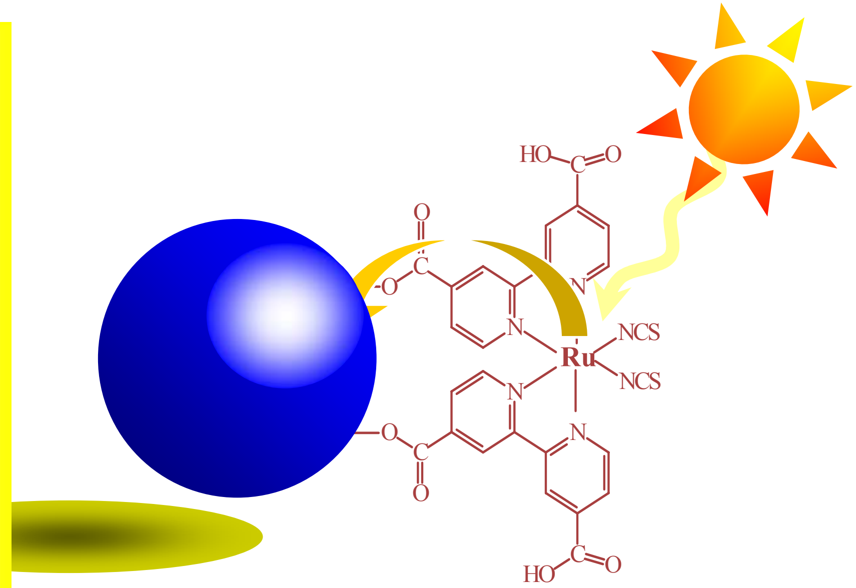
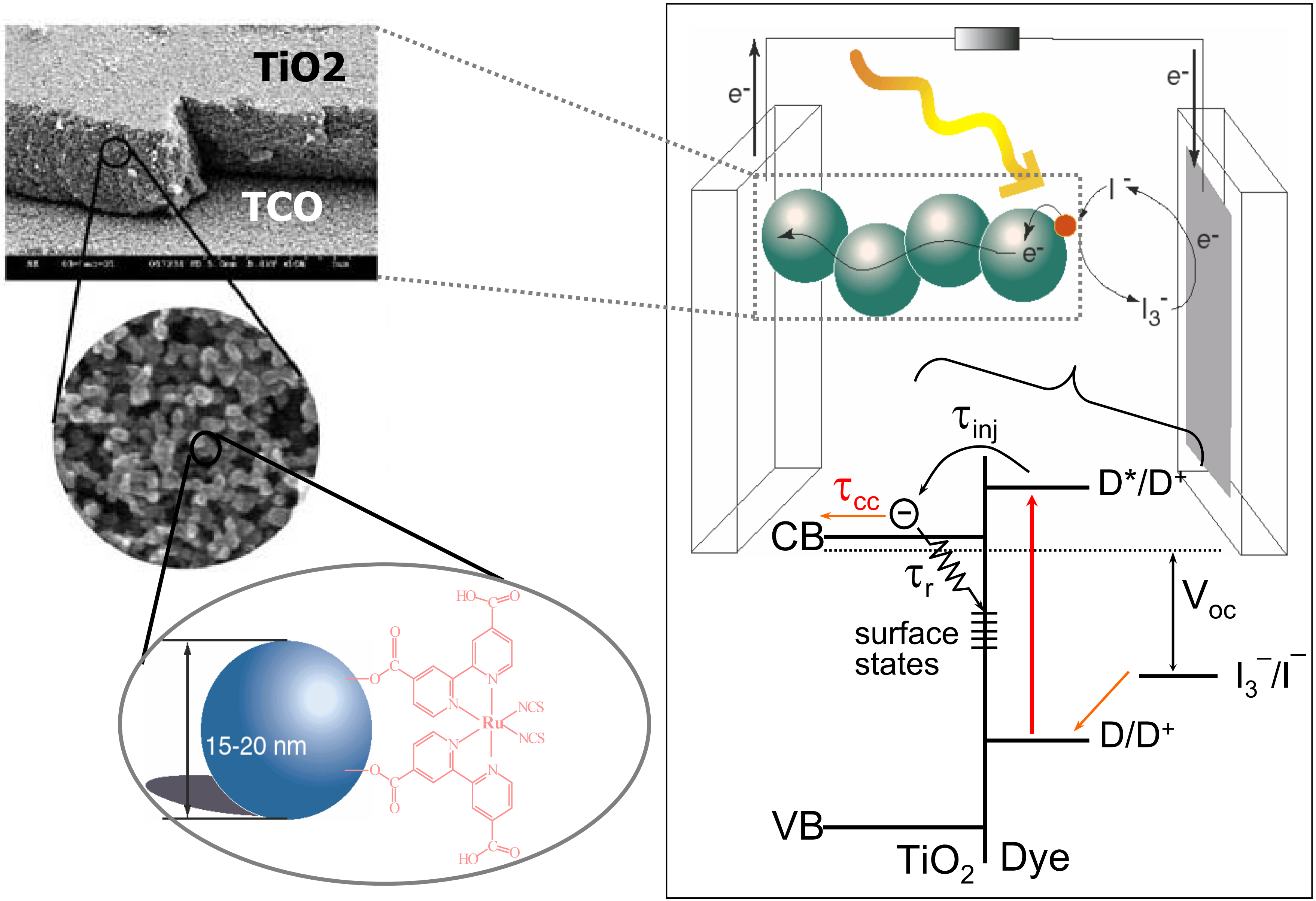
Material and Structural Design for High Efficiency Dye-Sensitized Solar Cell



Hyungjun Koo, Beomjin Yoo, Kicheon Yoo, Kyungkon Kim and **Nam-Gyu Park***

Center for Energy Materials
Korea Institute of Science and Technology (KIST)

DSSC: structure and operation principle



issues

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* efficiency as high as 11% has been achieved.
* higher efficiency is required in order to be in competition with Si solar cell

Approaches for improving efficiency

13%

$$\text{Efficiency } (\eta) = (J_{sc} \times V_{oc} \times FF)/P_{in}$$

η (%)	J_{sc}	V_{oc}	FF	P_{in}	cf.
10 → 13	18 → **23.4**	0.75	0.74	100	Case1: J_{SC} increased by 30%

13%

$$\text{Efficiency } (\eta) = (J_{sc} \times V_{oc} \times FF)/P_{in}$$

η (%)	J_{sc}	V_{oc}	FF	P_{in}	cf.
10 → 13	18	0.75 → **0.98**	0.74	100	Case2: V_{OC} increased by 30%

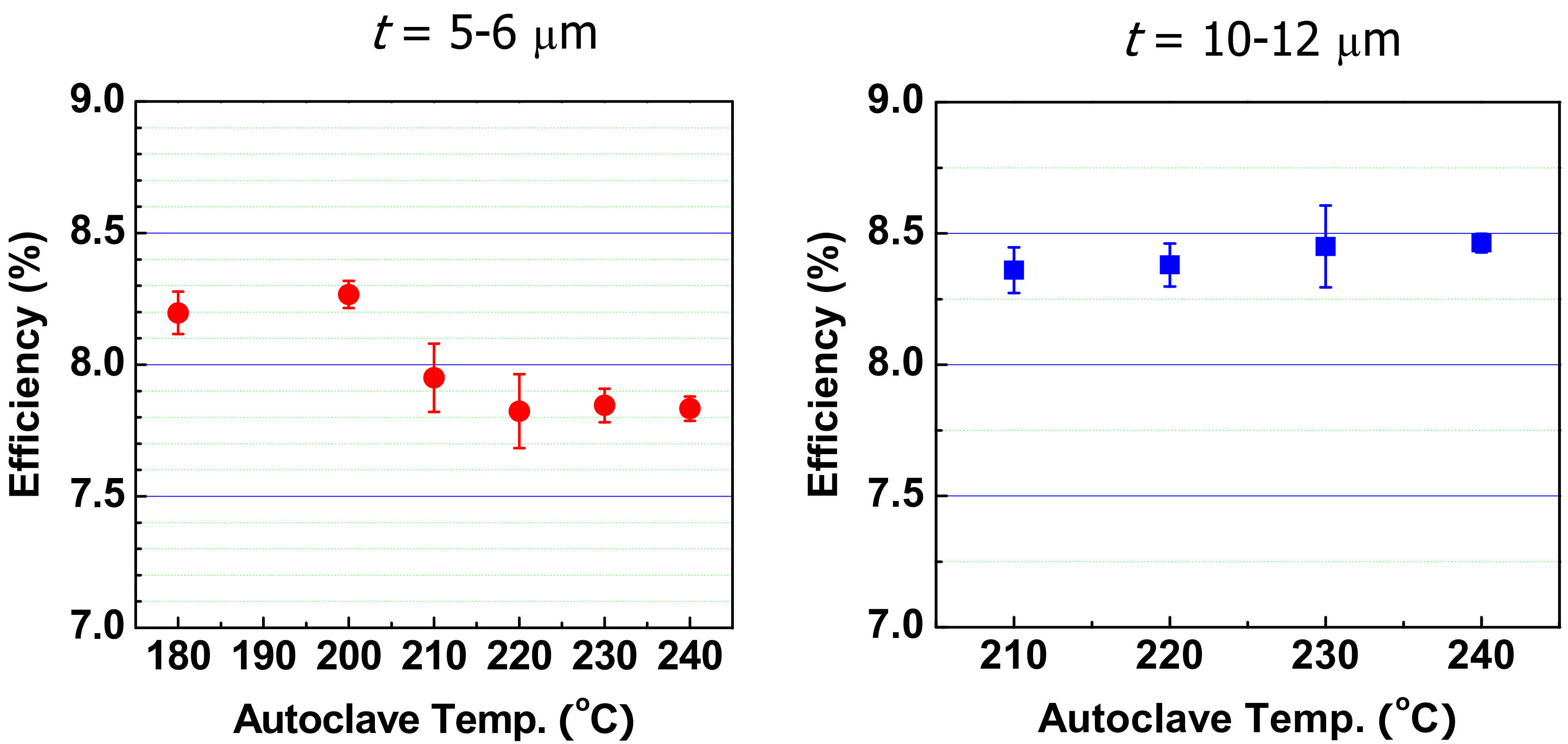
strategy for improving J_{SC}

structural and material design

light confinement by scattering:

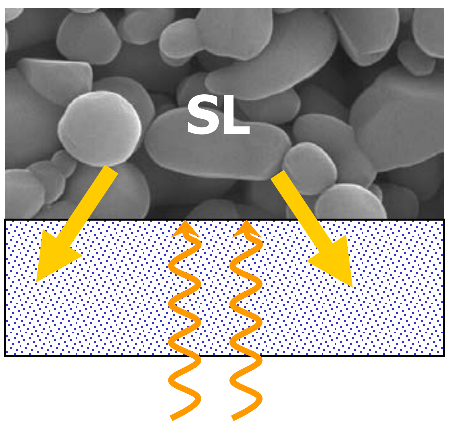
size-dependent scattering efficiency & bi-functional material

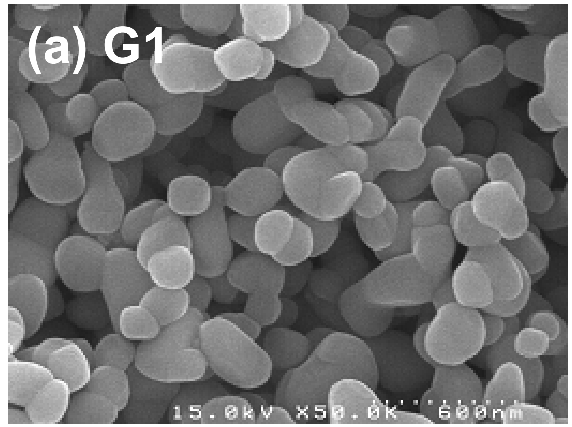
nanoparticle films for DSSC

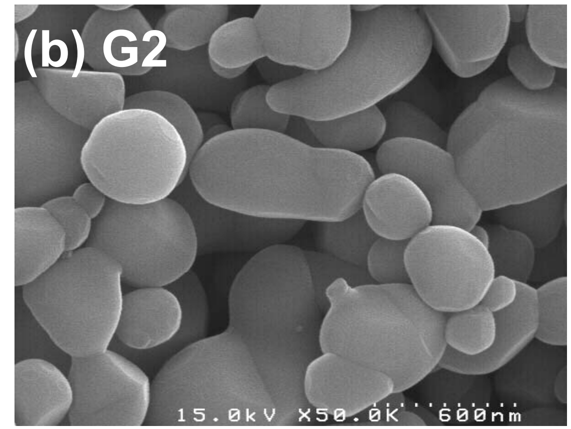


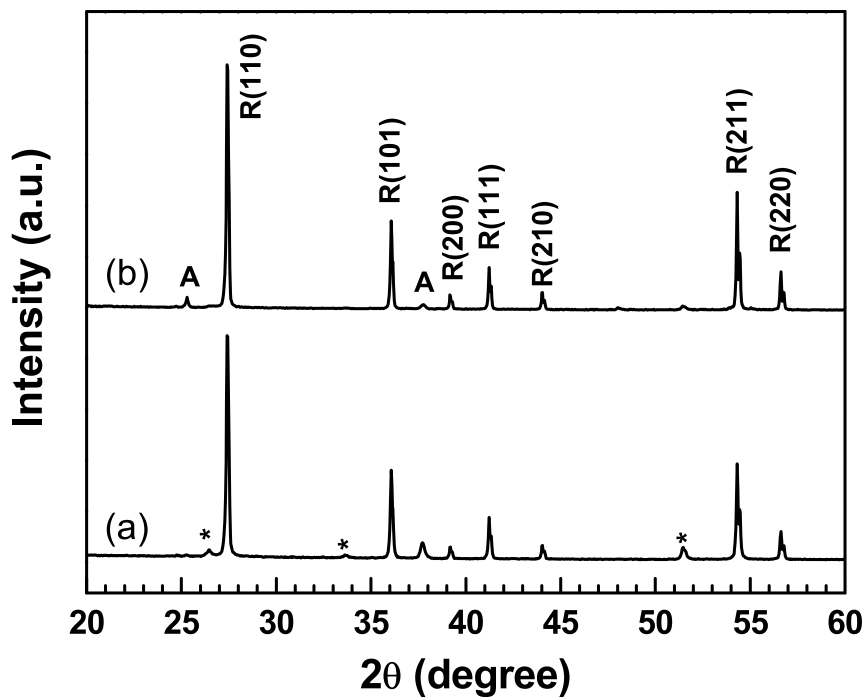
Simple increase of nanoparticle film may not improve the efficiency to great extent!

size-dependent scattering efficiency



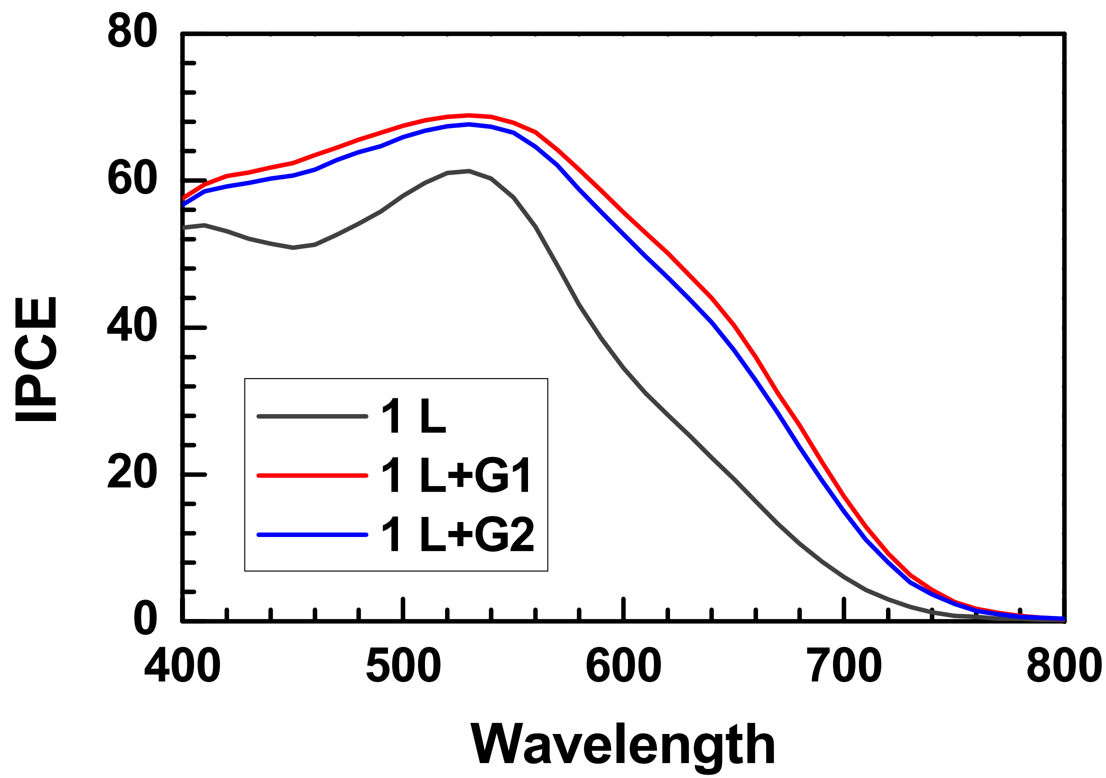




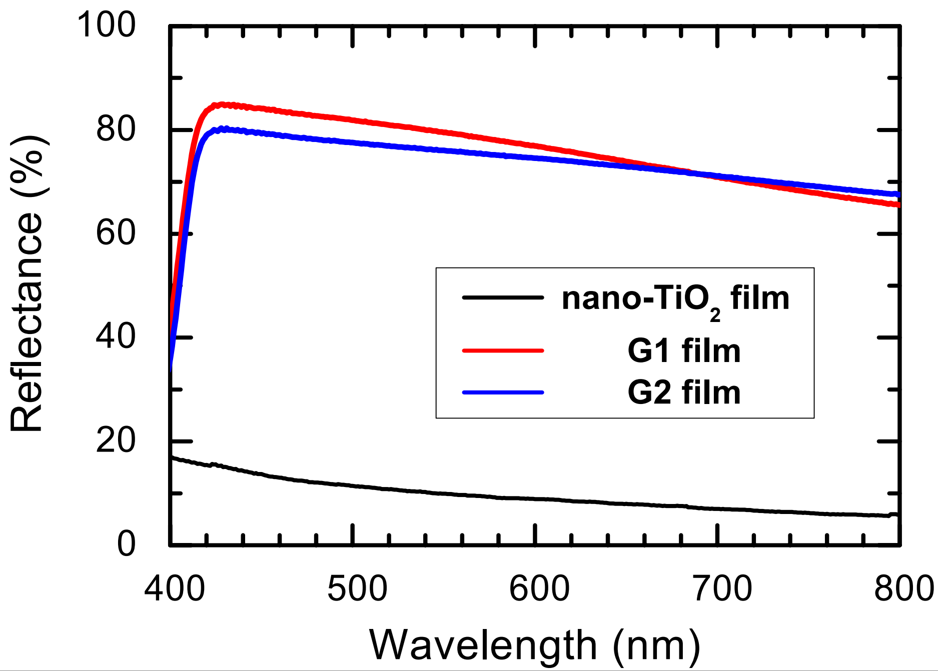


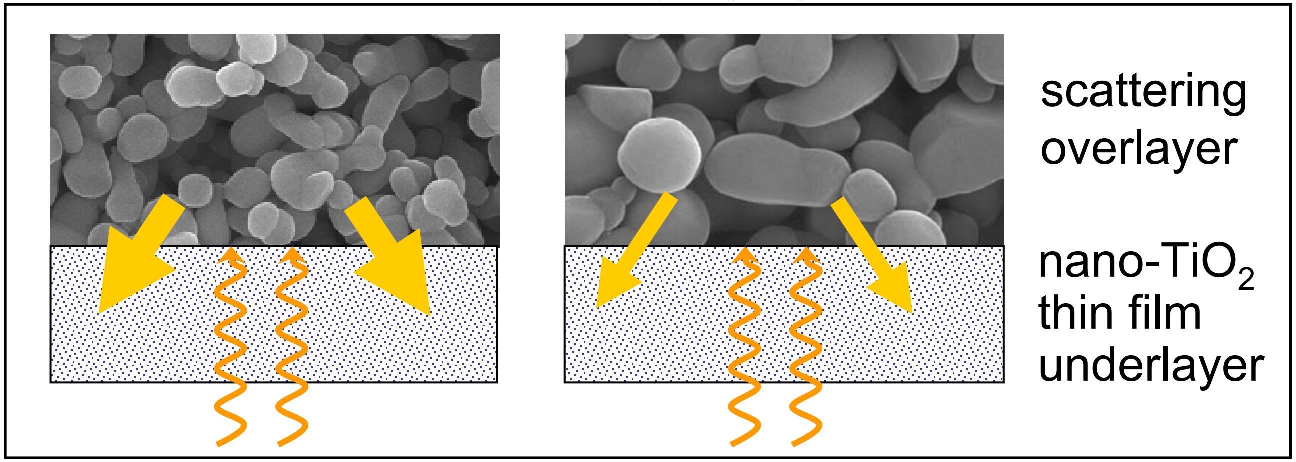
PV properties

	J_{sc} (mA/cm²)	V_{oc} (mV)	*FF* (%)	*Eff.* (%)	Increasing rate
1L (~7 μm)	12.2 ± 0.1	868 ± 2	71.1 ± 0.1	7.55 ± 0.12	
1L+G1	14.9 ± 0.0	852 ± 2	70.4 ± 0.3	8.94 ± 0.08	**+18.4%**
1L+G2	14.4 ± 0.1	866 ± 1	70.7 ± 0.4	8.78 ± 0.09	**+16.3%**



reflectance spectra





bi-functional material

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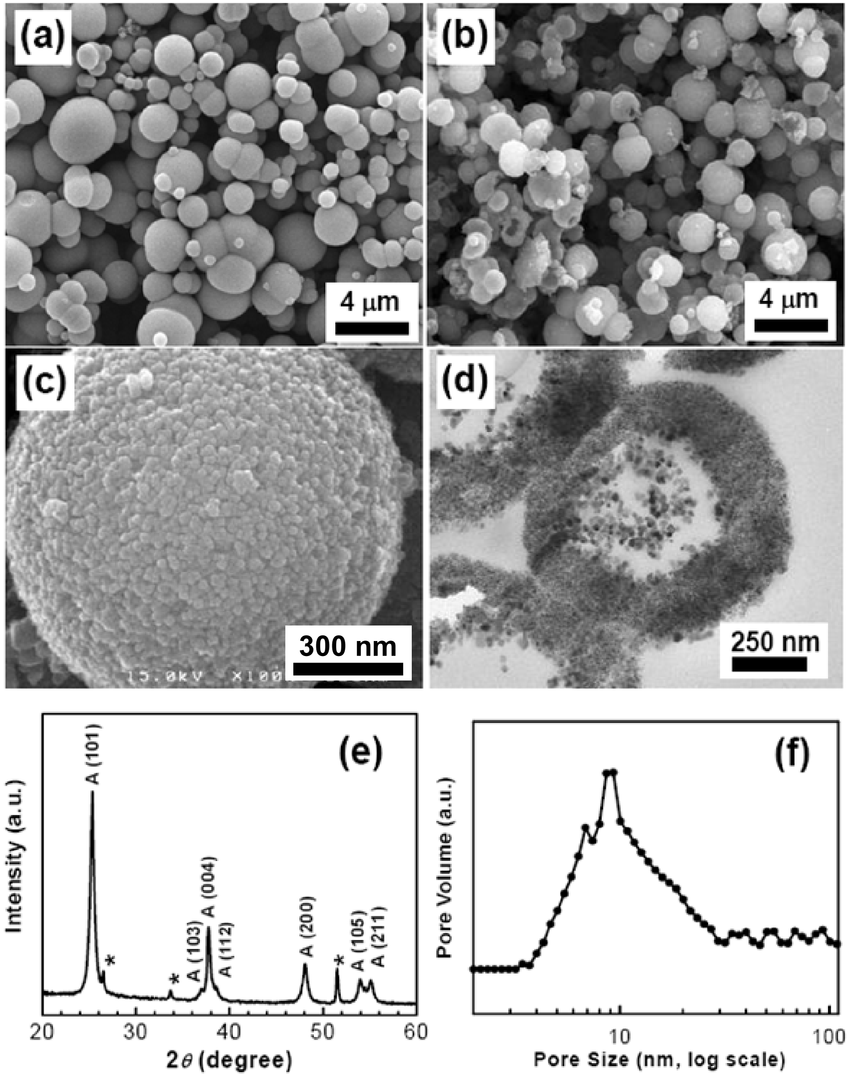
* spherical or flat surface large particles are normally used for light scattering

* except light scattering, such materials do not contribute to photocurrent generation due to low surface area

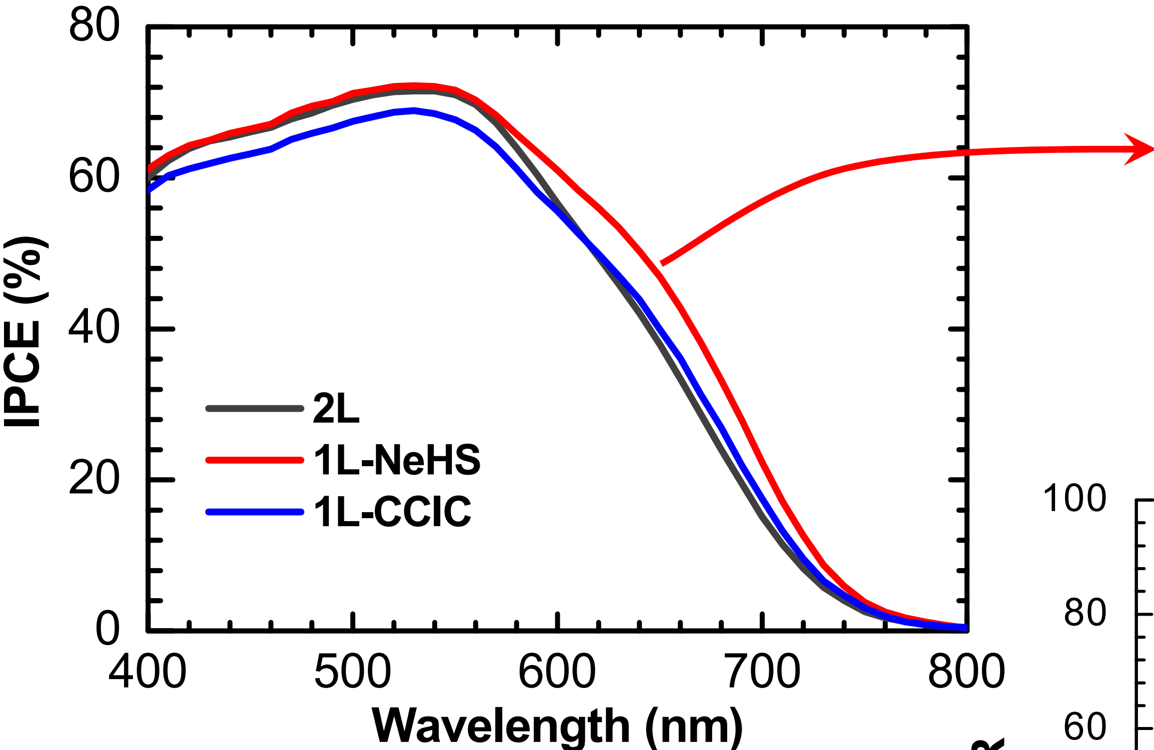
* motivation: design of bi-functional material exhibiting both light scattering and photocurrent generation efficiently

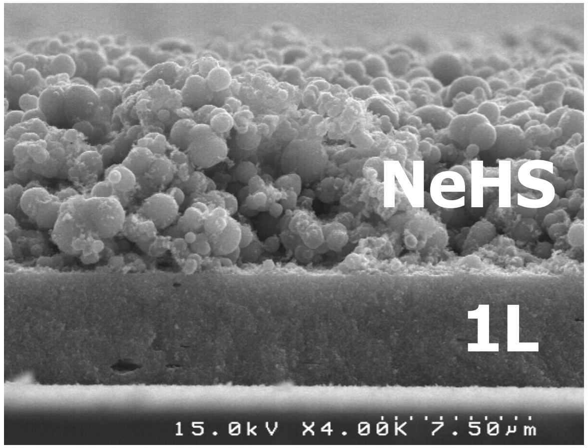


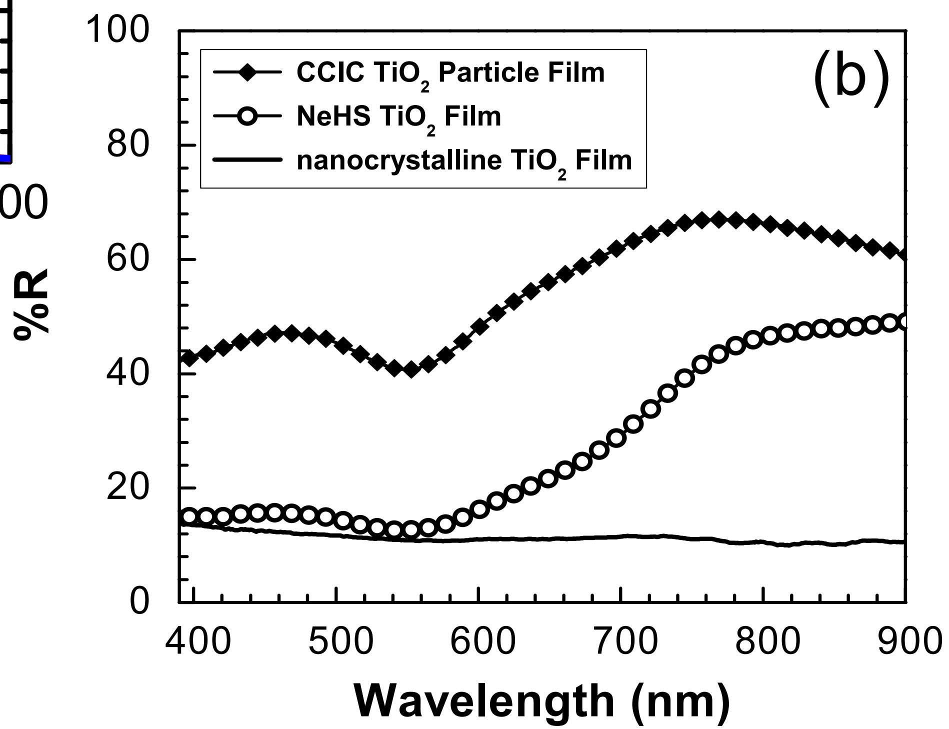
Nano-Embossing Hollow Sphere TiO2

(prepared by Prof. W.-I. Lee)

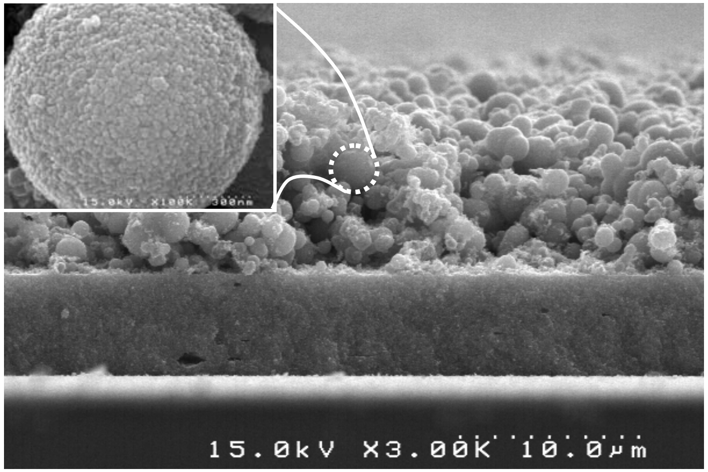
IPCE & reflectance comparison

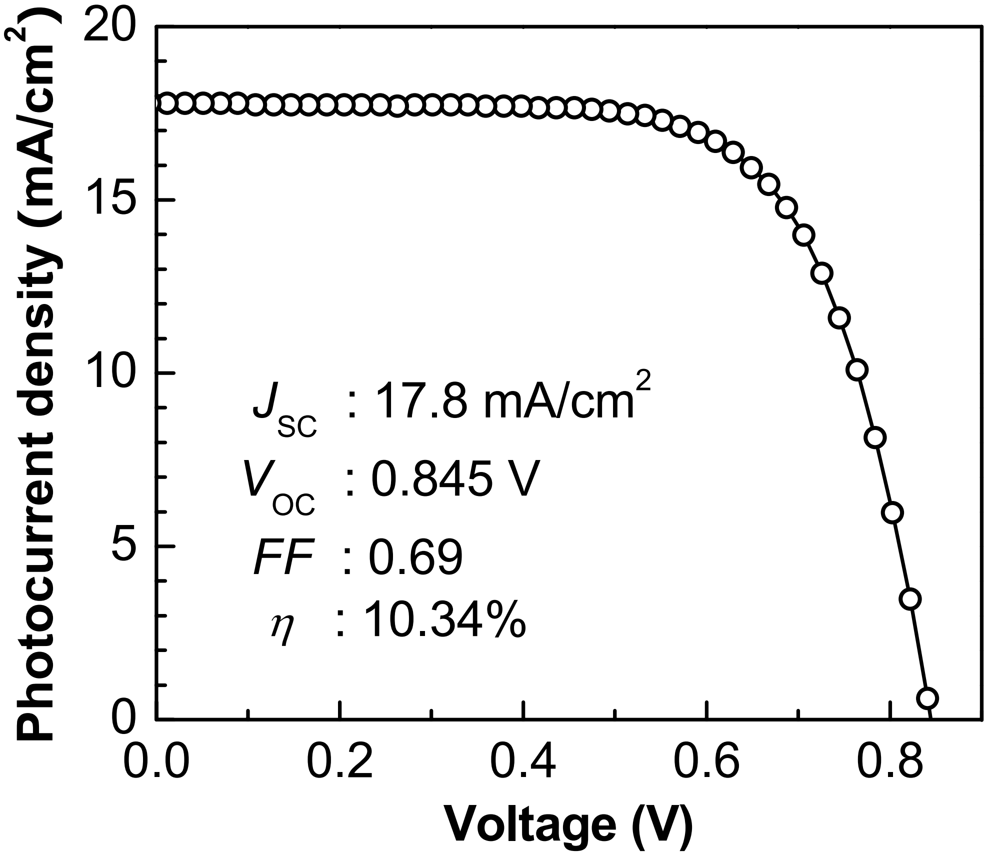






conversion efficiency

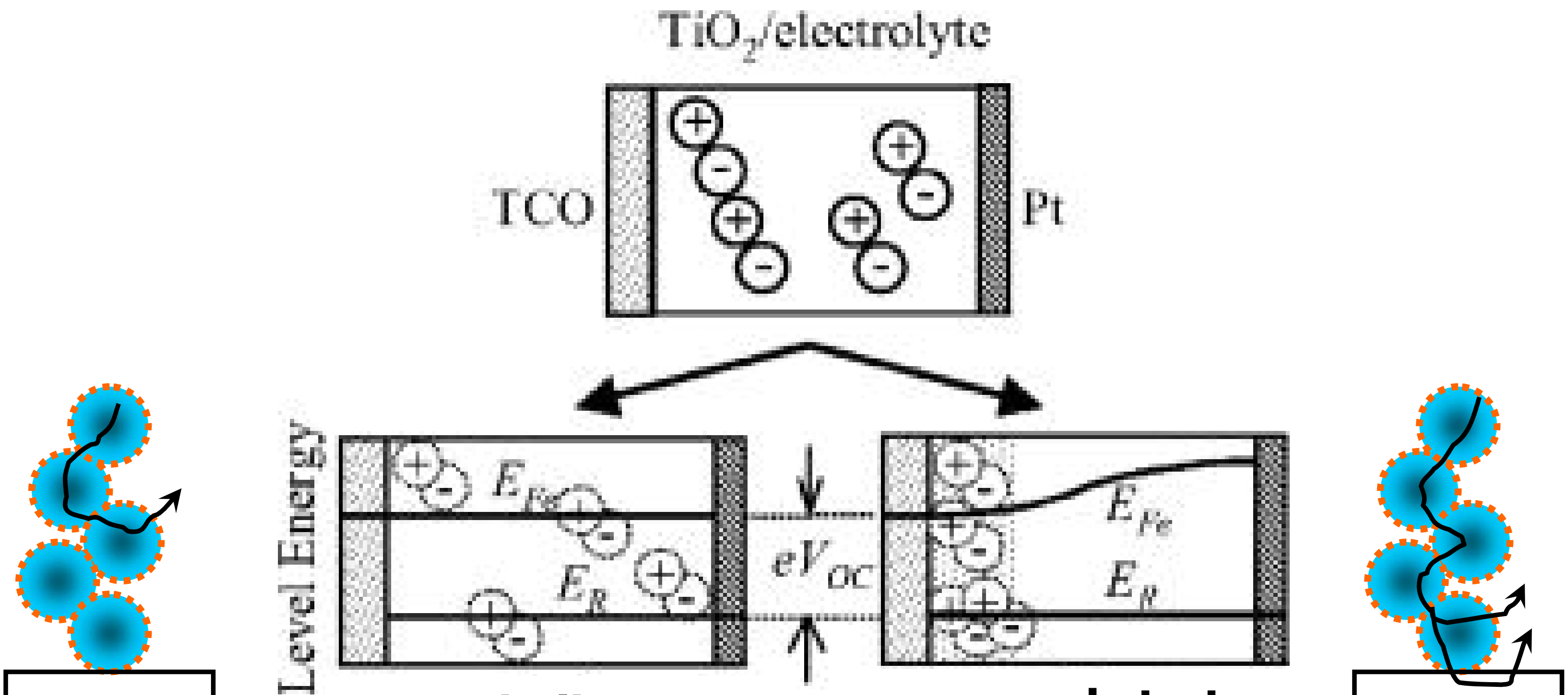




without long-term post-treatment of TiCl4

interfacial nano-engineering

locus of recombination

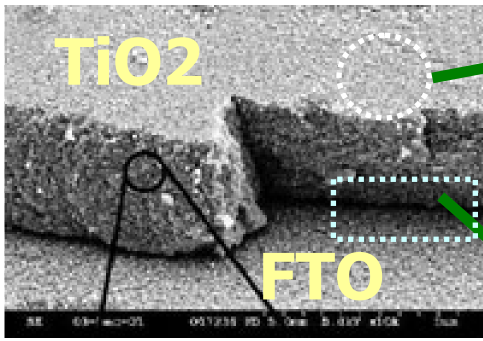


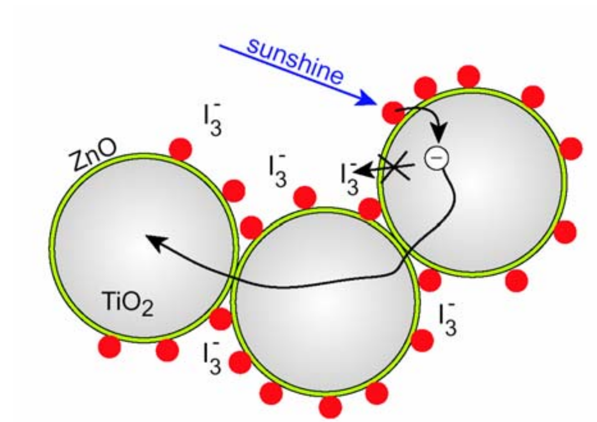
bulk recombination

near substrate recombination

methods for suppression of recombination

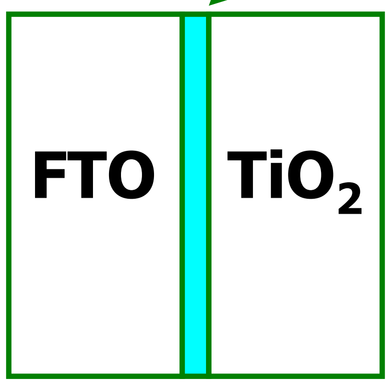
Mesoporous electrode





core-shell

(to protect bulk recombination)

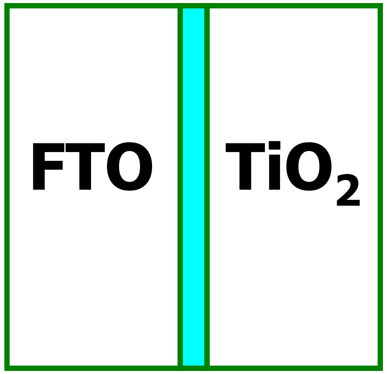


blocking layer

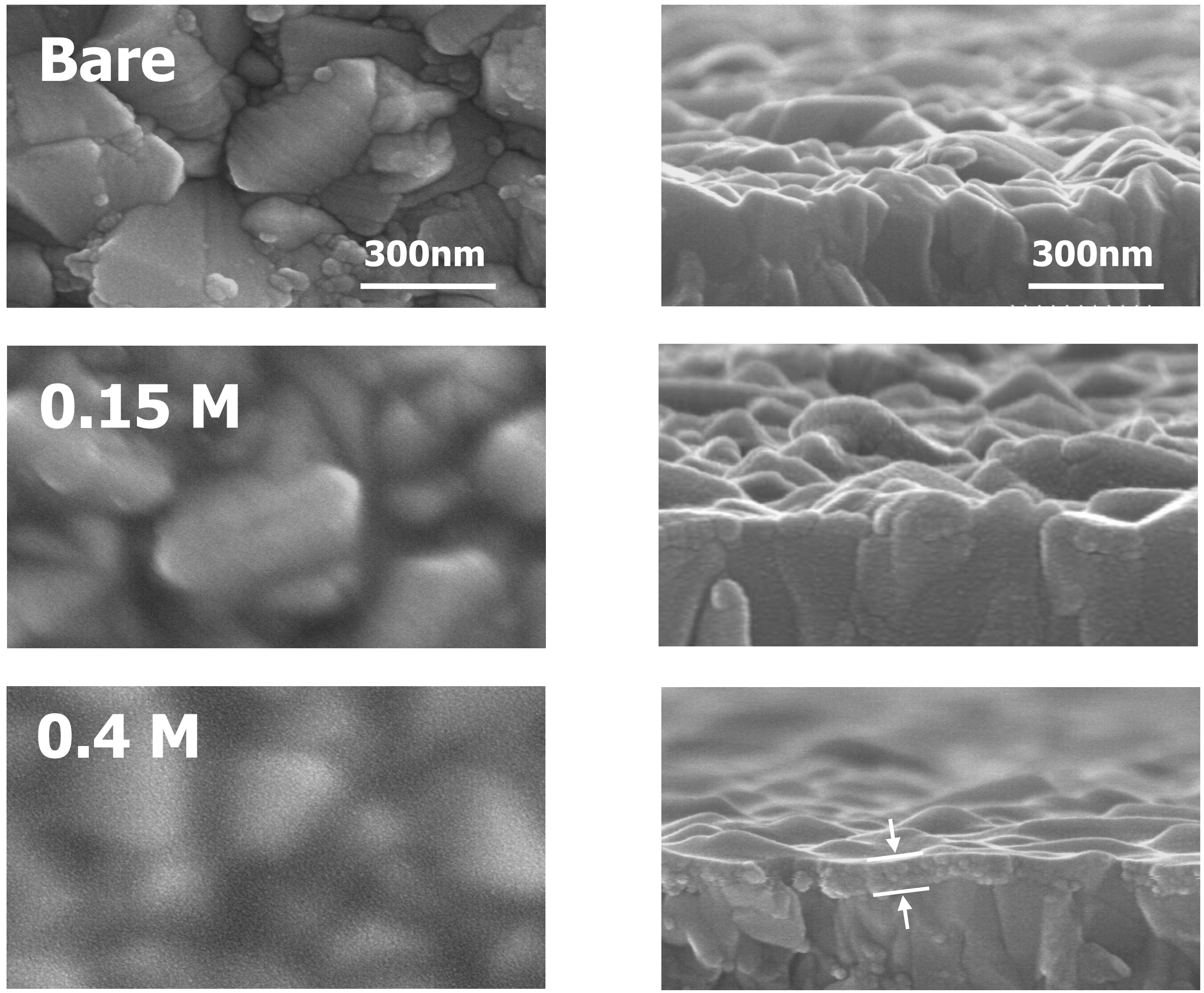
(to protect recombination at near substrate)

FTO/BL/TiO2: SEM

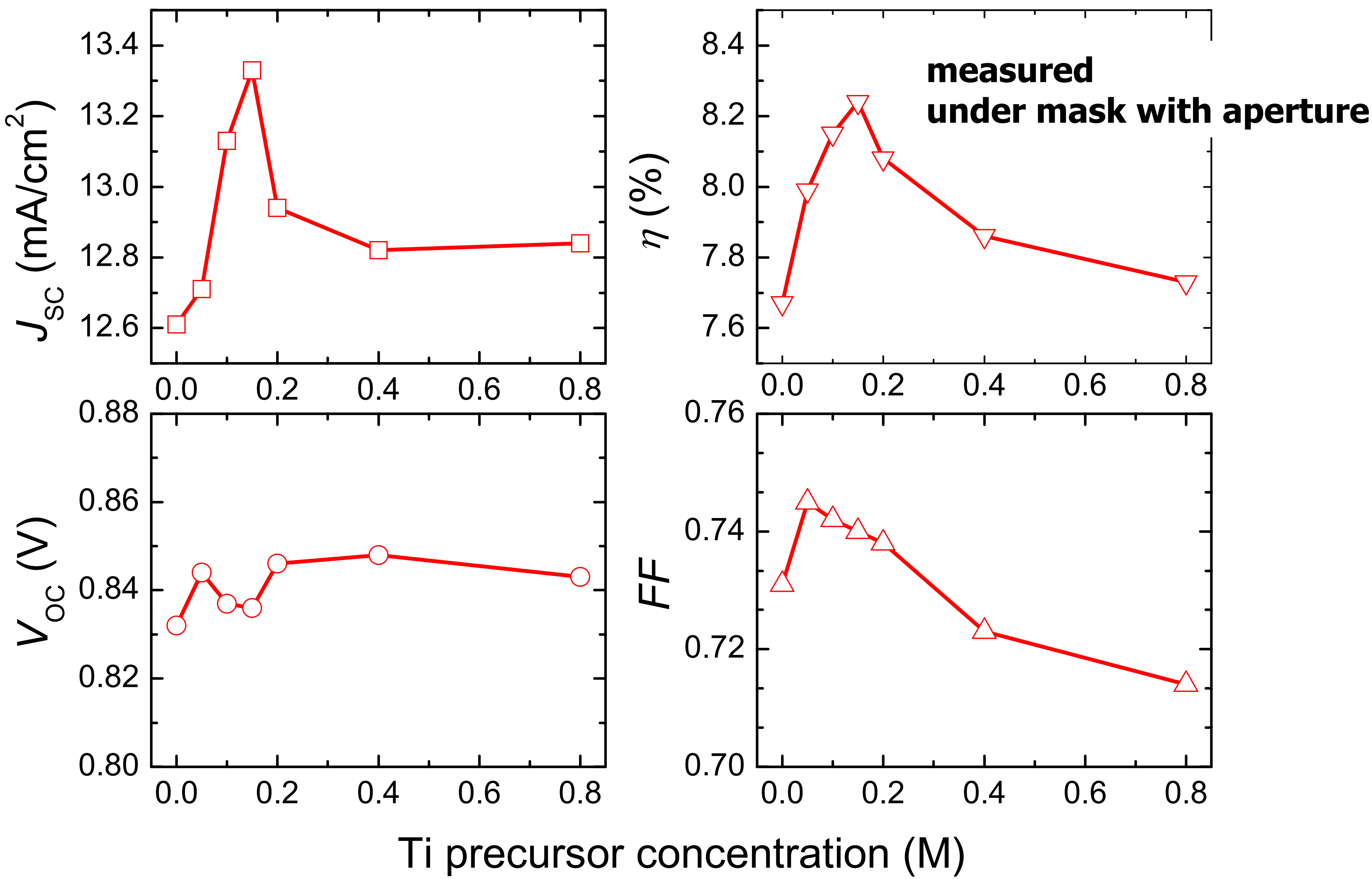
Chemically formed from Ti precursor solution



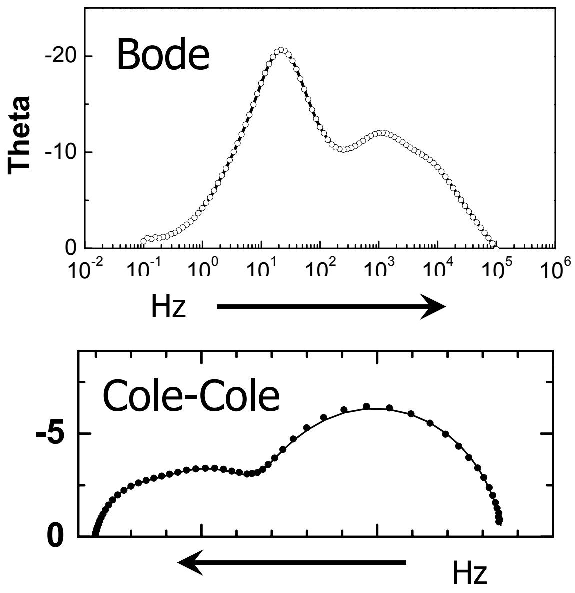
Blocking layer

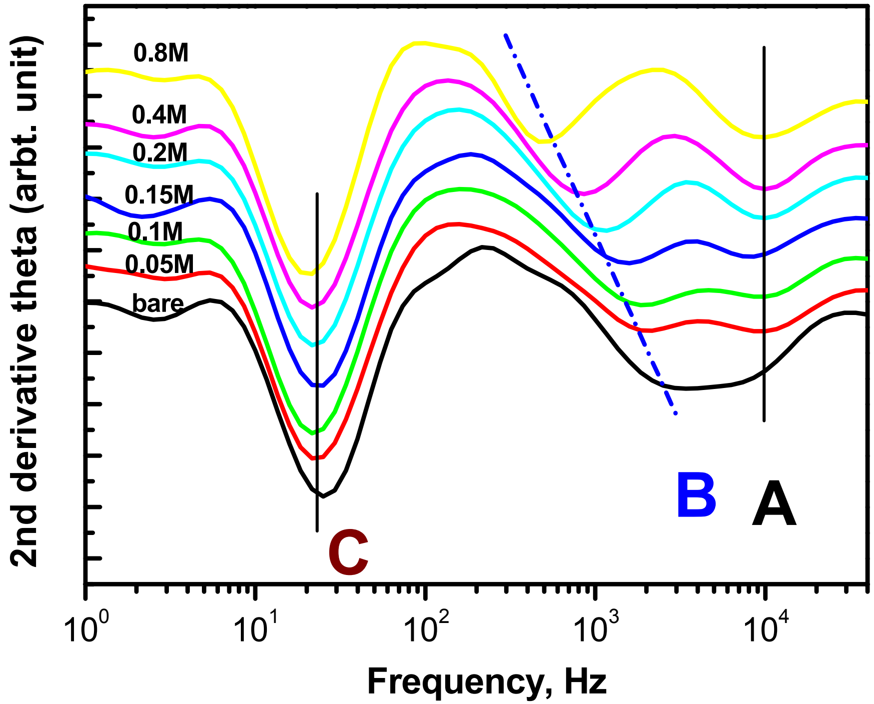


effect of Ti-precursor concentration on PV property

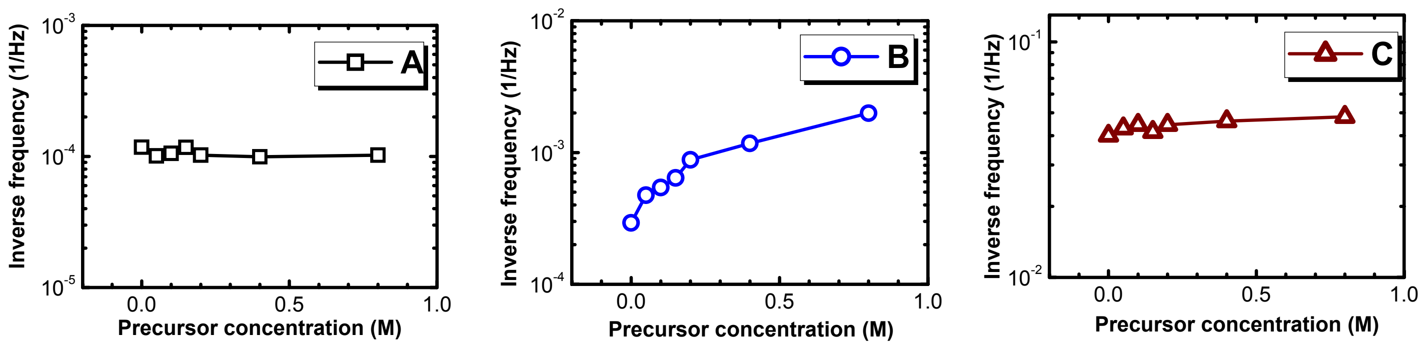


EIS (bode plot)

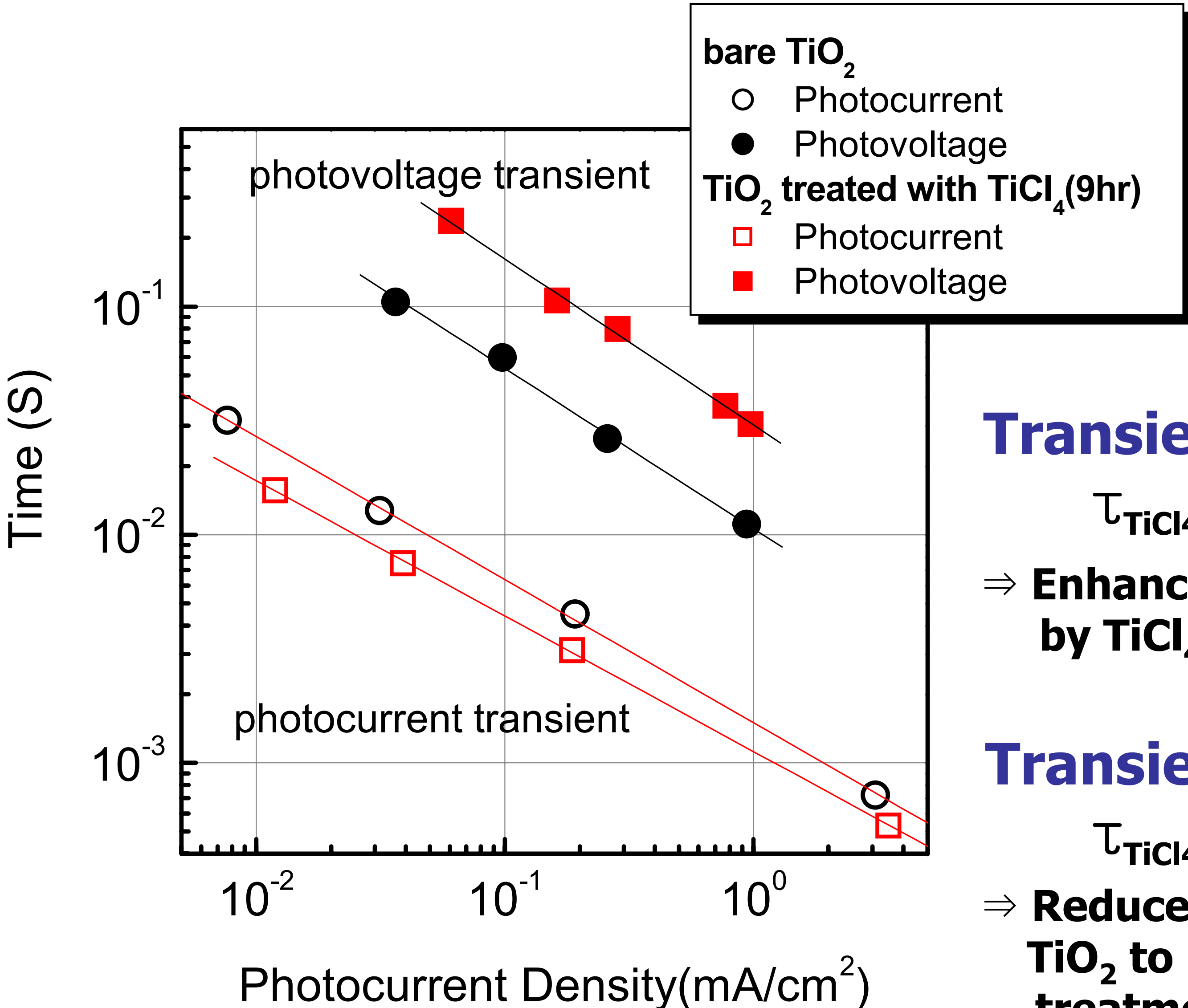


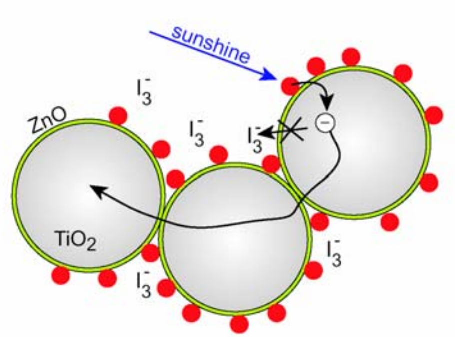


A: pt/electrolyte; B: FTO/electrolyte; C: TiO2/dye/electrolyte



Surface modification of bulk TiO2 film: fast electron transport, slow recombination





Transient photocurrent

$\tau_{\text{TiCl4 treatment}} < \tau_{\text{TiO2}}$

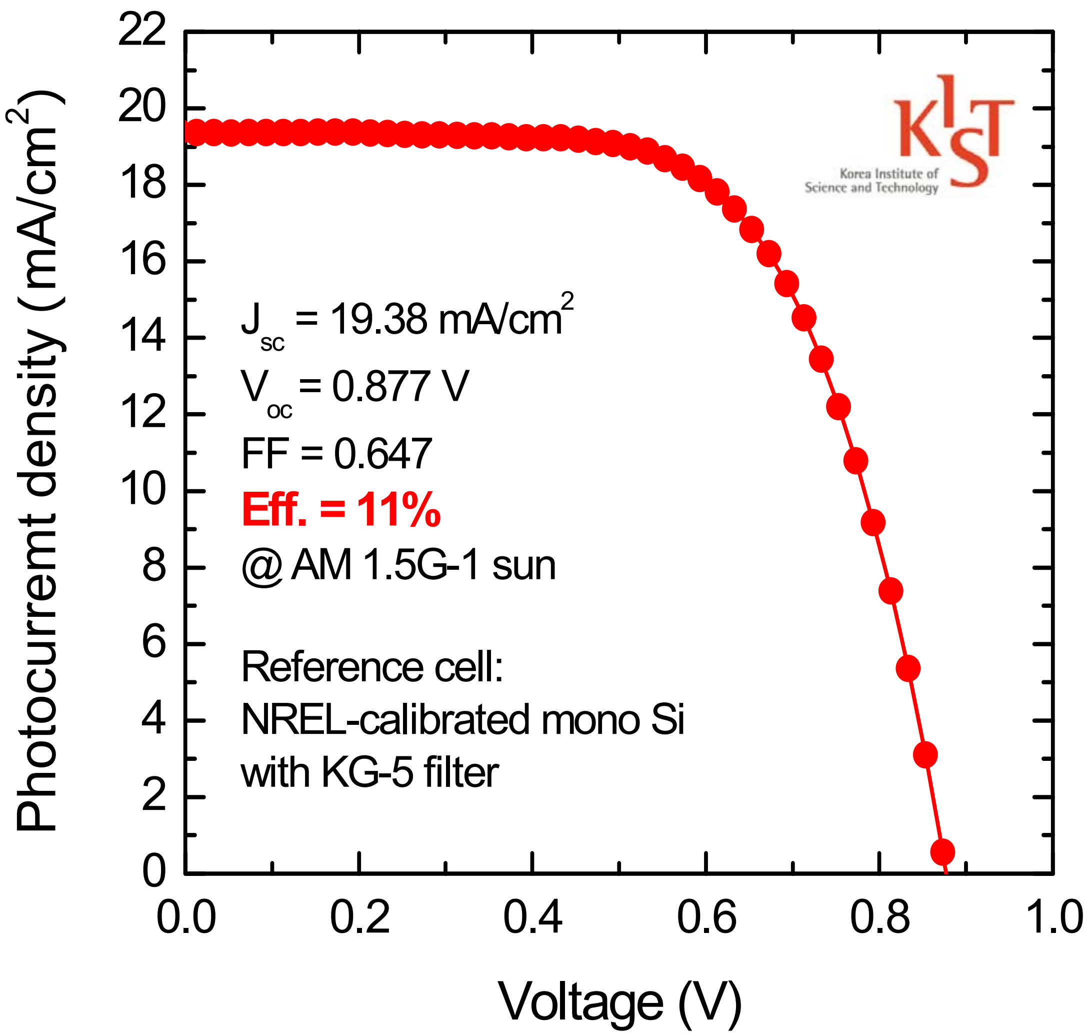
⇒ **Enhanced electron transport by $TiCl_4$ treatment**

Transient photovoltage

$\tau_{\text{TiCl4 treatment}} > \tau_{\text{TiO2}}$

⇒ **Reduced recombination from TiO_2 to electrolyte by $TiCl_4$ treatment**

DSSC best efficiency



close to the world best efficiency of 11.1% from EPFL

KIST Activity: Organic Photovoltaics

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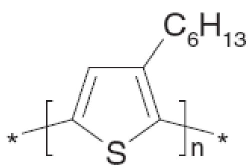
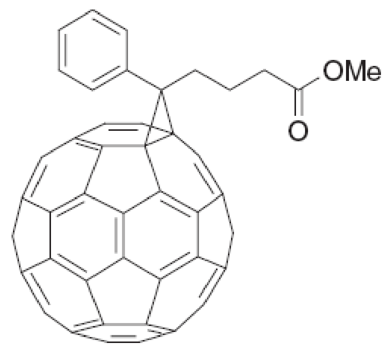
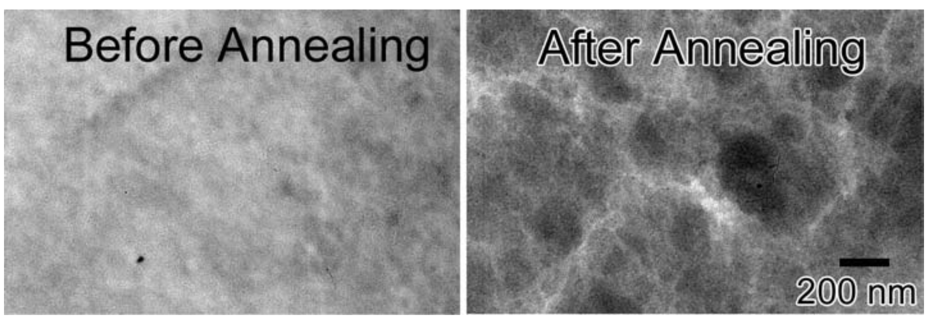
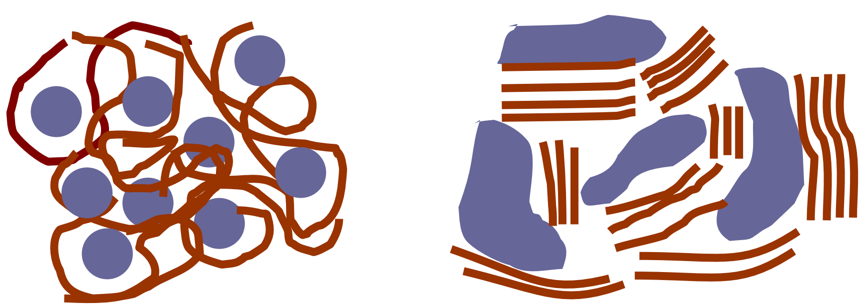


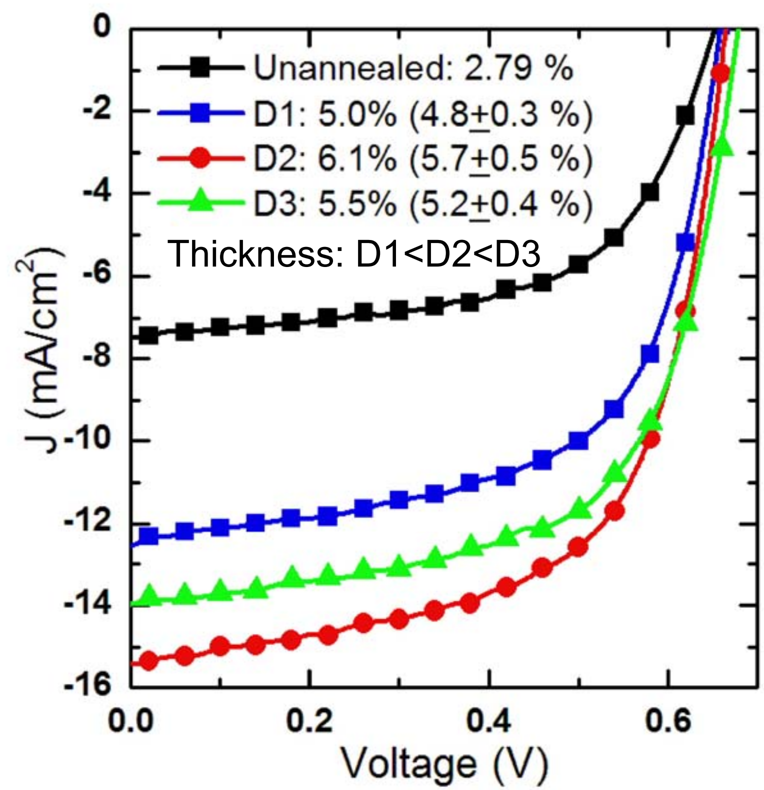


P3HT **PCBM**





Max. Eff. of 6.1% was obtained from D2



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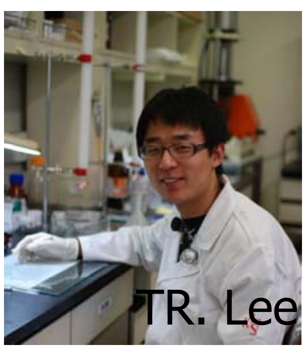

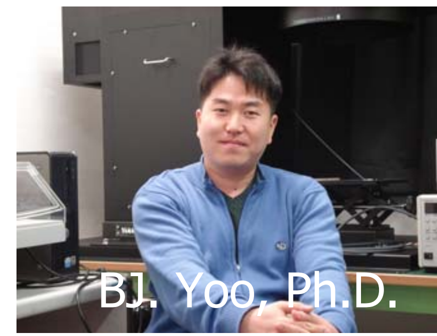

KIST Specialists Laboratory for Dye-Sensitized & Organic Solar Cells

$$$: KIST, MOST and MOCIE