

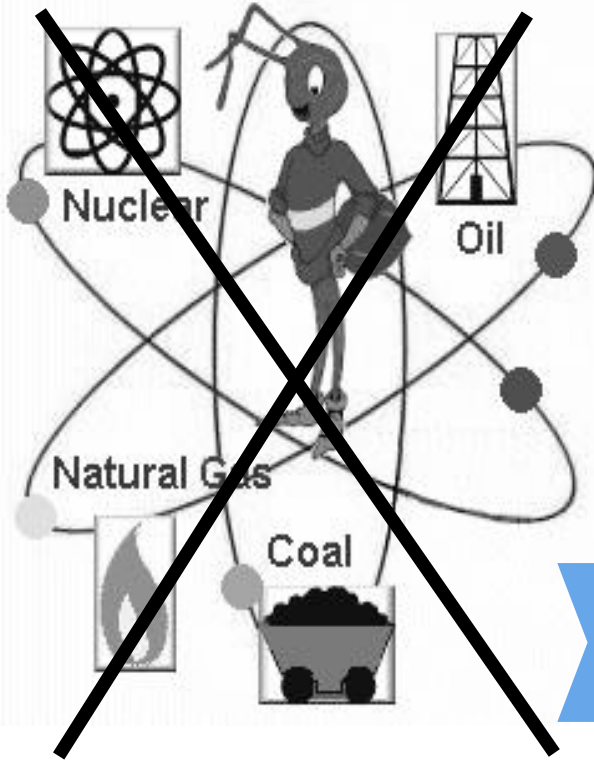


태양전지 원리-고체전자론 개론

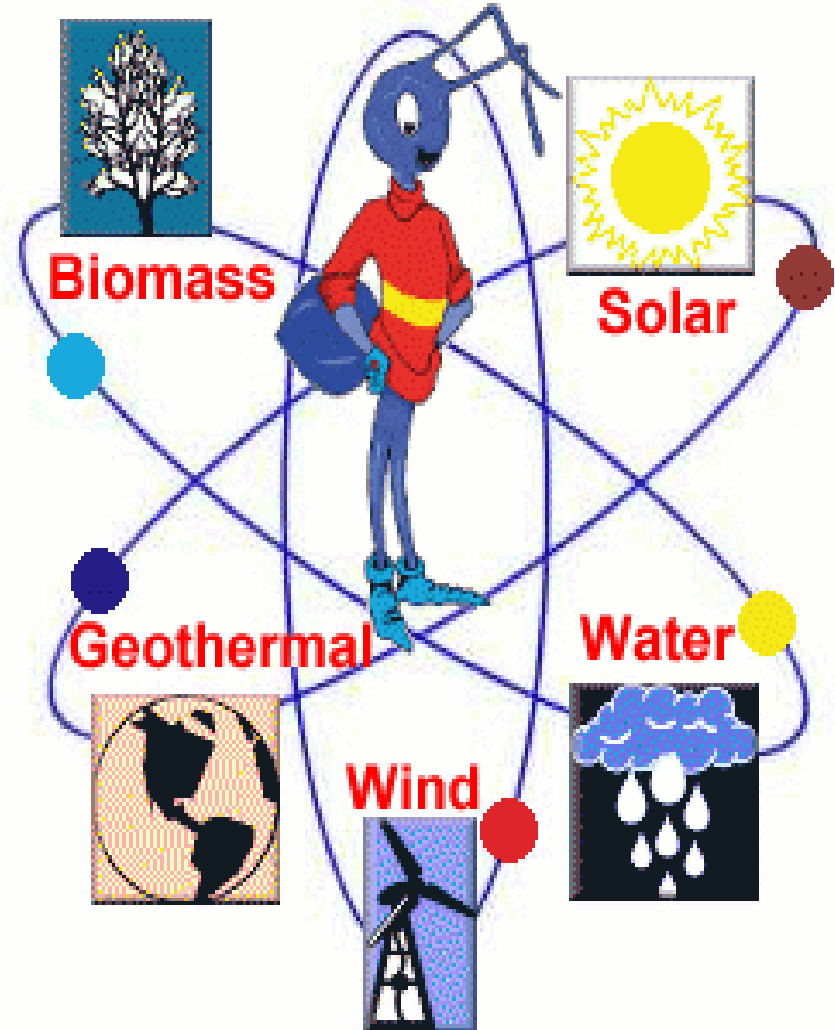
www.ssu.ac.kr



nonrenewable energy



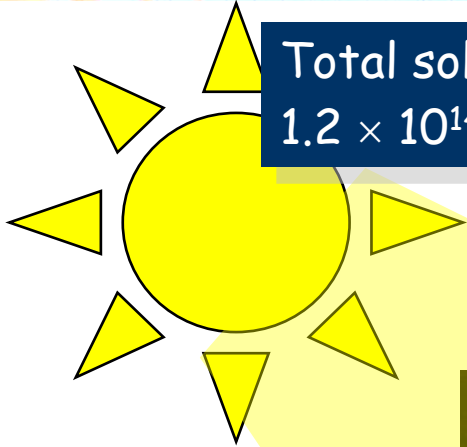
renewable energy





Importance of Solar Energy Utilization

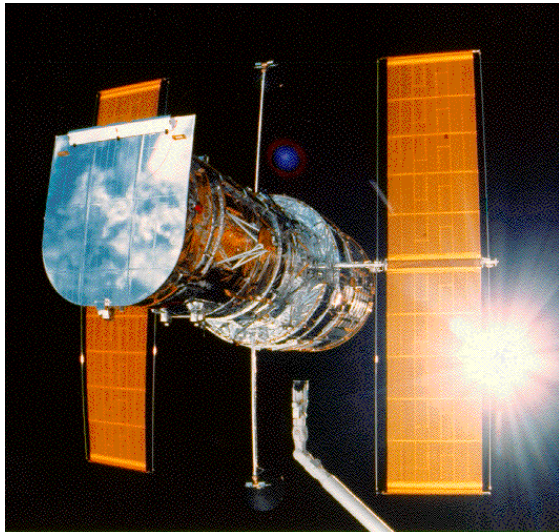
Total solar radiation falling on the earth
 1.2×10^{14} kW (10,000 times consumption)



Total global energy
Consumption 1.0×10^{10} kW

0.1% of total earth surface ☞ solar cells with 10% efficiency

1. SPACE TECHNOLOGY



2. VEHICLES



Drake Flight Research Center EC96-4480-29
The internal structure of the Constant velocity driven flying wing is evident in the craft seen in low altitude during a test flight. NASA Dryden Flight Research Center

3. BATTERY RECHARGING



4. REMOTE POWER





5. LIGHTING



7. RESIDENTIAL ELECTRICITY



6. MILITARY



© NREL, USA

8. PORTABLE POWER





What is Solar cell?

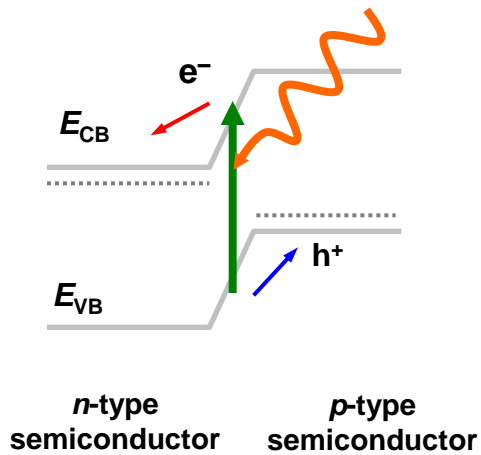
Conversion of **Light** into **Electricity**

How does it work?

1. Light Absorption
2. Charge Separation
3. Charge Collection

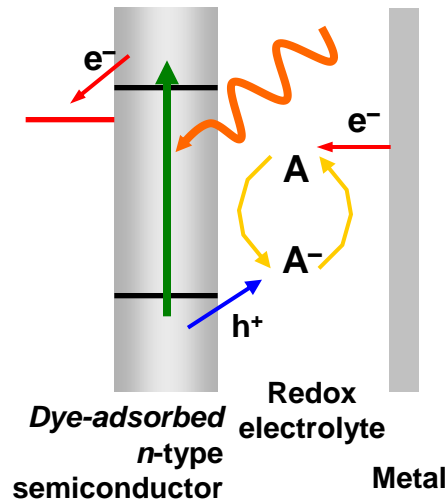
@ Type of solar cell

Inorganic *pn* Junction Solar Cell



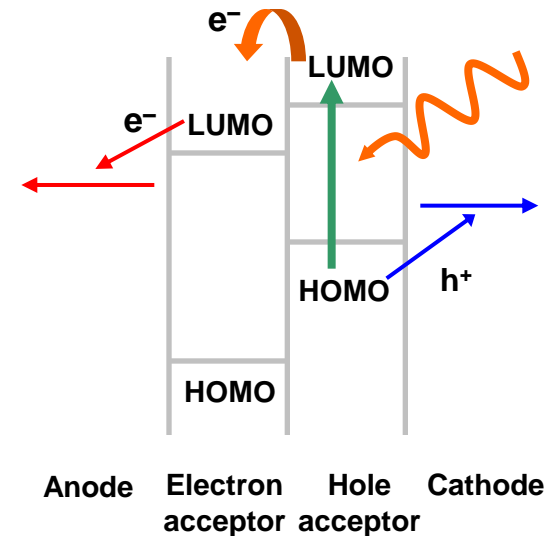
Si, CIS, CdTe
 Efficiency: very high
 Cost: very high

Dye-Sensitized Solar Cell



Dye- TiO_2
 Efficiency: **high**
 Cost: **low**

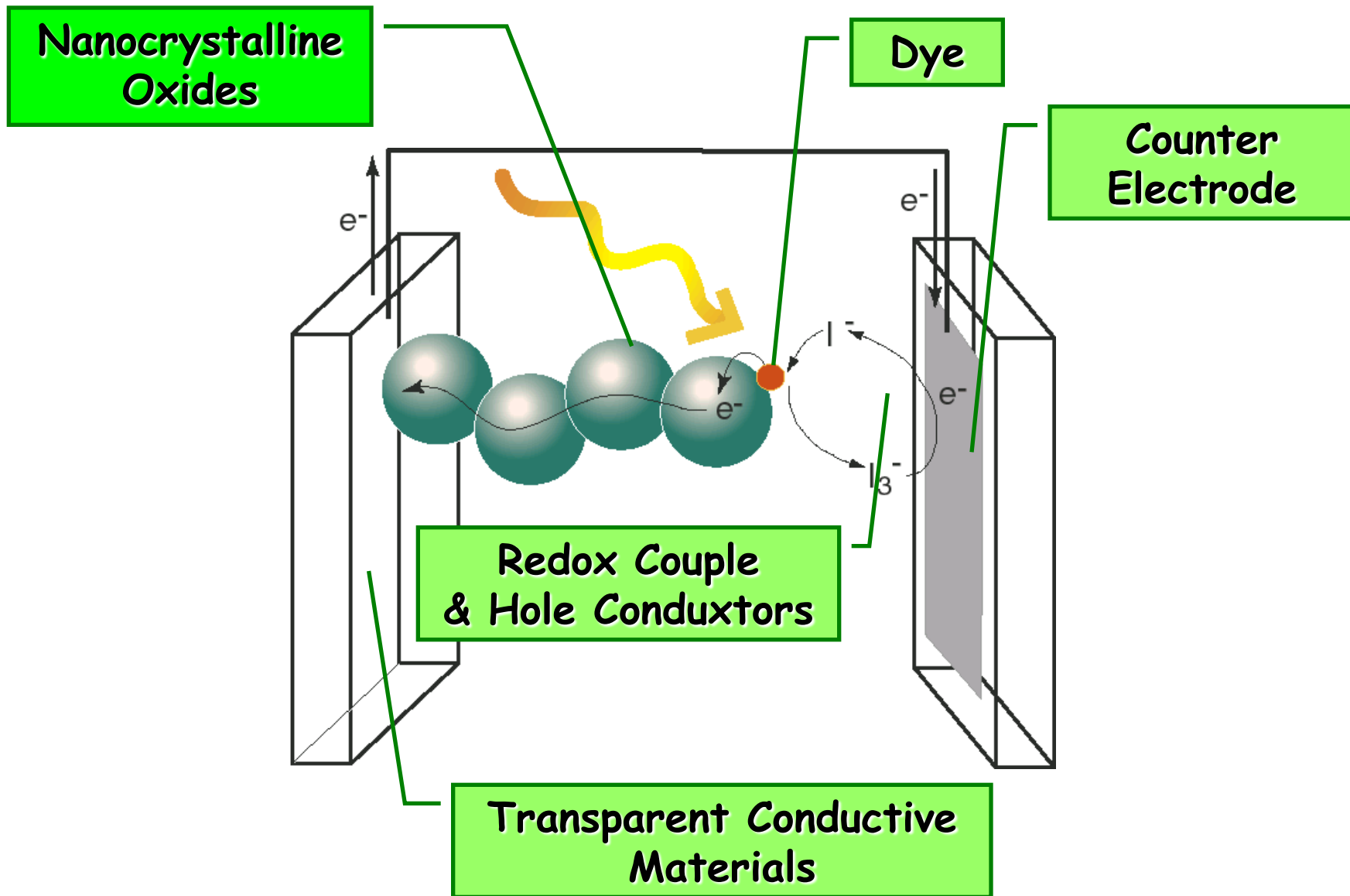
Conjugated Polymer Solar Cell



C_{60} , Polymers
 Efficiency: low
 Cost: **low**

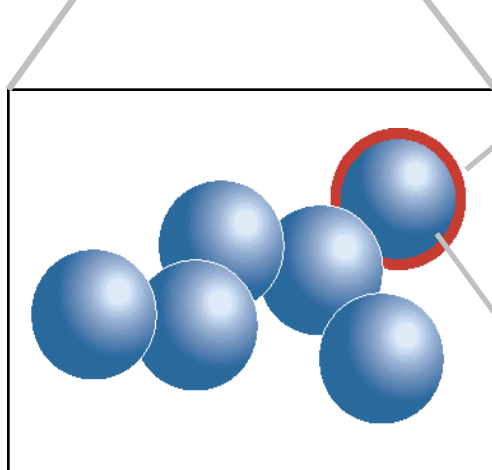
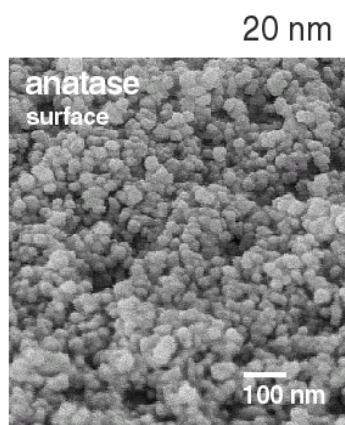
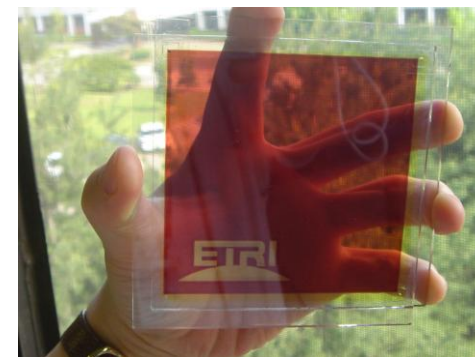
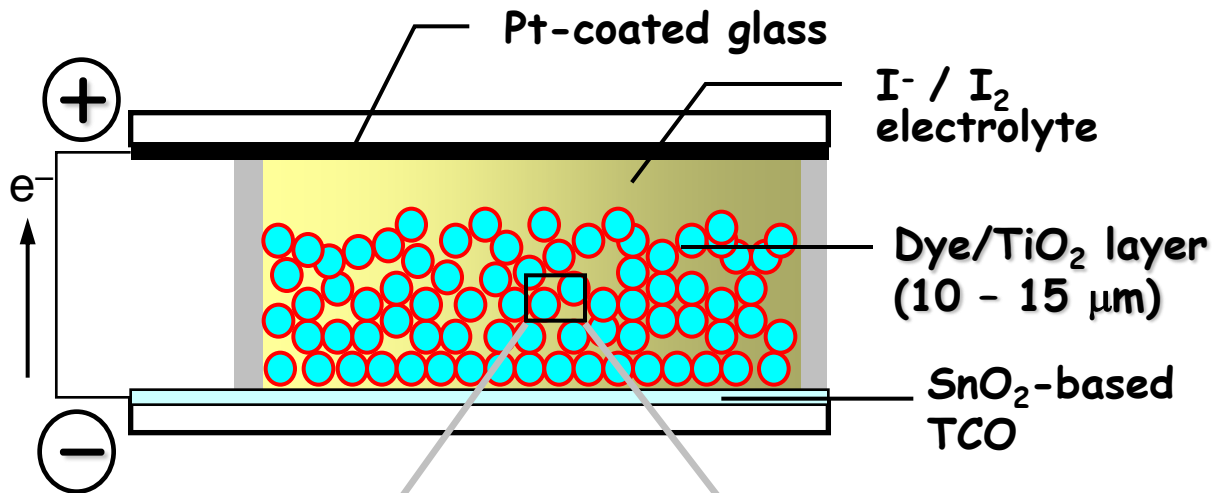


Materials for DSSC

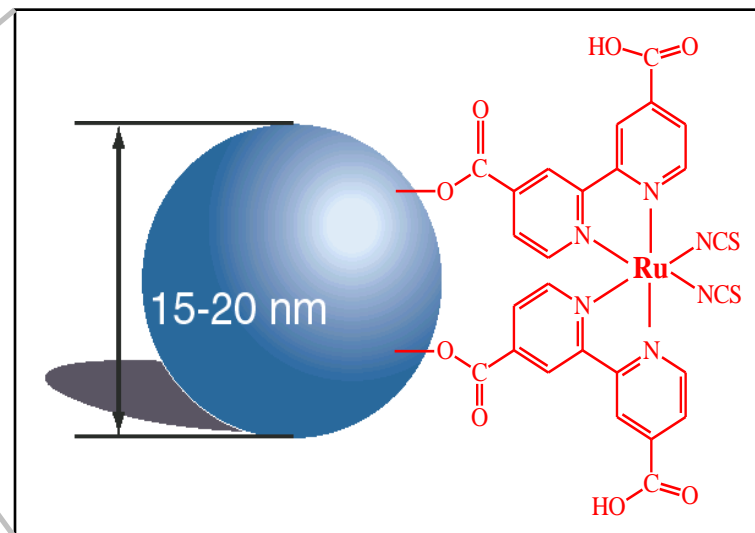




DSSC Structure



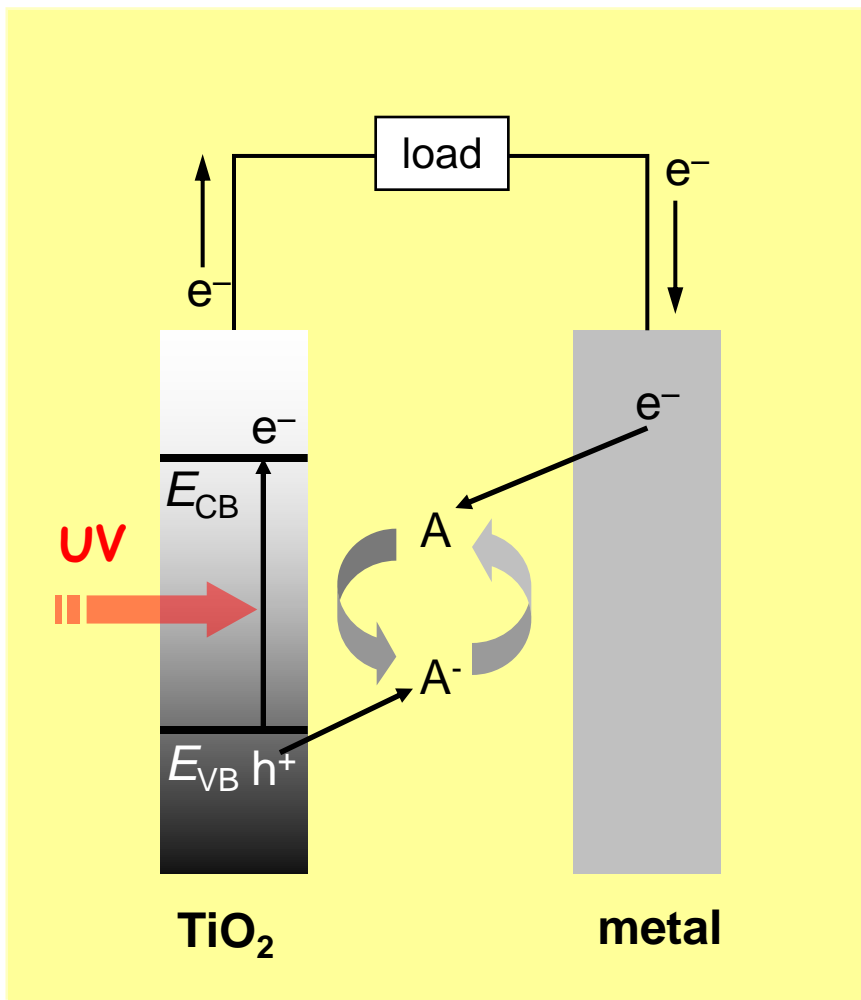
inter-connection



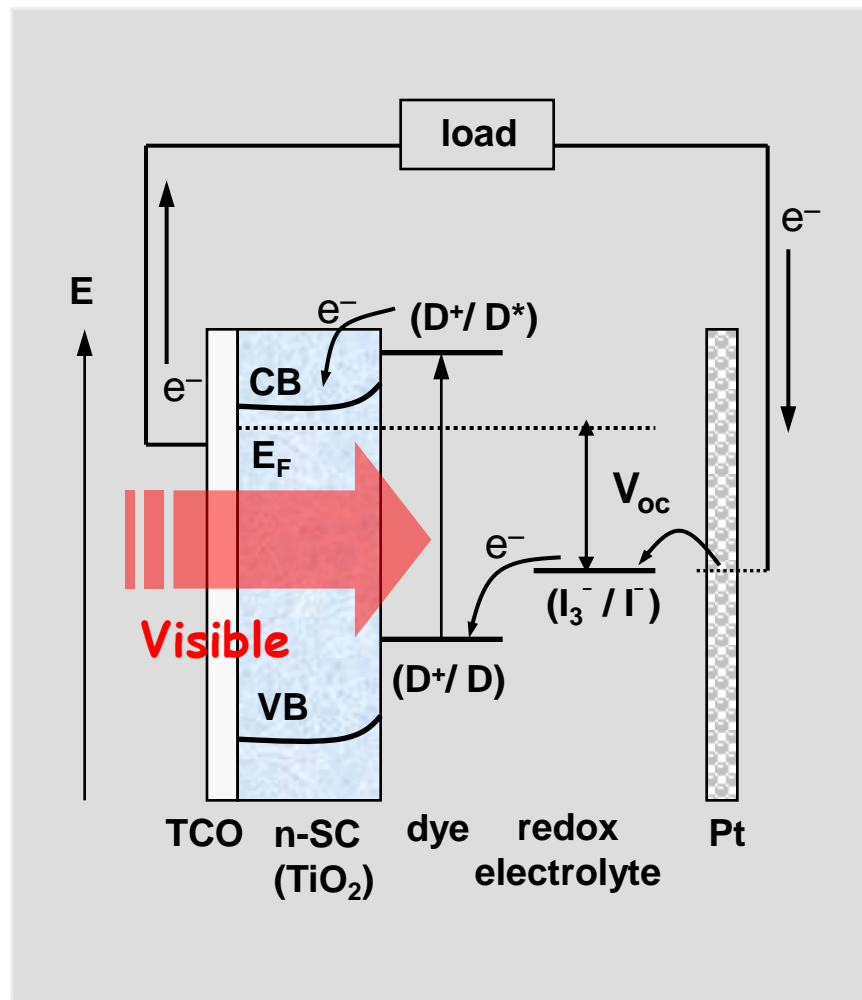


Role of Dye Molecules

TiO₂/liquid junction

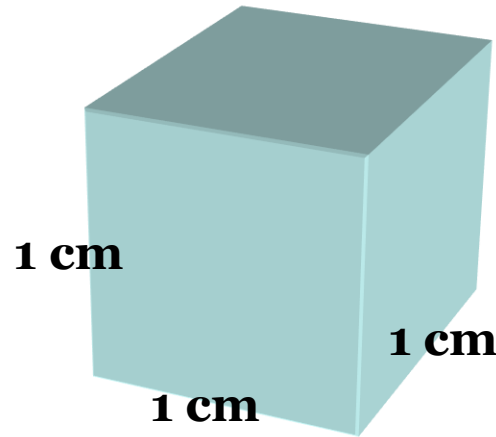


TiO₂/Dye/liquid junction



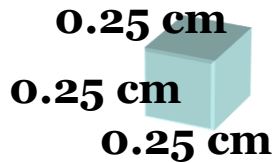
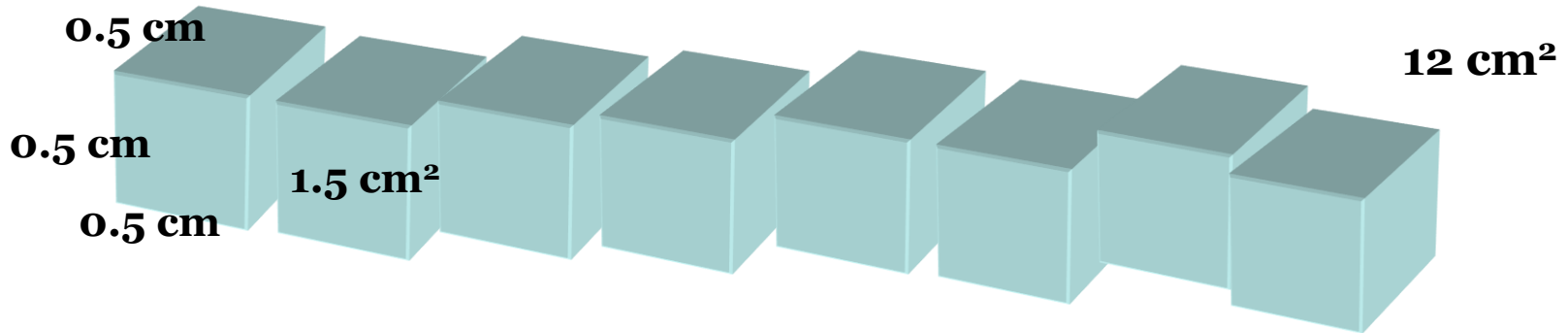


How to increase amount of dye → by increase of surface area



6 cm²

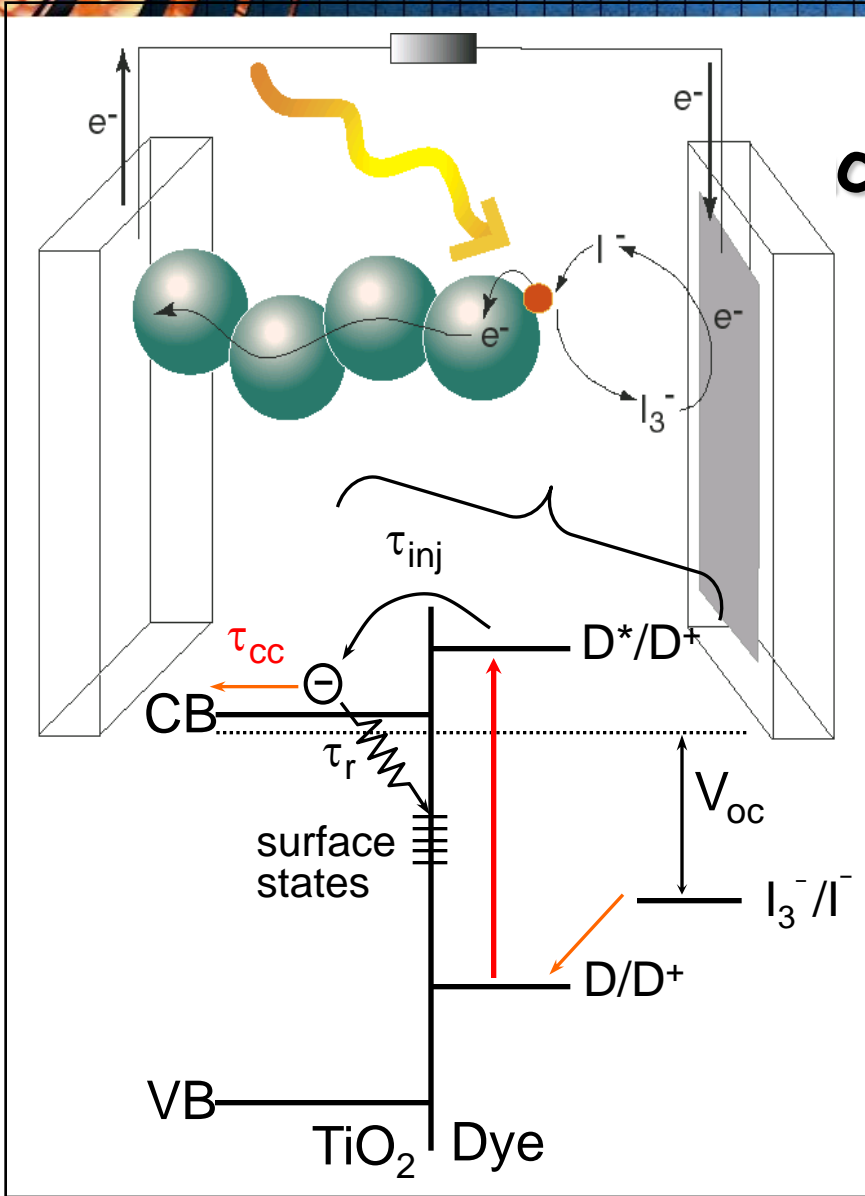
Nanotechnology



× 8 × 8

0.375/cell × 64 = **24 cm²**

$$\text{Surface area} = (1/2)^{n-1} \times 6 \times (8)^{n-1}$$



Principle

Anode:

$D + h\nu \rightarrow D^*$ absorption

$D^* \rightarrow D^+ + e^-$ (TiO₂) injection

$2D^+ + 3I^- \rightarrow 2D + I_3^-$ regeneration

Cathode:

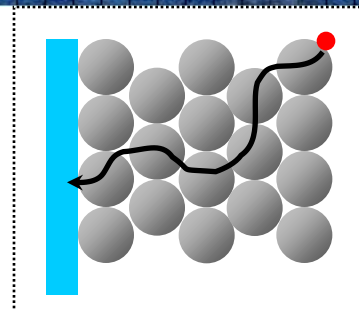
$I_3^- + 2e^-$ (Pt) \rightarrow $3I^-$

Cell:

$e^-(Pt) + h\nu \rightarrow e^-$ (TiO₂)



Nanoparticle Network: Interconnection?



투명전극



전자전달 용이

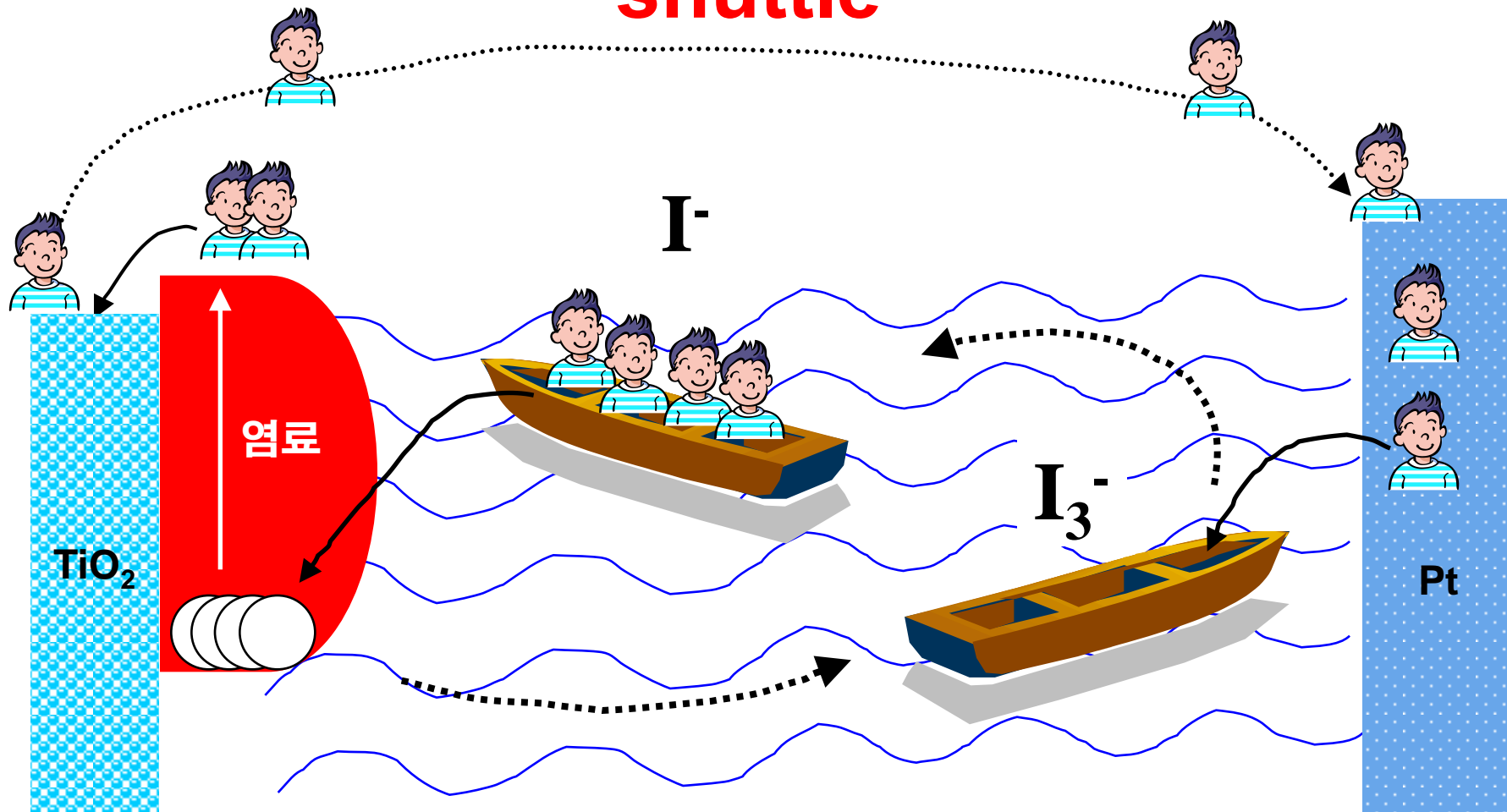


전자전달 불리



Ion Transport in Redox Electrolyte

“shuttle”



= 전자



Total reaction: 2-electron reaction



Successive reaction



* Two fast reactions are in equilibrium

Mass action law

$$n_{\text{I}}(x) = K_1 n_{\text{I}_3}^{-1/2}(x) n_{\text{I}^-}^{-1/2}(x)$$

답변완료 건전지 양극간에 전위차를 유지시키는것?

(2006-07-26 21:21 작성)

uhy8094

조회 : 114

답변 : 1

답변이 완료된 질문입니다.

건전지가 전위차를 제공하는건데
뭐가 건전지 양극간 전위차를 유지시키나요?



전문가 답변

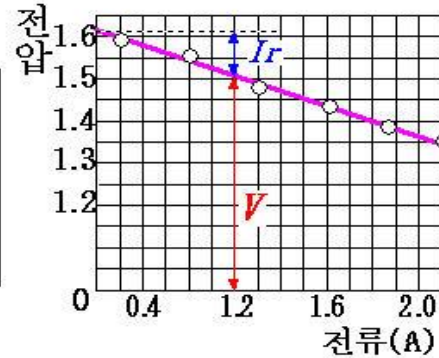
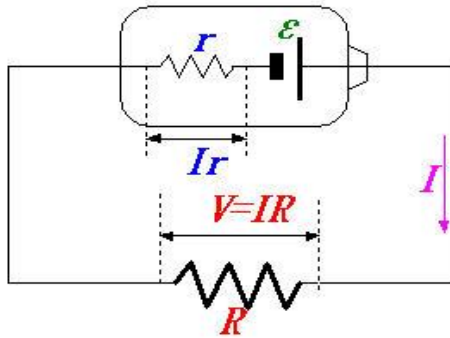
질문자가선택한답변

"건전지 양극간에 전위차를 유지시키는것?" 답변

± TOP

kdw8961 회원은 과학기술 전문가 봉사단입니다. (2006-07-26 21:48 작성)

정답은 전지의 기전력(E)입니다.
기전력은 두 극 사이의 전위차를 계속 유지시켜주는 능력입니다.
기전력에 대한 설명을 첨부합니다.



전류계, 전압계, 가변 저항기를 전지에 연결해서 회로를 만든다.
그런 다음 가변 저항기로 저항을 변화시키면서 저항과 전류의 값을 측정해 보면 다음 그래프와 같이 된다.

이 때에 전압계에 나타난 전압은 회로에 전류가 흐를 때 전지의 두 극 사이의 전위차이고, 이것을 전지의 단자 전압이라고 한다.

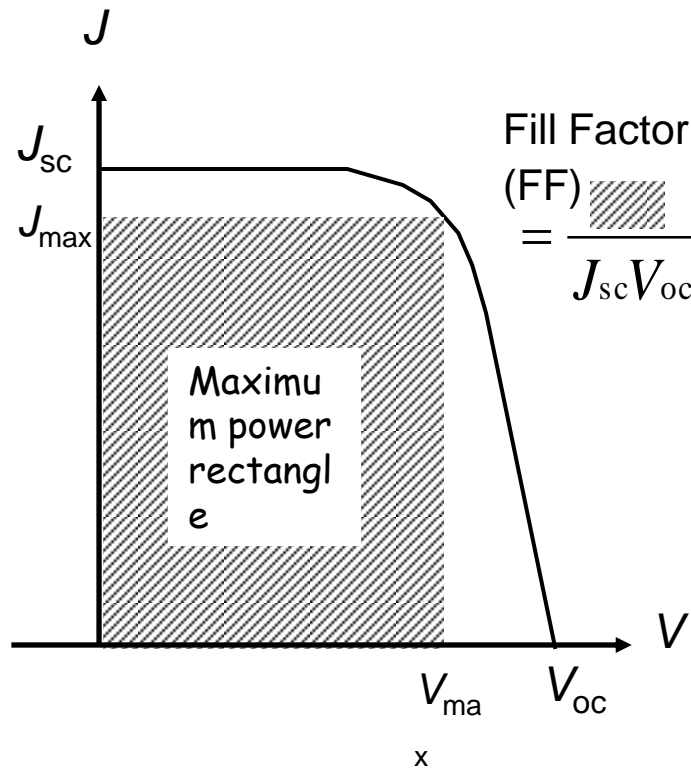
회로에 흐르는 전류가 증가함에 따라 단자 전압이 낮아지는 이유는 전지의 내부에도 저항이 있어서 이 저항에 의한 전압 강하가 일어나기 때문이다.
위 그래프에서 직선의 기울기는 전지가 가지고 있는 저항을 나타내며, 이 저항을 전지의 내부 저항이라고 한다.

그래서 전류가 흐르면 저항에 의한 전압 강하가 일어나 전압이 내려가는 것이다.
이같이 전지 내부에 있는 저항을 내부 저항이라고 한다. 그래프에서 전류가 0일 경우 내부 저항에 의한 전압 강하가 없고, 이때의 전압을 전지의 기전력이라고 한다.
그래프에서 직선을 연장해서 V축과 만날 때의 단자 전압이 전지의 기전력(E)이다.

$$V = E - Ir$$



Measurement of Conversion Efficiency



$$\begin{aligned}\eta &= \frac{P_{\text{output}}}{P_{\text{input}}} \\ &= \frac{J_{\text{max}} V_{\text{max}}}{P_{\text{input}}} \\ &= \frac{J_{sc} V_{oc} \text{FF}}{P_{\text{input}}}\end{aligned}$$

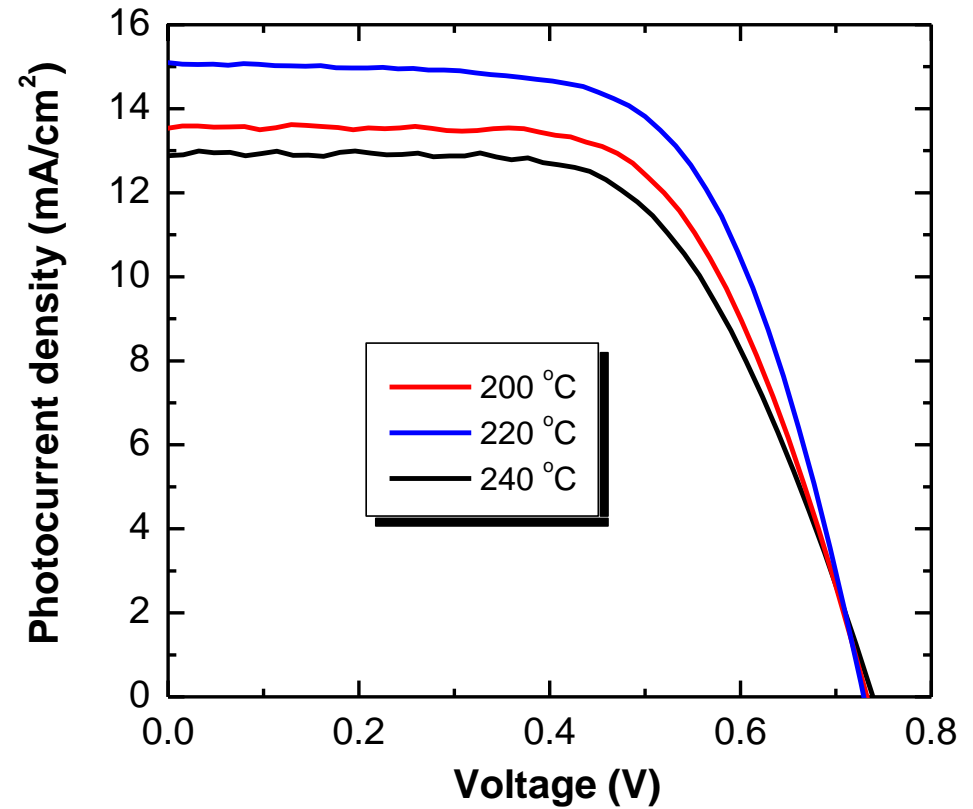
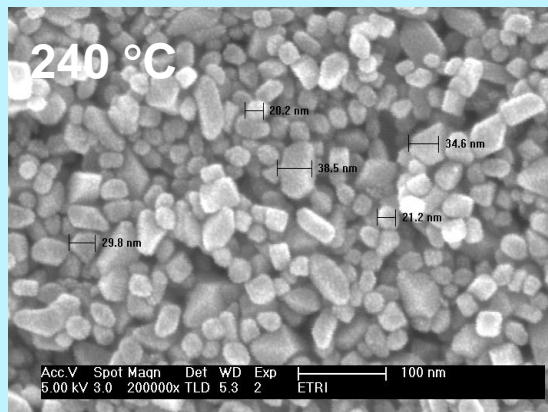
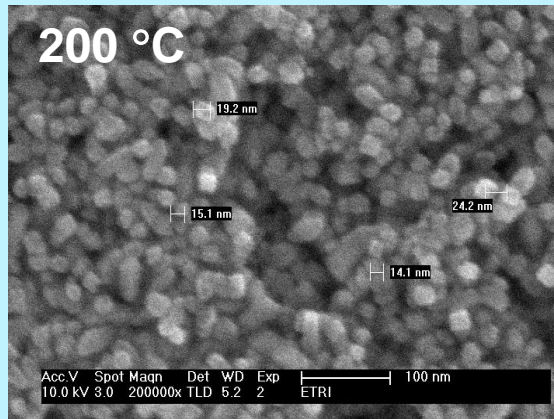


Anatase, Rutile, Brookite

SnO₂, ZnO ...



Hydrothermal Temperature of TiO₂ Nanoparticle



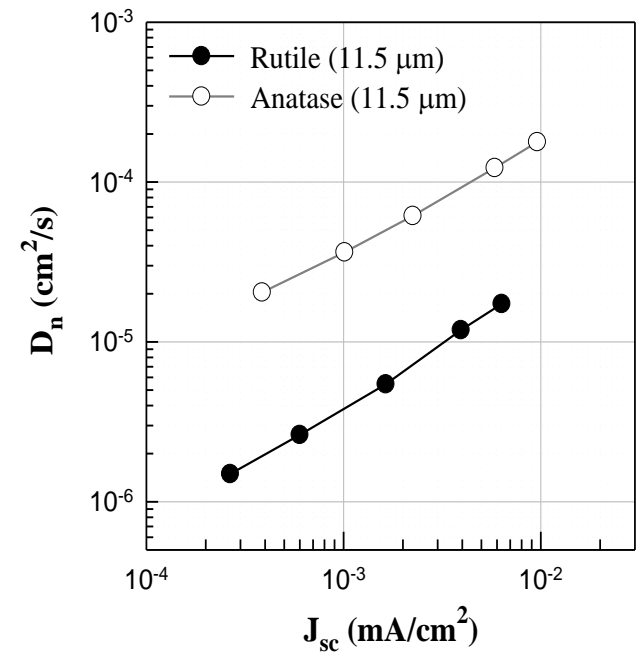
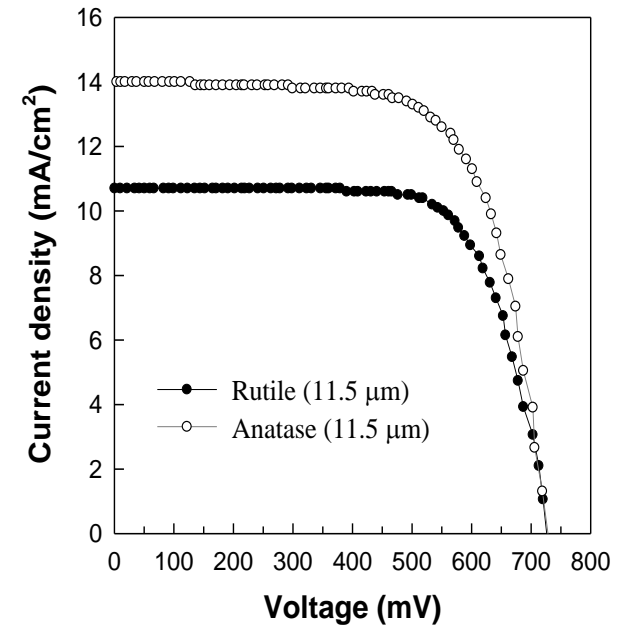
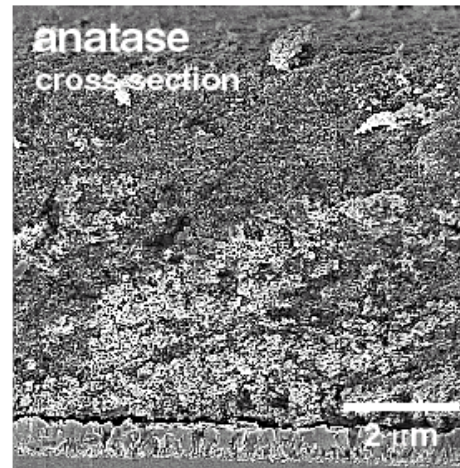
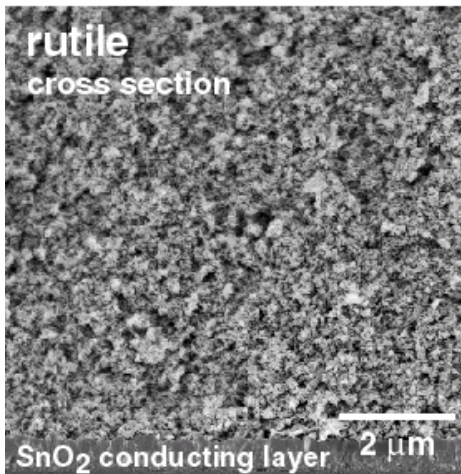
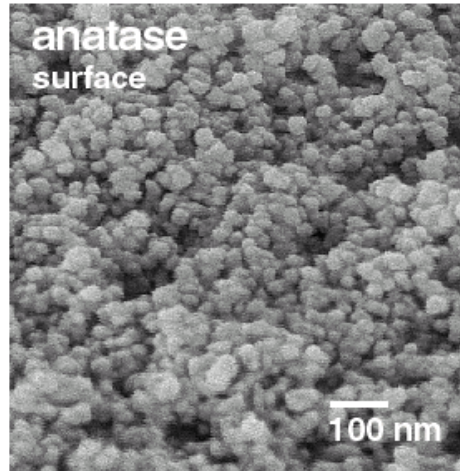
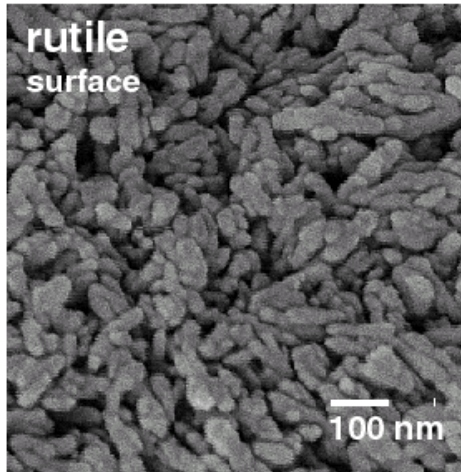
	V_{oc} (V)	J_{sc} (mA/cm ²)	FF (%)	η (%)
200 °C	0.733	13.5	62.9	6.24
220 °C	0.729	15.1	63.4	6.97
240 °C	0.739	12.9	61.1	5.82



Anatase vs. Rutile TiO₂

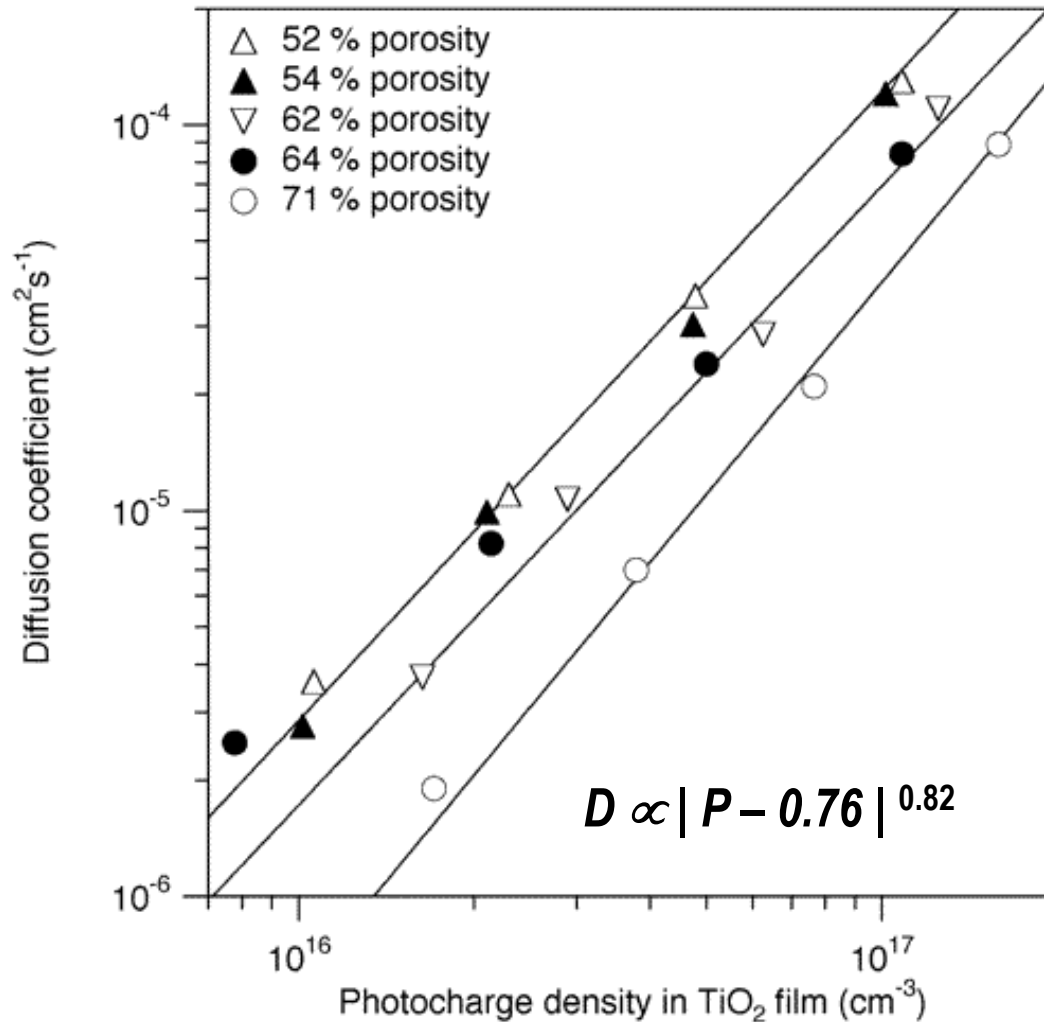
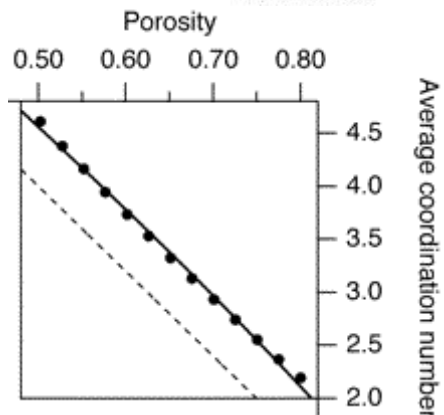
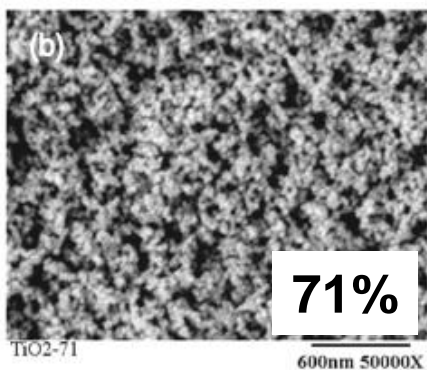
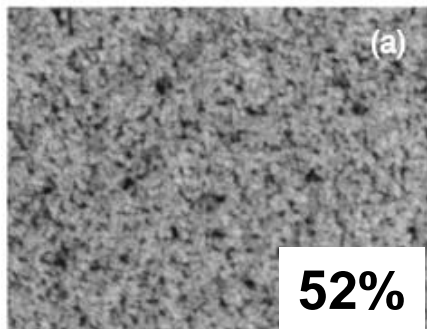
20X80 nm

20 nm



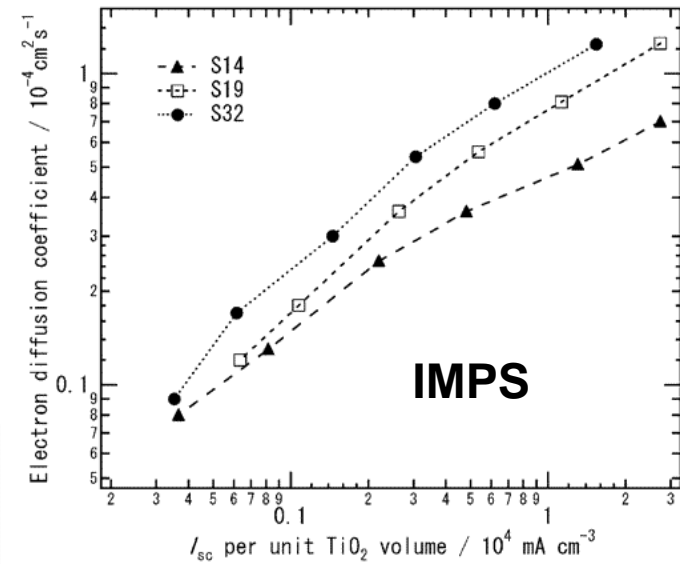
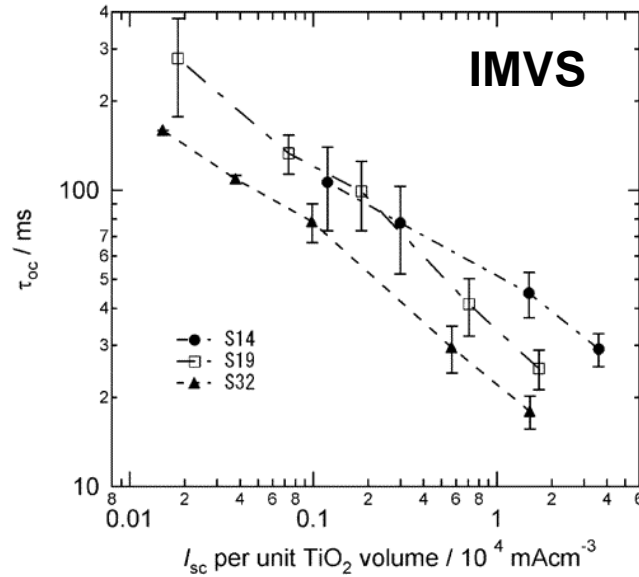
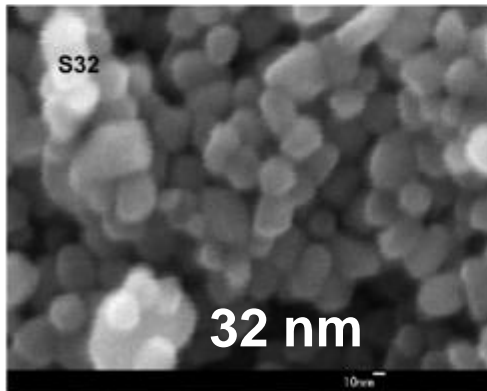
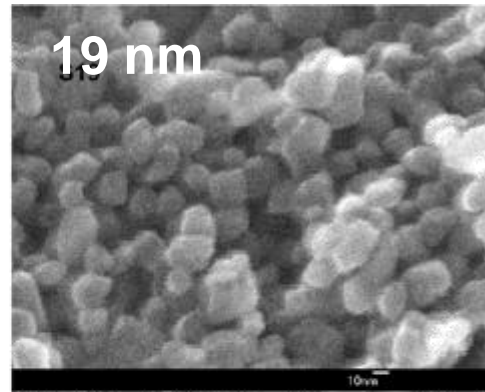
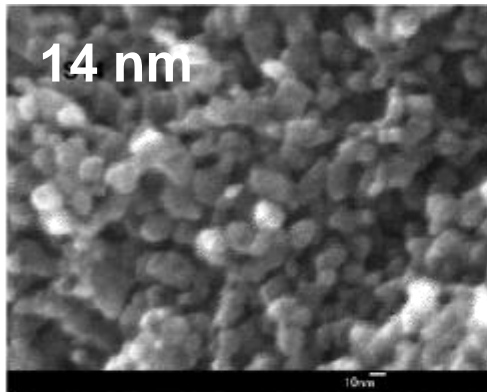


Network Geometry vs Electron Transport





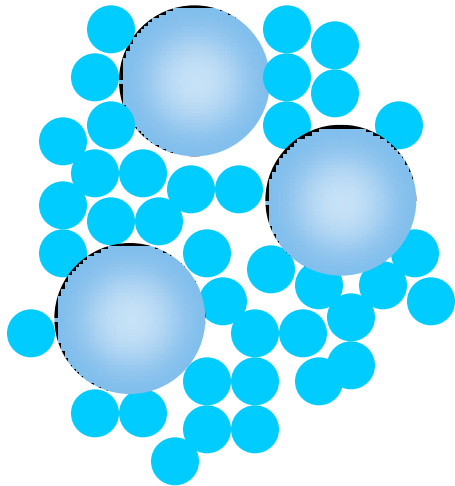
Particle Size vs Electron Transport



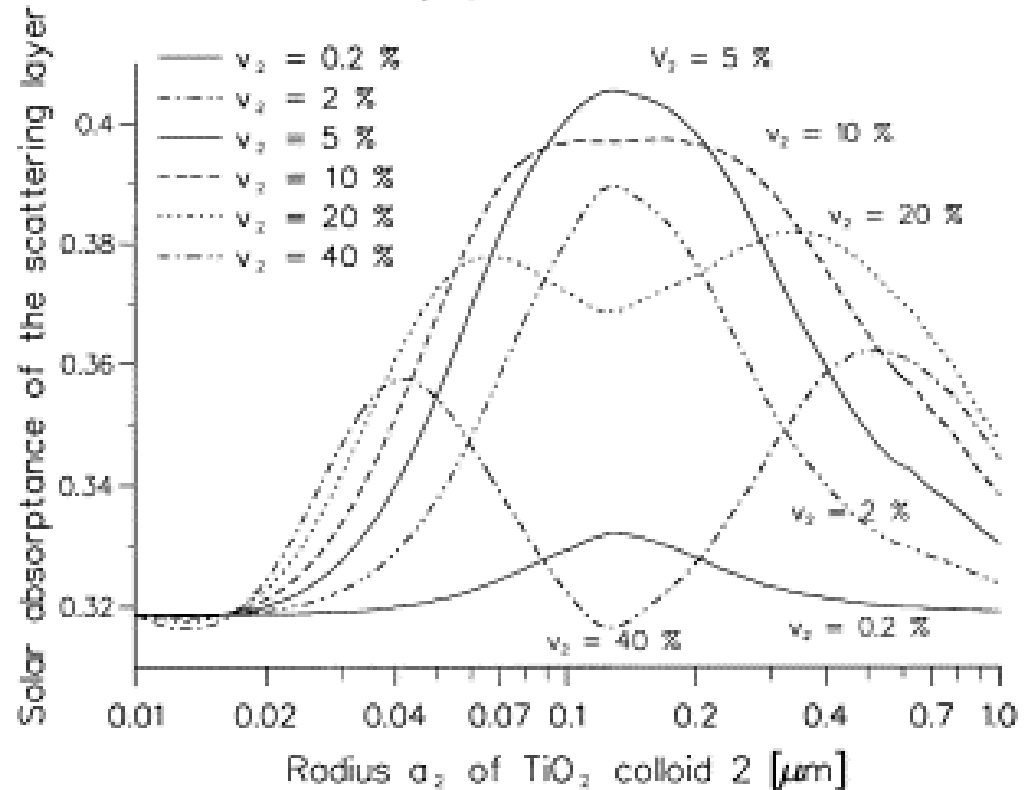
* Diffusion coefficient D increases and recombination rate decreases with the increase of the particle size from 14 nm to 19 nm and up to 32 nm.



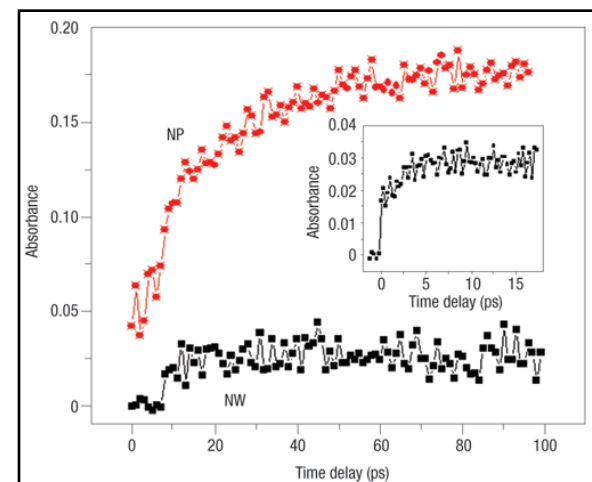
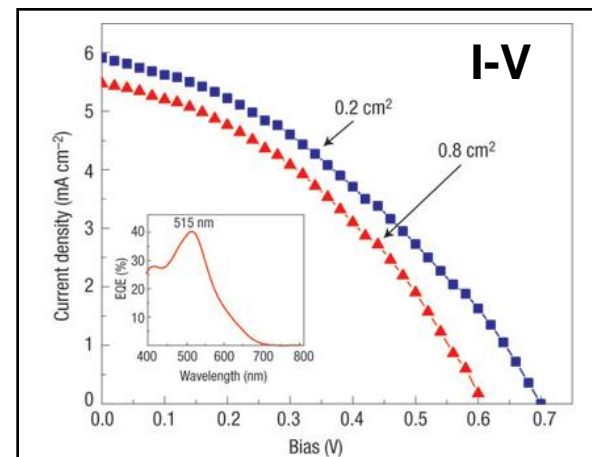
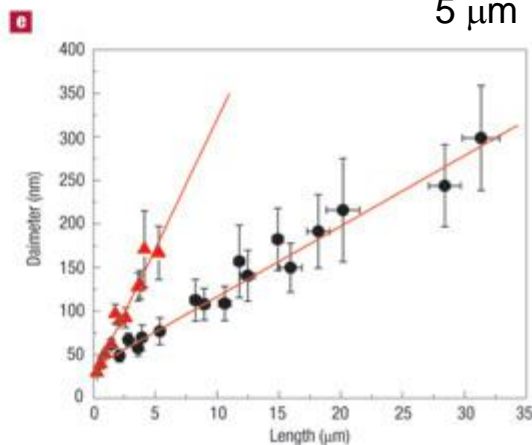
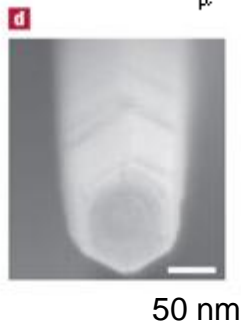
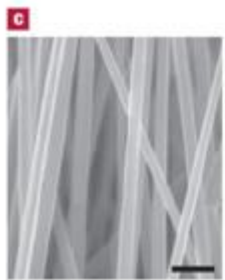
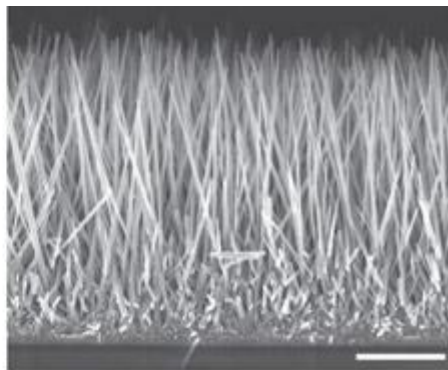
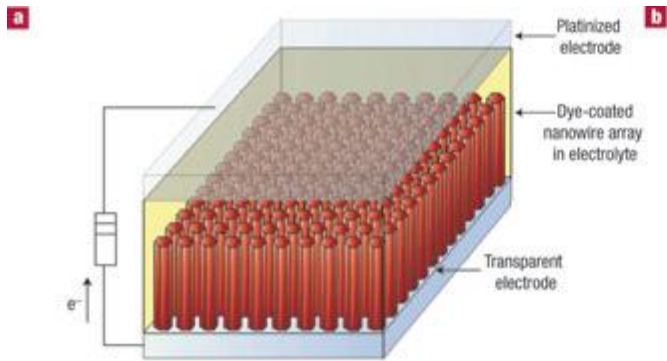
Binary Mixture: Theoretical Calculation



Binary particle mixtures



@ ZnO Nanowire for DSSC

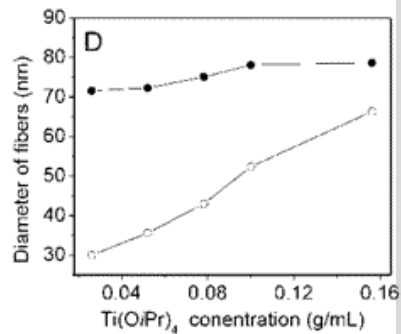
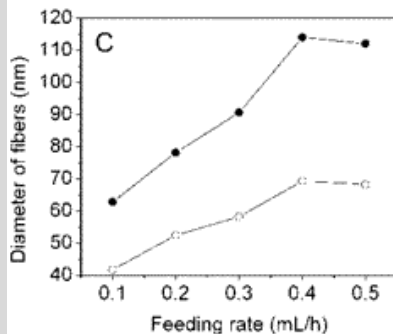
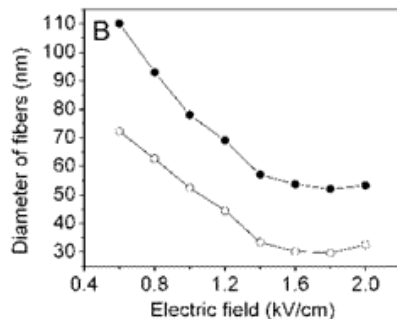
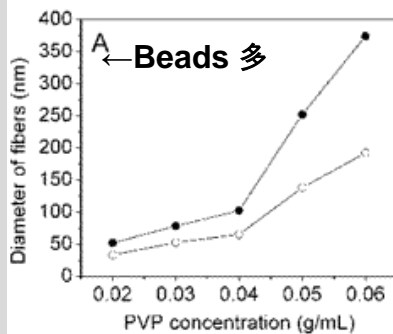
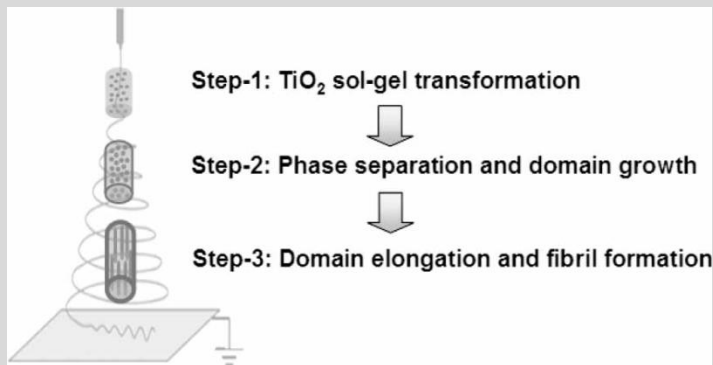


e^- injection: mid-IR transient
 np: nanoparticle, nw: nanowire

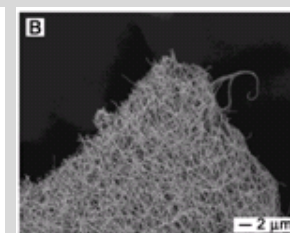
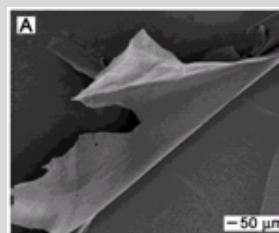
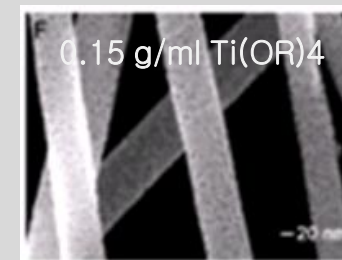
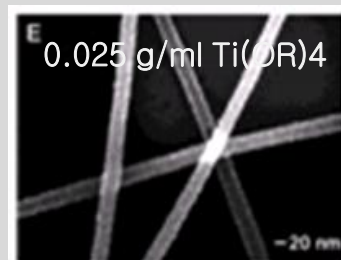
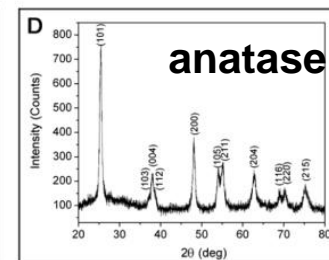
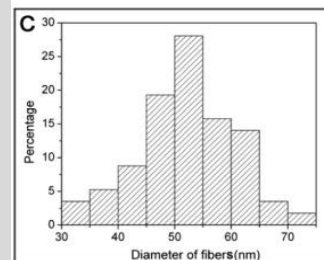
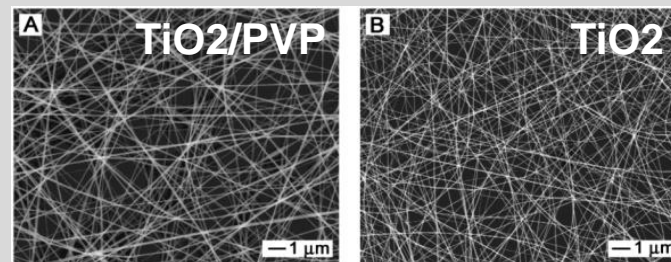
Matt Law, Lori E. Greene, Justin C. Johnson, Richard Saykally, Peidong Yang
Nature Materials 4, 455-459 (01 Jun 2005)



전기방사 조건



SEM images

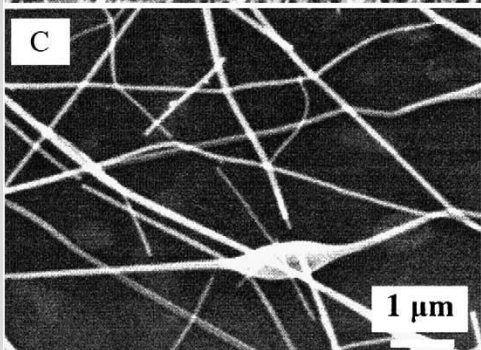
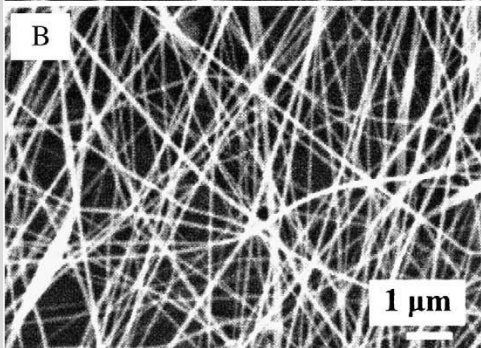
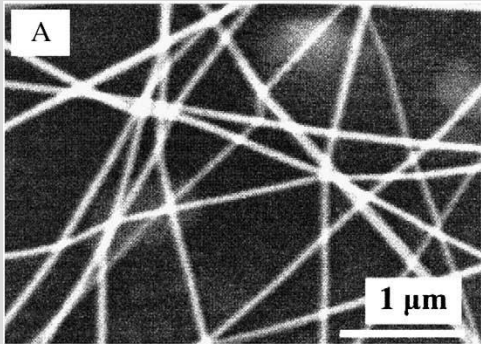


쉽게 날라감



Electro spinning method (TiO₂ fiber)

제일 가는 파이버
= 54nm



Ti-OR4 : 1.5ml
acetic acid : 3ml
ethanol : 10ml
PPV : 0.45 g
22-gauge needle
0.3 ml/h
2 kV/cm
600 °C for 3h

최적 조건?

내 실험

PPV : 0.35-0.50 g

PVP concentration

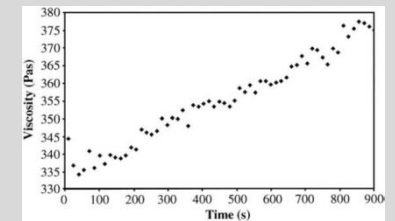
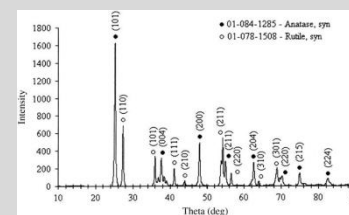
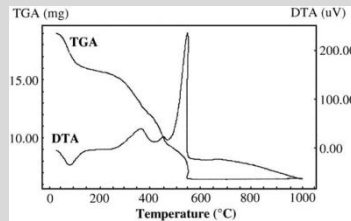
低 ————— 高

Diameter

細 ————— 太

Beads and aggregations

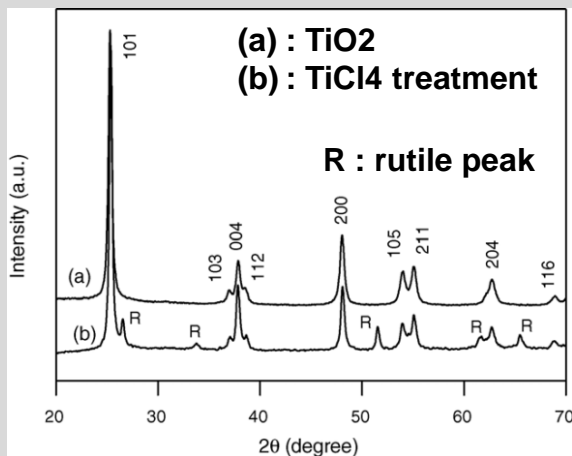
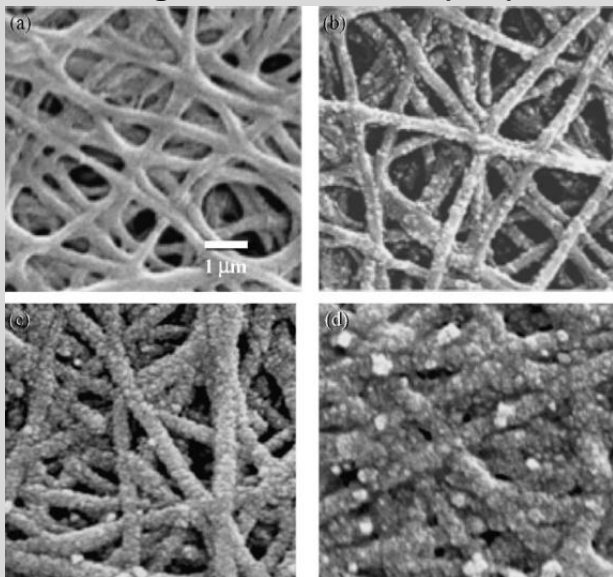
多 ————— 少



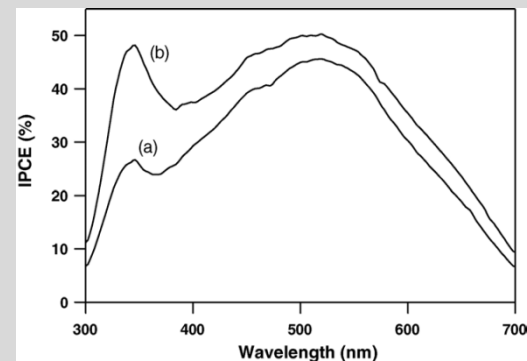
@ TiCl₄ treatment

SEM & XRD

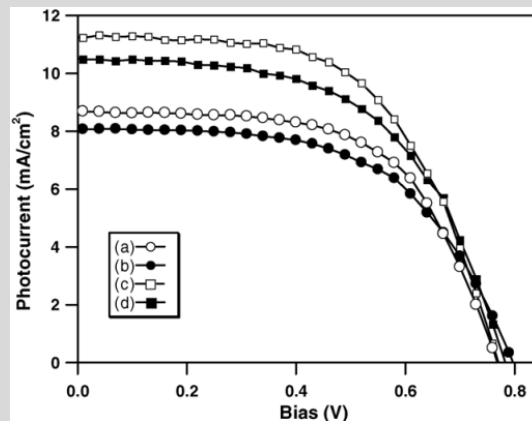
Immersing into a 0.1M TiCl₄ (24h)



성능 평가



(a) : TiO₂
(b) : TiCl₄ treatment



(a) : TiO₂ (with liquid electrolytes)
(b) : TiO₂ (with liquid gel)
(c) : TiCl₄ treatment (with liquid electrolytes)
(d) : TiCl₄ treatment (with gel electrolytes)

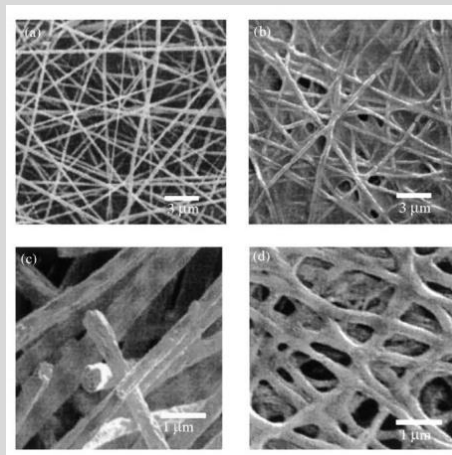
Devices	V _{oc} (V)	J _{sc} (mA/cm ²)	FF	η (%)
a	0.77	8.67	0.60	4.01
b	0.80	8.07	0.59	3.80
c	0.77	11.24	0.58	5.02
d	0.78	10.52	0.56	4.60

@ Vapor treatment

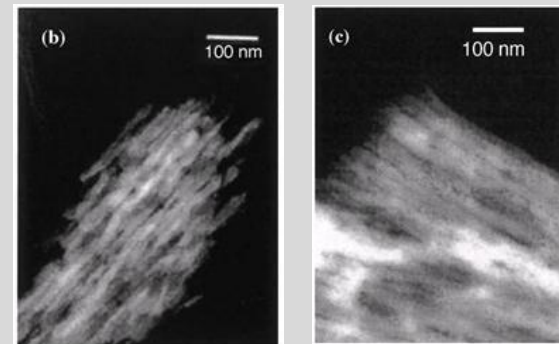
Vapor treatment (SEM & TEM)

PVAc/TiO₂ 전기방사 후,
THF vapor하에서 1시간.

PVAc film이 fiber위에 형성.



- (a): without vapor treatment
- (b): with vapor treatment
- (c): after calcination without vapor treatment
- (d): after calcination with vapor treatment

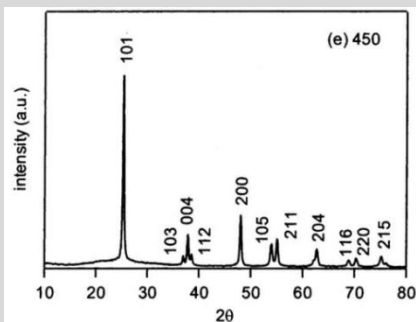


before calcination after calcination

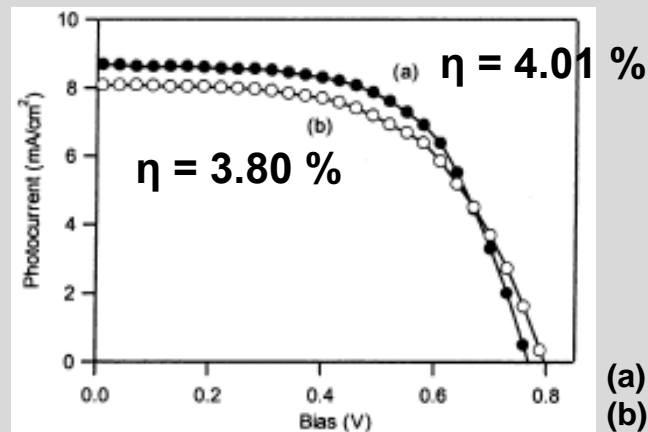


Fiber structure!!

XRD & I-V curve



anatase

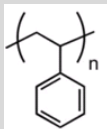


- (a) : with liquid electrolytes
- (b) : with gel electrolytes

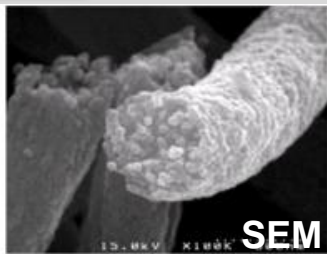


Various support polymer

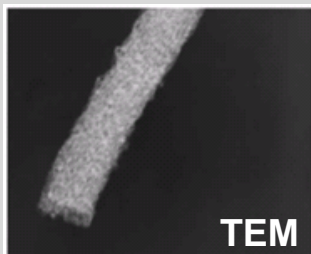
SEM & TEM



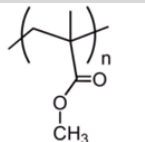
Polystyrene (PS)



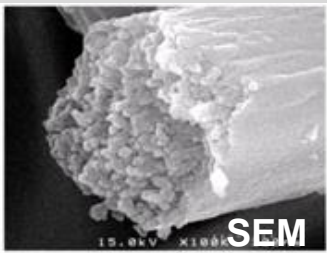
SEM



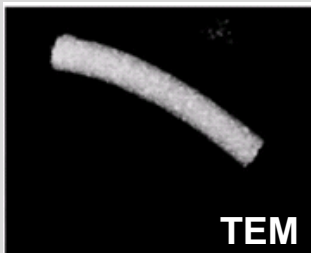
TEM



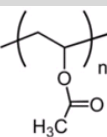
Poly(methyl methacrylate) (PMMA)



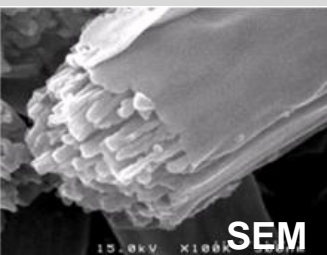
SEM



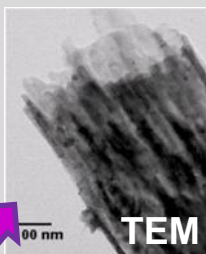
TEM



Poly(vinyl acetate) (PVAc)



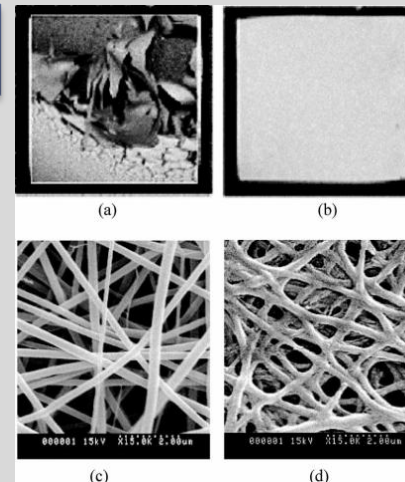
SEM



TEM

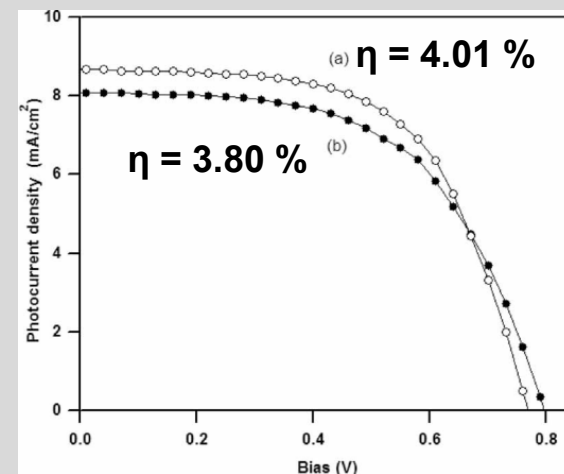
PS : powder pattern
PMMA : powder pattern
PVAc : Fiber structure

Vapor treatment



(a)(c): TiO₂ nanofiber without vapor treatment
(b)(d): TiO₂ nanofiber with vapor treatment

IPCE



(a) : with liquid electrolytes
(b) : with gel electrolytes



Surface treatment layer

문제점 (소결 후)

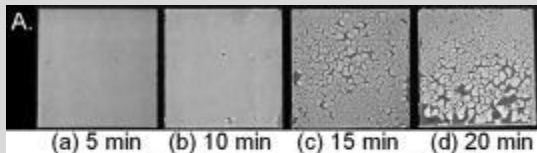
1. Shrinking effect
2. poor adhesion

STL : surface treatment layer

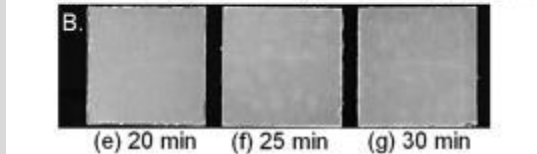
Diluted 방사액 (1:5 in ethanol)을 사용

Spin coating (1300rpm, 10s)

Drying on the hotplate (75 °C)

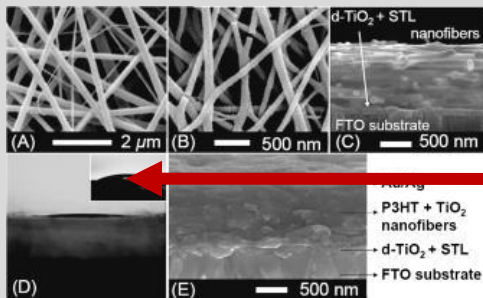


without **STL**

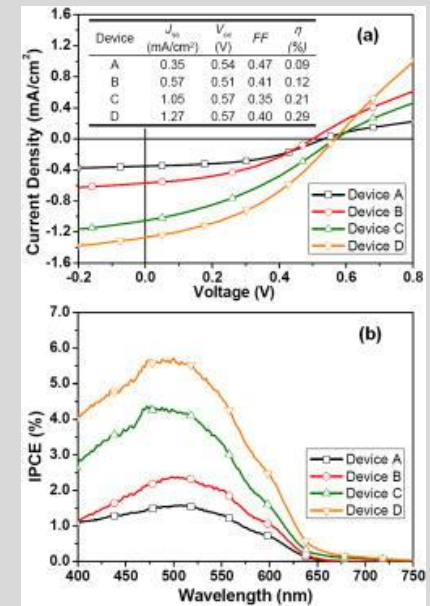


with STL

under various electrospinning time



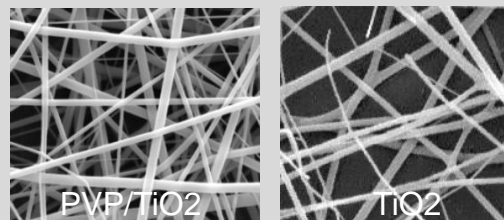
Contact angle : 5°
 = P3HT on TiO2 nanofiber
 Contact angle : 22°
 = P3HT on TiO2 nanoparticle



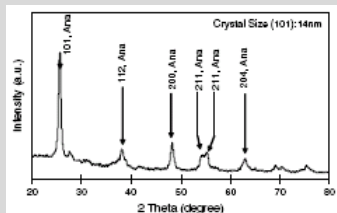
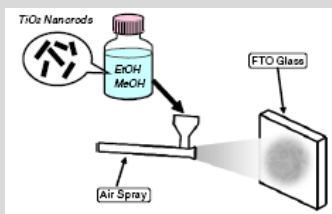
- Device A : FT0/d-TiO₂/STL/P3HT/Au/Ag
- Device B : FT0/d-TiO₂/STL/TiO₂ nanofiber/P3HT/Au/Ag
- Device C : FT0/d-TiO₂/STL/TiO₂ nanofiber/N719/P3HT/Au/Ag
- Device D : FT0/d-TiO₂/STL/TiO₂ nanofiber/TiCl₄ treatment/N719/P3HT/Au/Ag

DSSC실험에 있어서 필요한 결론 :
STL은 fiber와 glass의 접착력을 향상시킨다.

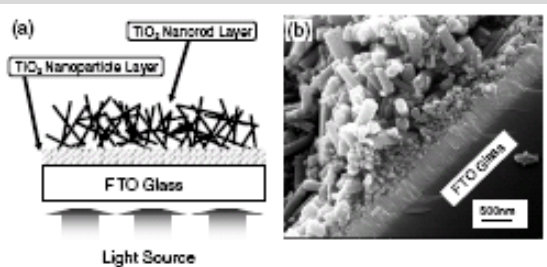
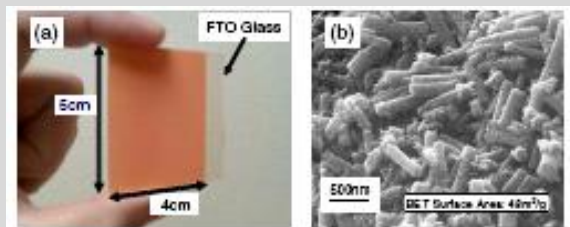
@ Spray method



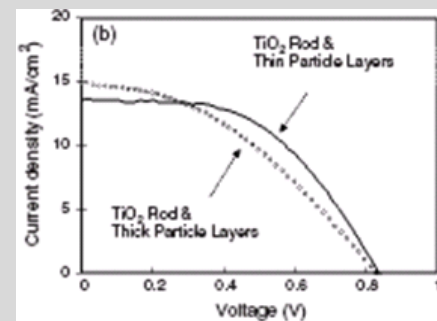
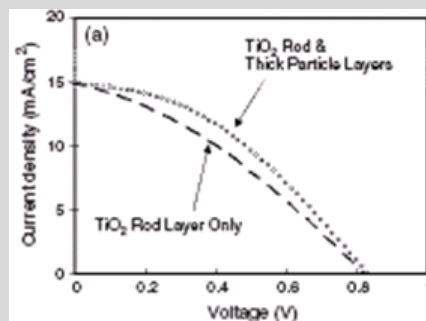
anatase



TiCl₄ treatment



Surface treatment layer

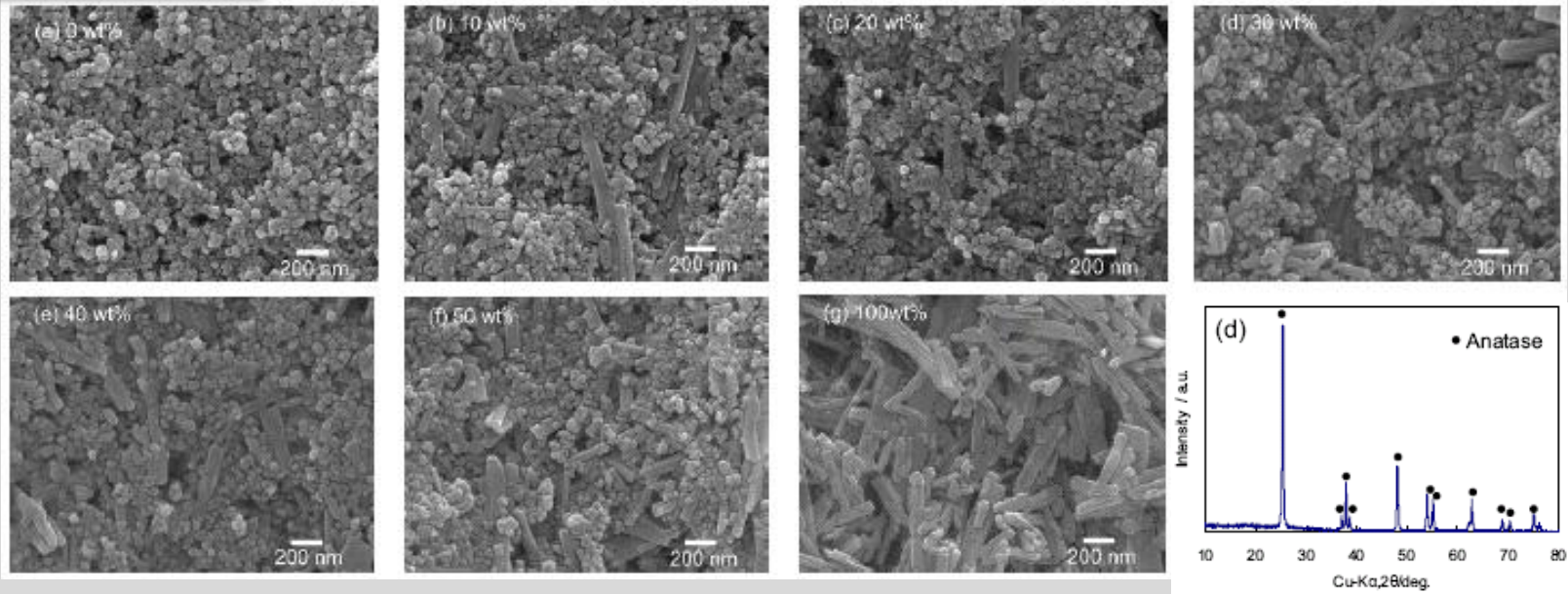


Sample number	Thickness of TiO ₂ electrode (μm)	J _{sc} (mA cm ⁻²)	V _{oc} (V)	FF (%)	η (%)
TiO ₂ rod layer only					
No.1	15	13.5	0.832	40.7	4.58
No.2	16	14.6	0.832	34.7	4.22
No.3	18	14.5	0.832	33.5	4.04
Ave.	15-18	14.2	0.832	36.3	4.28
TiO ₂ rod layer + thick particle layer					
No.1	13	16.2	0.830	36.9	4.98
No.2	14	14.7	0.831	39.9	4.87
No.3	16	14.9	0.823	35.7	4.38
Ave.	13-16	15.2	0.830	37.5	4.75
TiO ₂ rod layer + thin particle layer					
No.1	13	13.0	0.832	47.9	5.16
No.2	14	13.0	0.848	47.1	5.19
No.3	14	13.6	0.840	50.8	5.80
No.4	15	13.4	0.815	44.8	4.88
Ave.	13-15	13.3	0.834	47.7	5.26

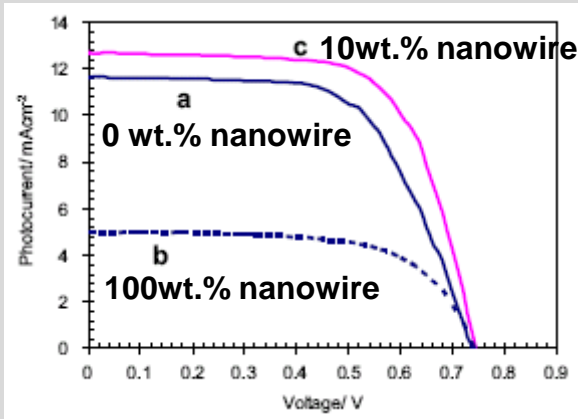


Nanowire & Nanoparticle

SEM & XRD



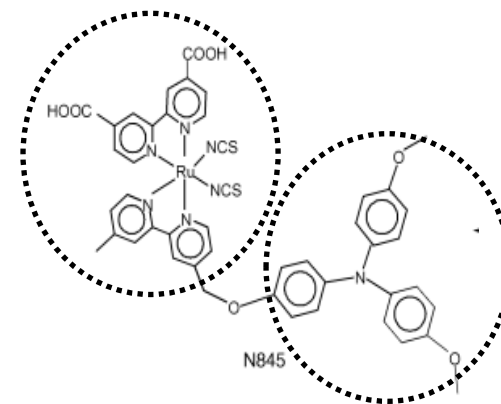
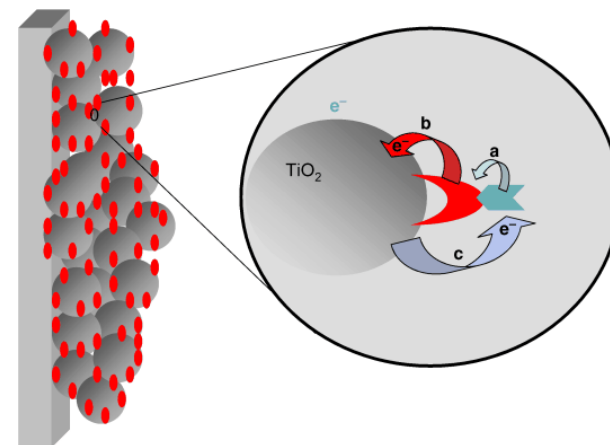
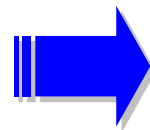
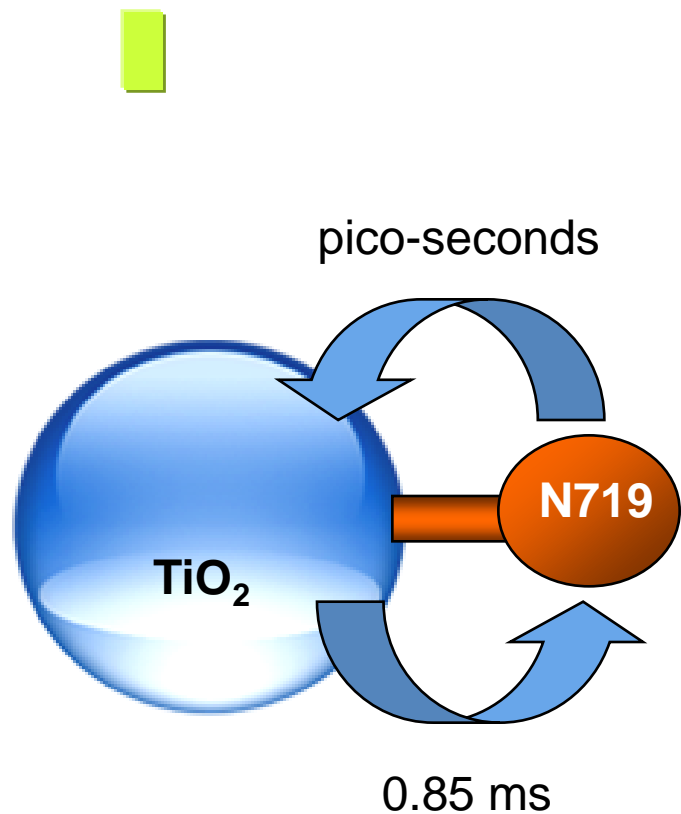
I-V curve & JSC



Nanowire contents (%)	Jsc (mA/cm ²)	Voc (V)	FF (-)	Efficiency (%)
0	12.11	0.74	0.63	5.59
10	13.23	0.74	0.66	6.53
20	12.89	0.72	0.68	6.29
30	12.17	0.73	0.65	5.77
40	9.92	0.73	0.68	4.90
50	11.99	0.71	0.64	5.42
100	5.06	0.74	0.64	2.42



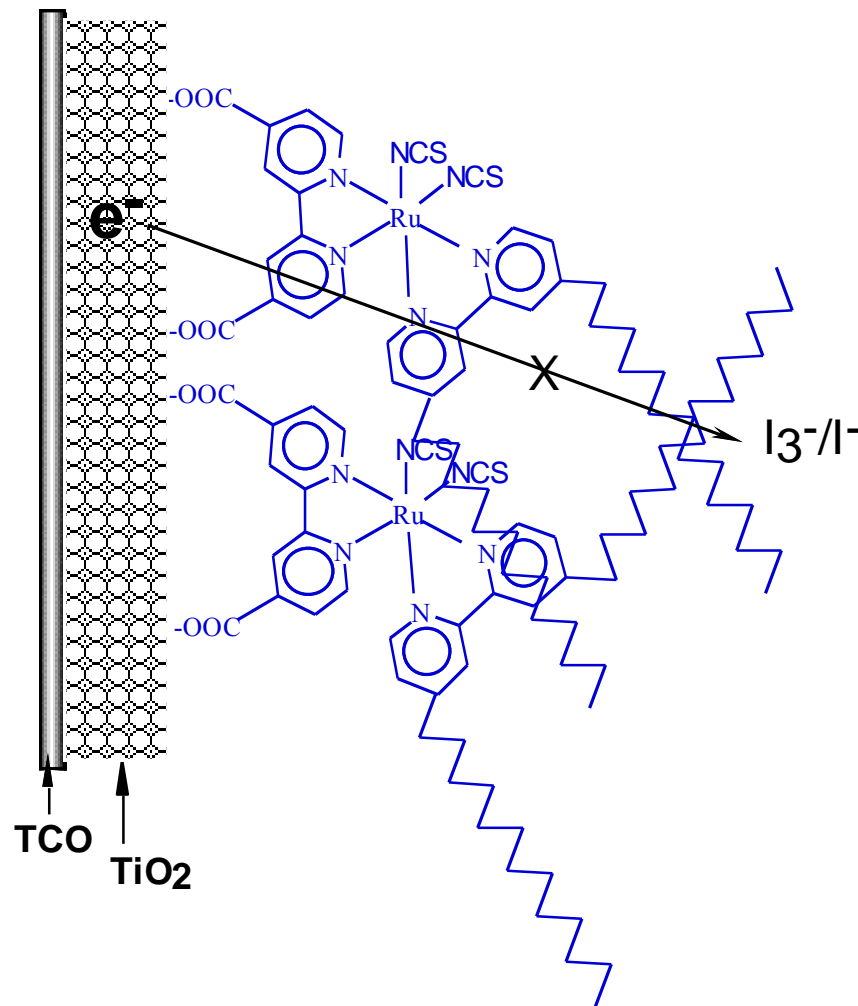
Suppression of Recombination from TiO₂ to Dye: Supramolecular Approach



Narukuni Hirata, Jean-Jacques Lagref, Dr. Emilio J. Palomares, Dr., James R. Durrant, Dr., M. Khaja Nazeeruddin, Dr., Michael Gratzel, Prof., Davide Di Censo, Chemistry - A European Journal, Volume 10, Issue 3, Pages 595-602 (2004)



TiO₂/Dye/Electrolyte Interface Engineering





Thank You !