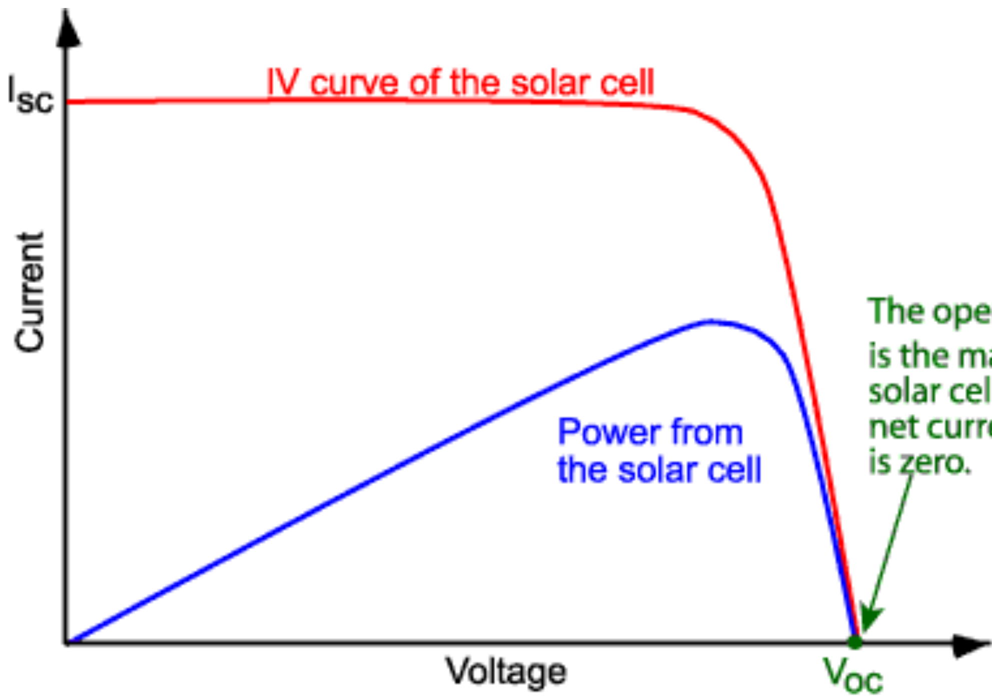
The number of photons. (i.e., the power of the incident light source).

The spectrum of the incident light. For most solar cell measurement, the spectrum is the AM1.5 spectrum;

The optical properties. Absorption and reflection of the solar cell.

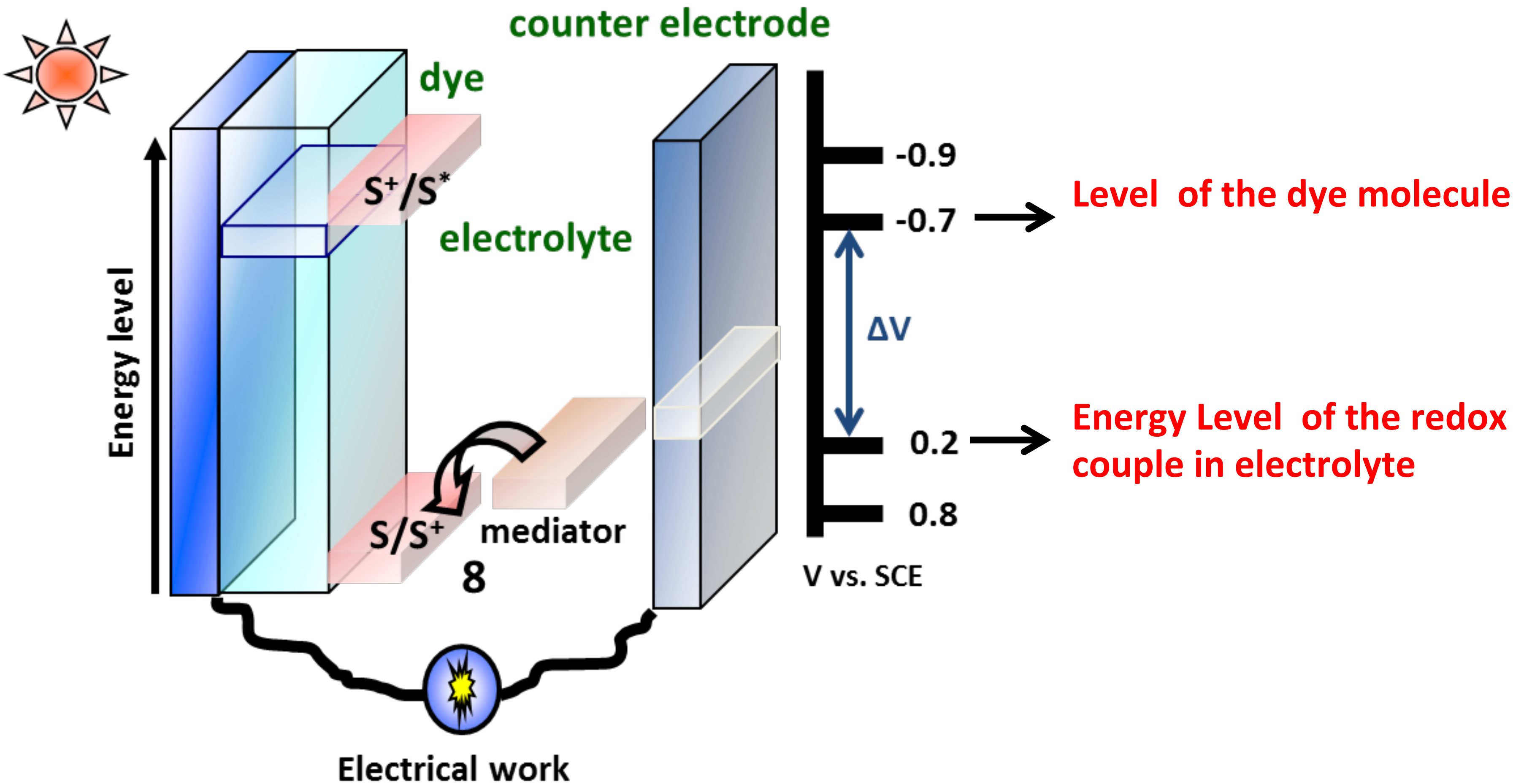
The collection probability of the solar cell, which depends chiefly on the surface passivation and the minority carrier lifetime in the base.

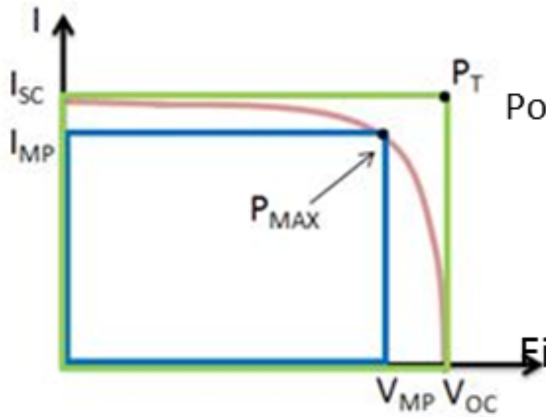
The open-circuit voltage, V_{OC}, is the maximum voltage available from a solar cell, and this occurs at zero current.



PARAMETERS

Open-Circuit Voltage (V_{OC})



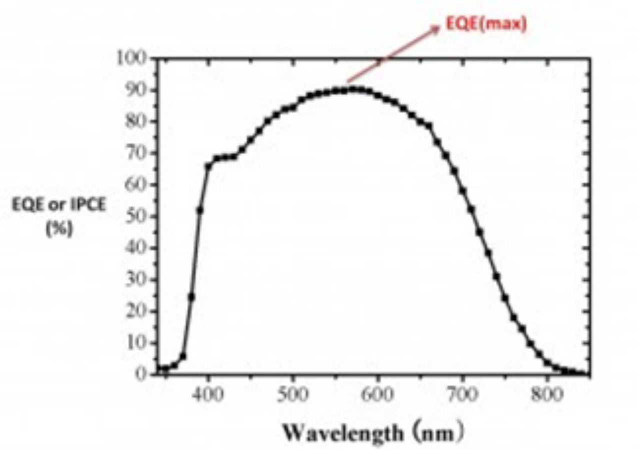


Power conversion efficiency: PCE = *P*max / *P*in

$$= \frac{I_{SC} V_{OC} FF}{\phi}$$

Fill factor:

$$FF = \frac{P_{max}}{I_{SC} V_{OC}} = \frac{I_{max} V_{max}}{I_{SC} V_{OC}}$$



$$\text{IPCE} = \frac{J_{sc}(\lambda)}{e\Phi(\lambda)} = 1240 \frac{J_{sc}(\lambda)\ [\text{A cm}^{-2}]}{\lambda\ [\text{nm}] P_{in}(\lambda)\ [\text{W cm}^{-2}]}$$

V_{OC} open circuit voltage (~0.7 V)
Determined by thermodynamics, energy level and redox potential

I_{SC} short circuit current (maximum ~20 mA/cm^2)
Determined by number of electrons generated by absorbing light

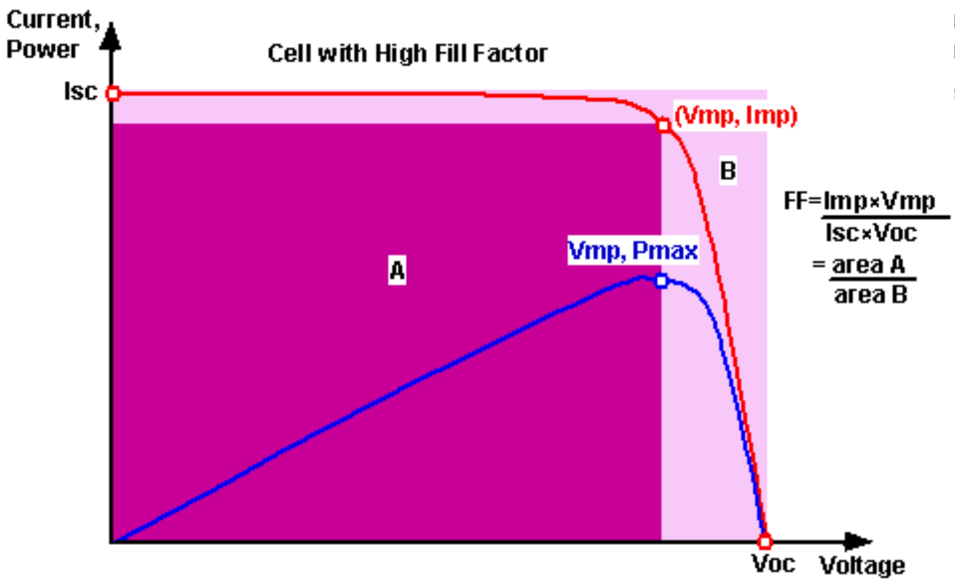
FF fill factor (~0.7)
Determined by quality of film, recombination, resistance, etc.

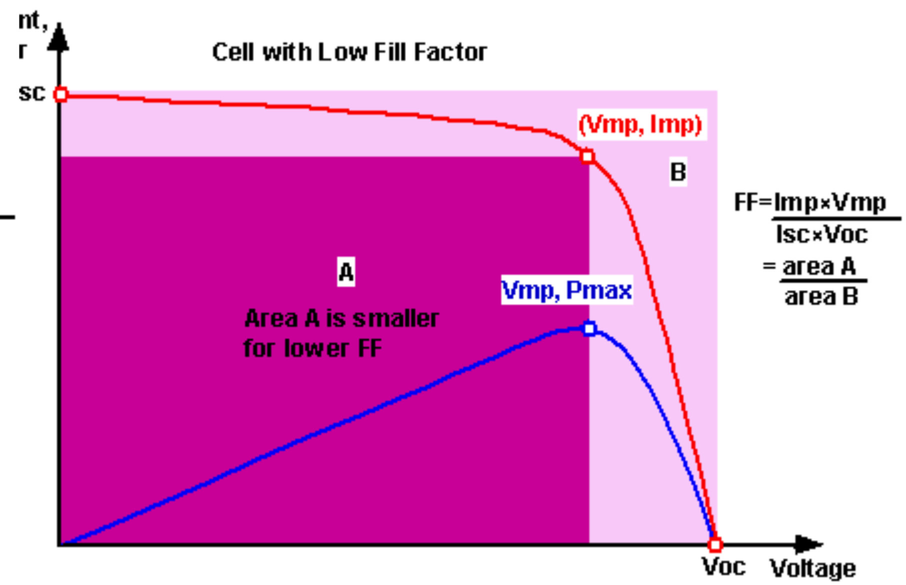
P_{max} power conversion efficiency (maximum ~10%)
Determined by the previous three factors

IPCE or EQE incident photon-to-current conversion efficiency or external quantum efficiency (peak close to 100%)
Spectral response of a solar cell, related to I_{SC}

ϕ and P_{in} incident light power

PARAMETERS Fill Factor (FF)





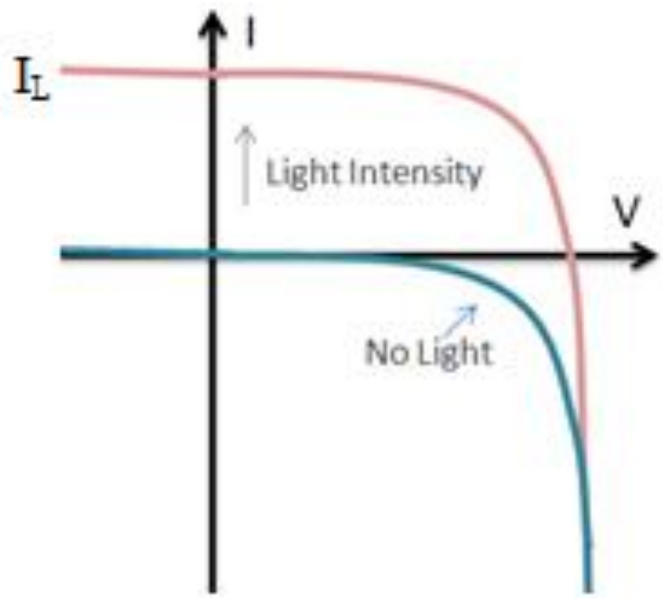
Higher FF → Higher efficiency

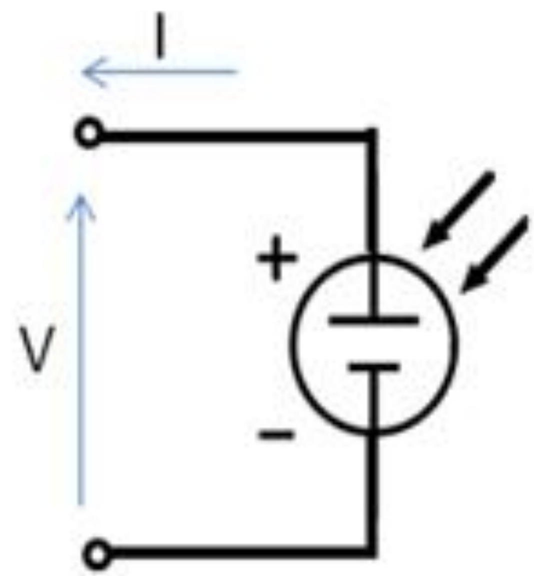
Lower FF → Lower efficiency

The short-circuit current and the open-circuit voltage are the maximum current and voltage respectively from a solar cell.

However, at both of these operating points, the power from the solar cell is zero.

The "fill factor", more commonly known by its abbreviation "FF", is a parameter which, in conjunction with V_{oc} and I_{sc}, determines the maximum power from a solar cell





PV cells can be modeled as a current source in parallel with a diode. When there is no light present to generate any current, the PV cell behaves like a diode. As the intensity of incident light increases, current is generated by the PV cell

The efficiency is the most commonly used parameter to compare the performance of one solar cell to another.

Efficiency is defined as the ratio of energy output from the solar cell to input energy from the sun.

$$P_{max} = V_{OC} I_{SC} FF$$

$$\eta = \frac{V_{OC} I_{SC} FF}{P_{in}}$$

The efficiency of a solar cell is determined as the fraction of incident power which is converted to electricity and is defined as

:where V_{oc} *is the open-circuit voltage;*

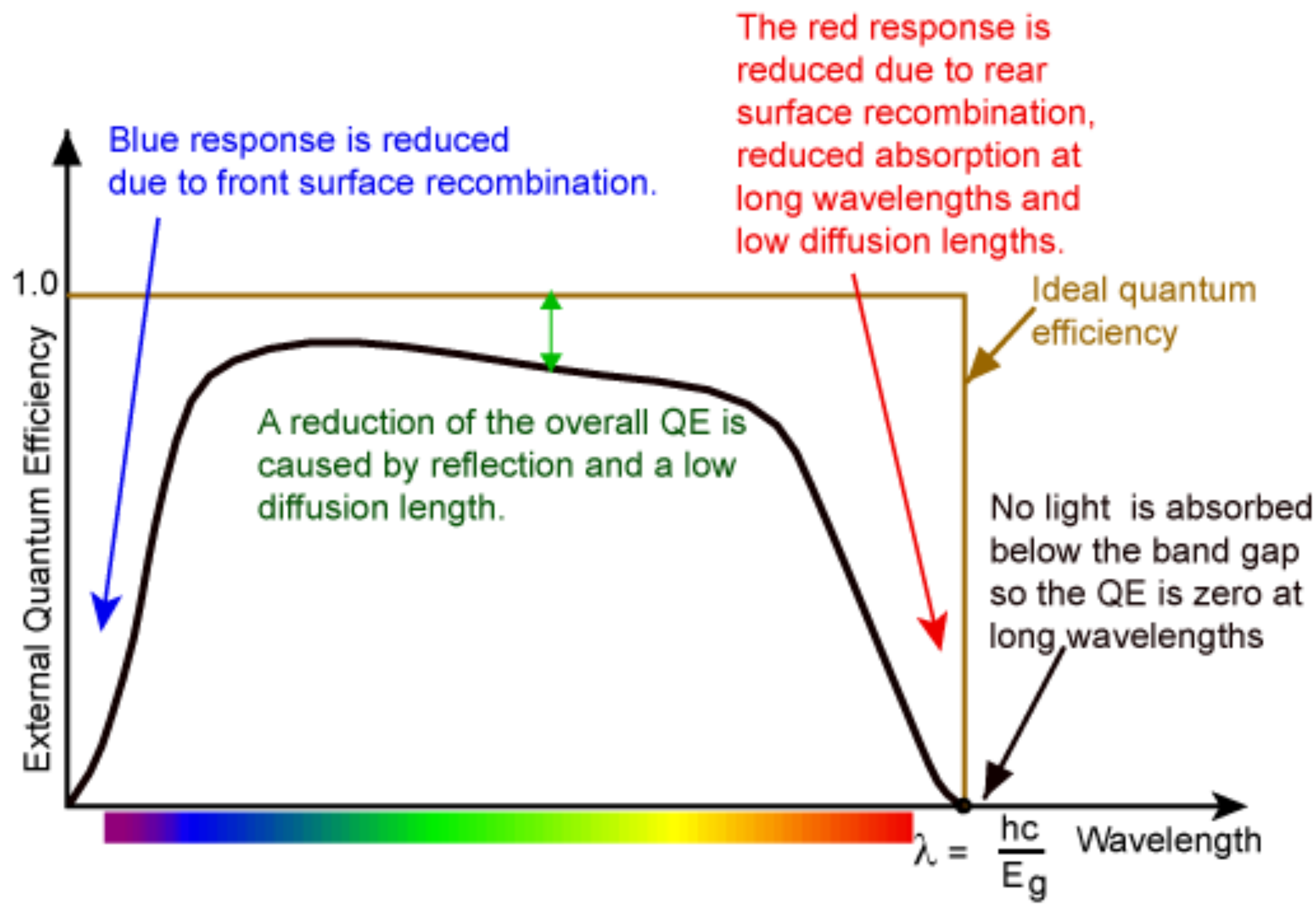
where I_{sc} *is the short-circuit current; and*

where FF is the fill factor

where η *is the efficiency.In a 10 x 10* cm^2 *cell the input power is 100* mW/cm^2 *x 100* cm^2 *= 10 W.*

PARAMETERS

Quantum Efficiency



- ❑ **The ratio of the number of carriers collected by the solar cell to the number of photons of a given energy incident on the solar cell.**
- ❑ While the QE ideally has the square shap, the QE for most solar cells is reduced due to recombination effects. The same mechanisms which affect the collection probability also affect the QE.