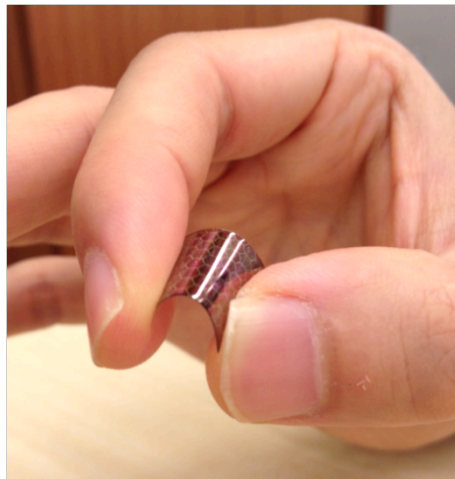


Low-cost solar cells

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Low-Cost Solar Cells

$$\text{Overall cost} = \text{fabrication cost} / (\text{efficiency} \times \text{lifetime})$$

Targeted properties for low -cost solar cells

Acceptable Efficiency and Lifetime

Low Fab. Cost: affordable

- Organic Solar Cell (OSC)
- Hybrid Solar Cell (HSC)

Added values:

e.g. innovative ways to utilize solar cells.

Global warming



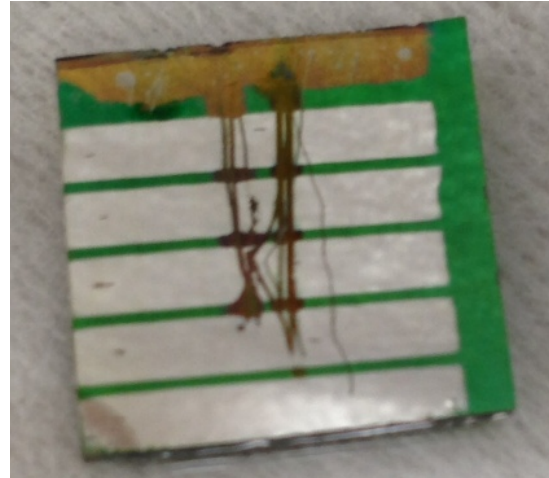
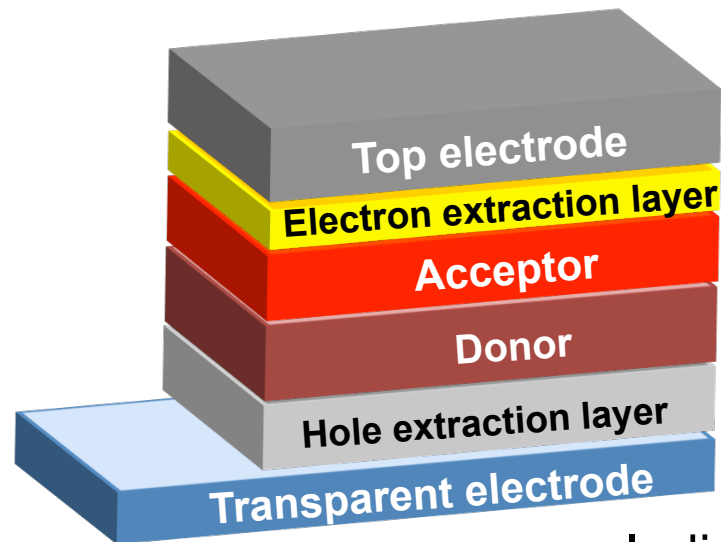
Renewable energy



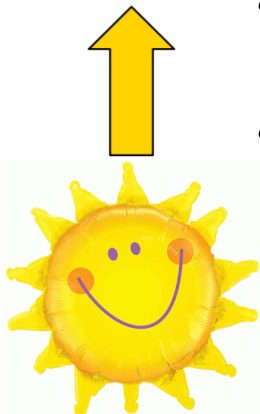
Organic Solar Cell (OSC)

$$\text{Overall cost} = \text{fabrication cost} / (\text{efficiency} \times \text{lifetime})$$

OSC Structure



OSC on conventional Indium Tin Oxide (ITO) glass substrate

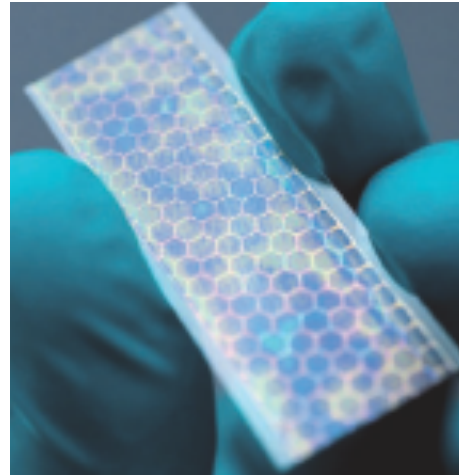
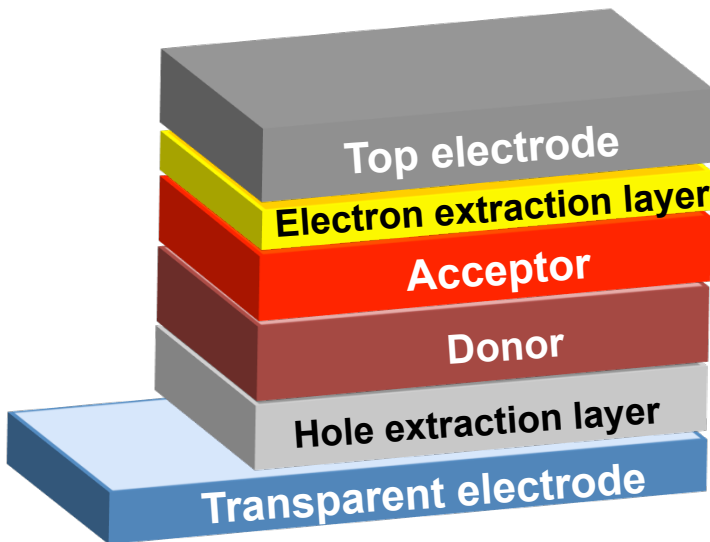


- Indium is the **61st** abundant of elements in Earth's crust (**49 ppb**).
→ limited reserve and expensive (**>50%** of the total cost).
- Rigid → incompatible with low cost fabrication e.g. roll-to-roll.
- Thick and heavy → substantial infrastructure needed for installation.

Organic Solar Cell (OSC)

$$\text{Overall cost} = \text{fabrication cost} / (\text{efficiency} \times \text{lifetime})$$

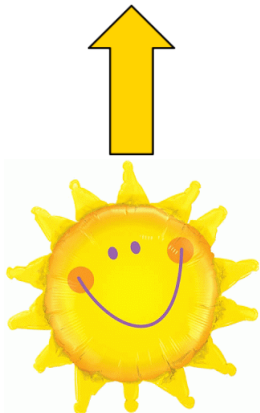
OSC Structure



Flexible transparent electrode
"Flextrode"

ZnO		
PEDOT:PSS		
Ag grid		Ag grid
PET		

$R < 10 \text{ Ohm/sq}$
 $T > 65\% \text{ at } 500\text{nm}$



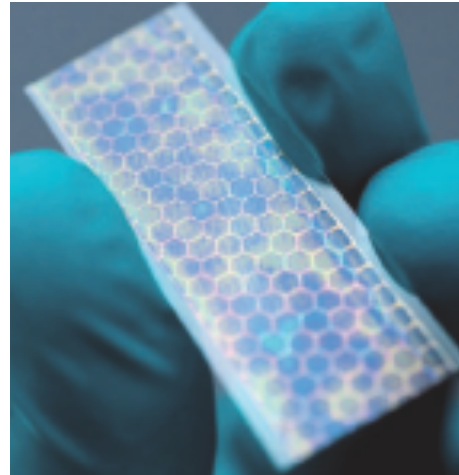
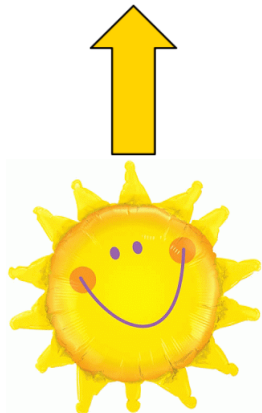
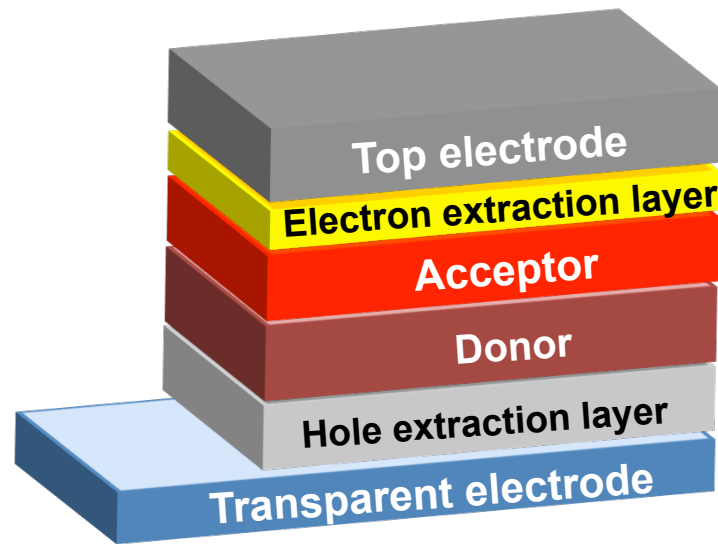
- PET, PEDOT:PSS, ZnO are cheap.
- Thin and light → minimal infrastructure needed for installation.
- Next step: Replace Ag with cheap materials.

Organic Solar Cell (OSC)

Overall cost = **fabrication cost** / (**efficiency** × **lifetime**)

- Flexible → compatible with low cost fabrication e.g. roll-to-roll.

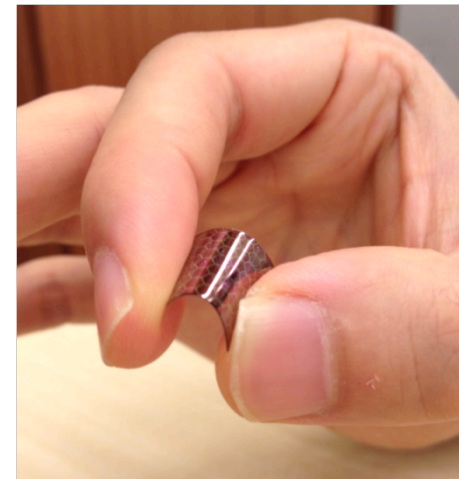
OSC Structure



Flexible transparent electrode
"Flextrode"



Roll-to-roll coater

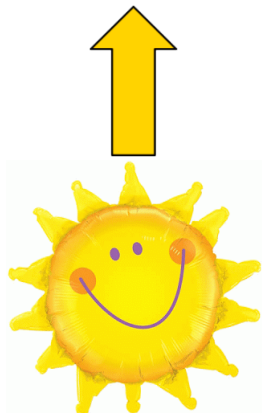
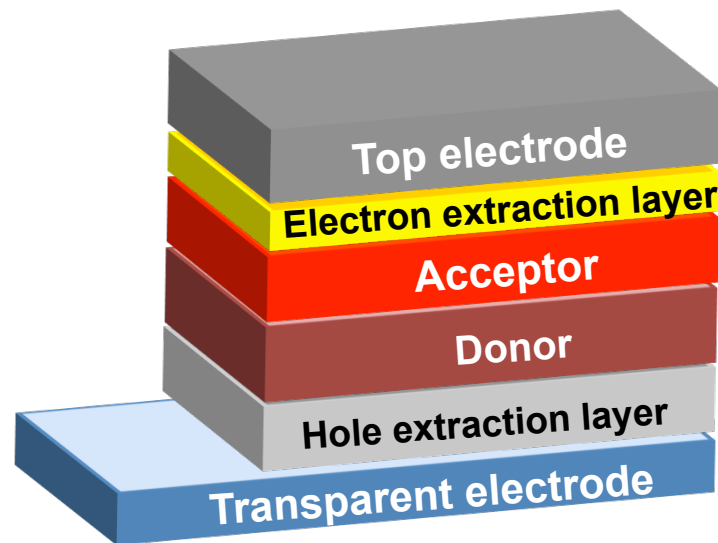


Organic Solar Cell (OSC)

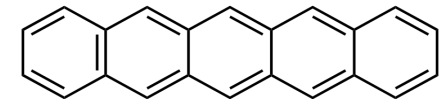
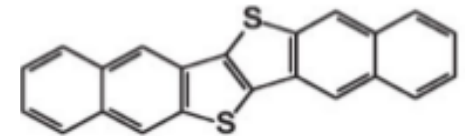
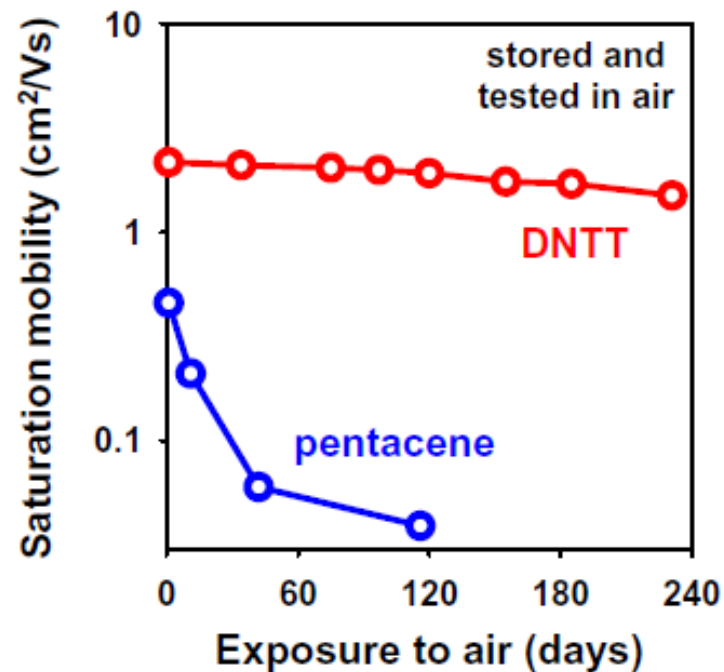
$$\text{Overall cost} = \text{fabrication cost} / (\text{efficiency} \times \text{lifetime})$$

High performance materials → improve efficiency and lifetime.

OSC Structure

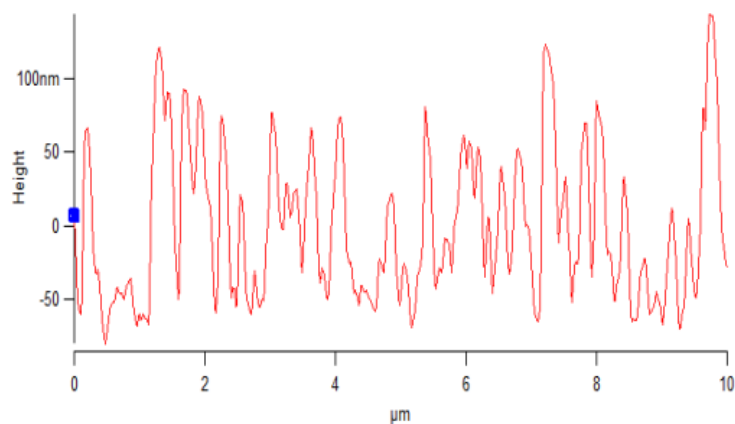
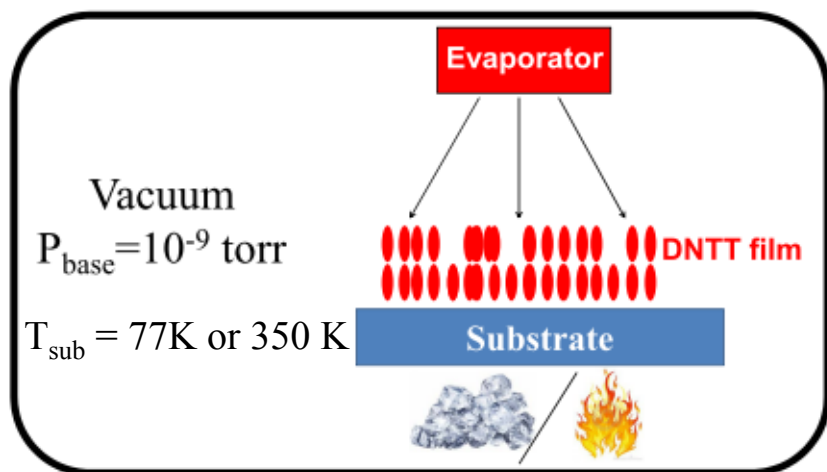


DNTT: higher mobility **and** air stable.

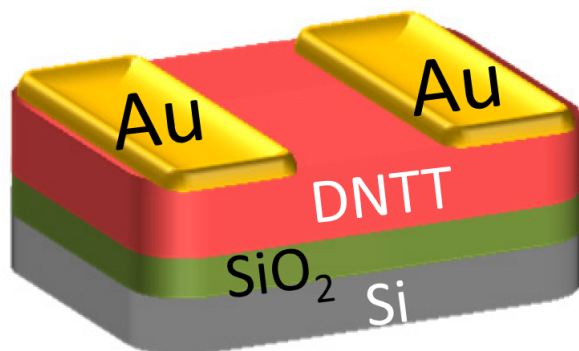


U. Zschieschang et al., *Organic Electronics* **12**, 1370 (2011)

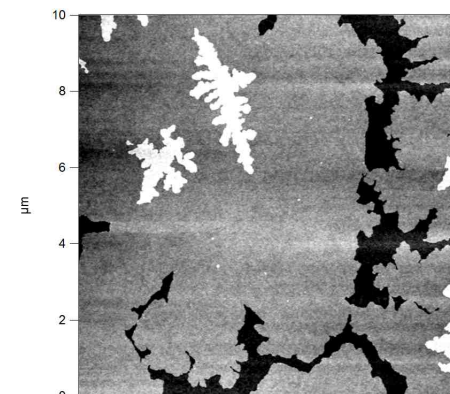
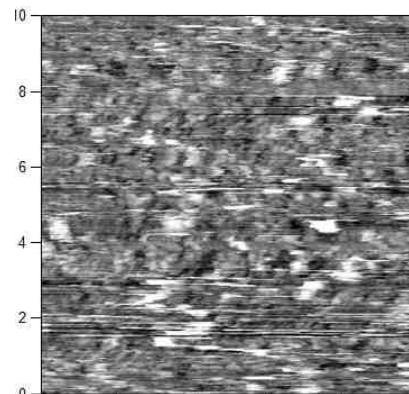
Structure-property relationship of organic films



Mobility measurements on organic field effect transistors

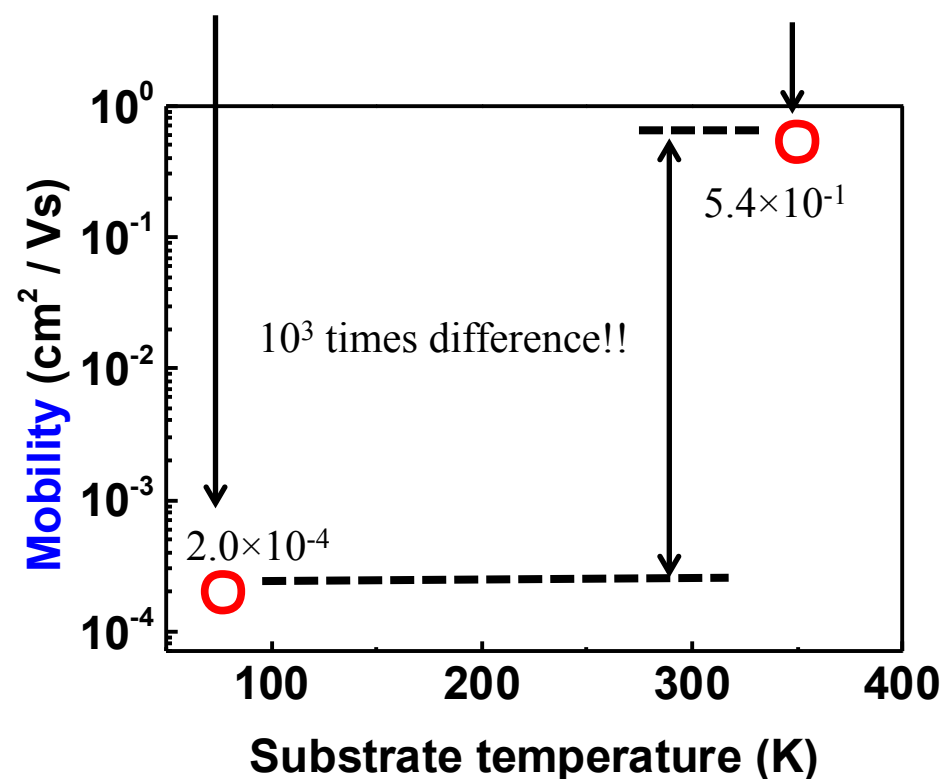


Film **structures** revealed by atomic force microscopy topography images ($10\ \mu\text{m} \times 10\ \mu\text{m}$)



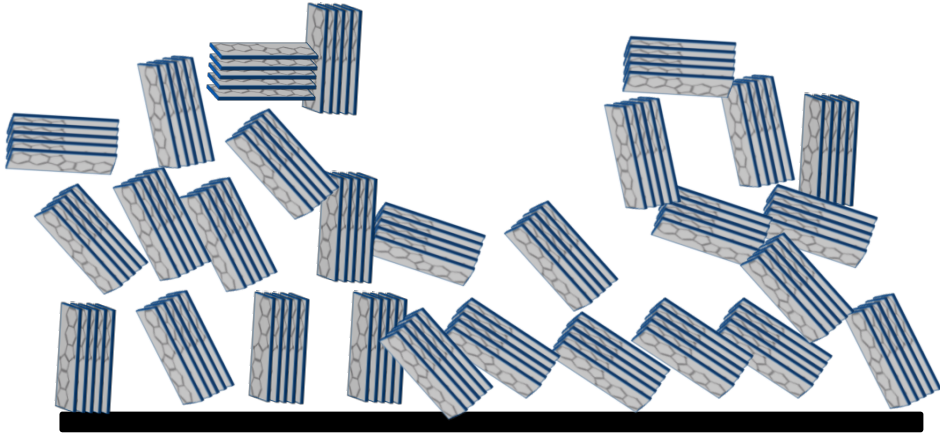
$T_{\text{sub}} = 77\text{K}$: Amorphous and rough

$T_{\text{sub}} = 350\text{K}$: Polycrystalline



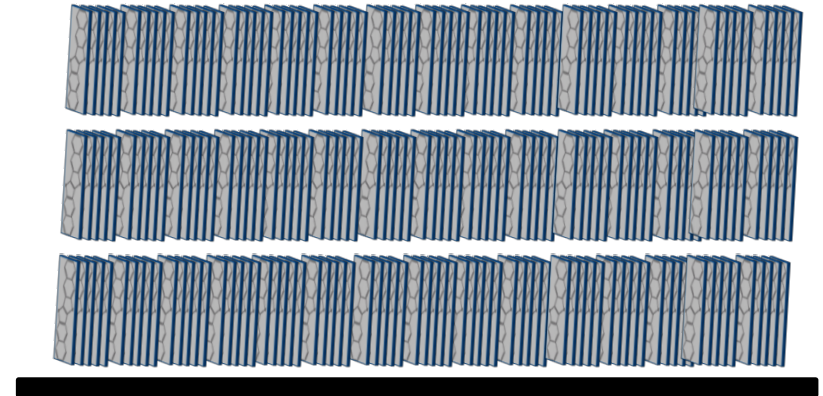
Thin film structure $\leftrightarrow$ Properties

μ $\rightarrow$



$T_{\text{substrate}} = 77\text{K}$; Amorphous and rough

μ $\rightarrow$



$T_{\text{substrate}} = 350\text{ }^{\circ}\text{C}$; Highly crystalline



The same material: DNTT
Higher $T_{\text{substrate}} \rightarrow$ highly crystalline films.

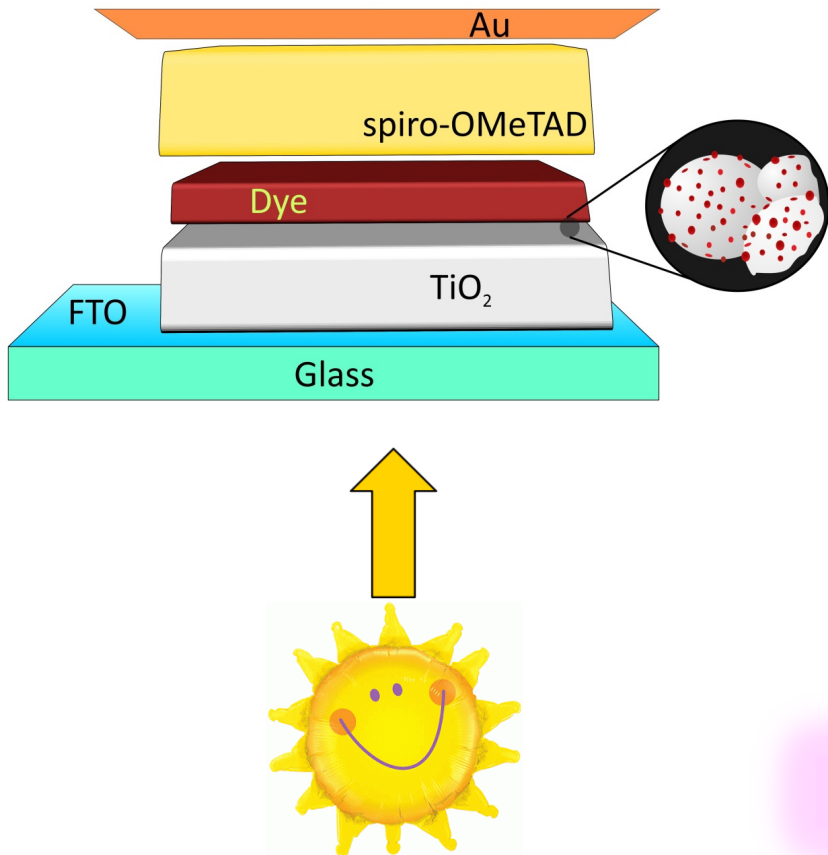
$\rightarrow$ Higher mobility
(> 3 orders of magnitude enhancement)



Hybrid Solar Cell (HSC)

$$\text{Overall cost} = \text{fabrication cost} / (\text{efficiency} \times \text{lifetime})$$

Solid state dye-sensitized solar cell (ss-DSC) structure



- Thin film technology
- Solution processable
- Color can be tuned by using different dyes
- Compatible with transparent electrode

The world's first solar window

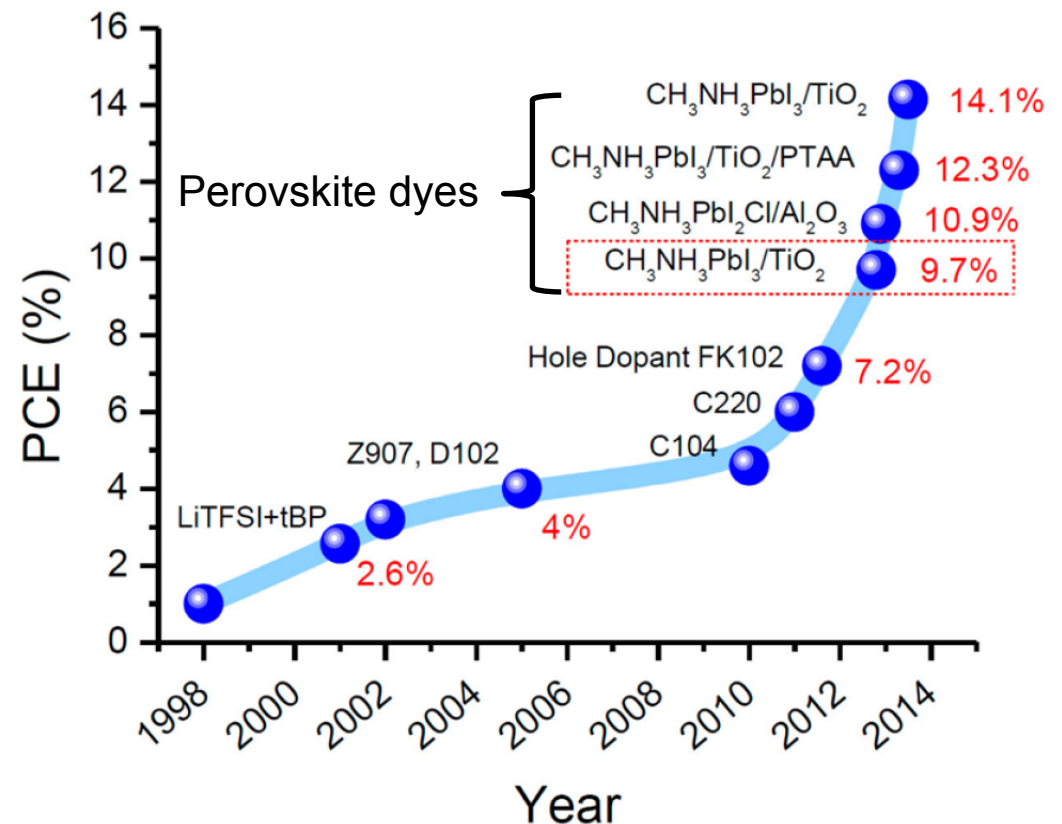
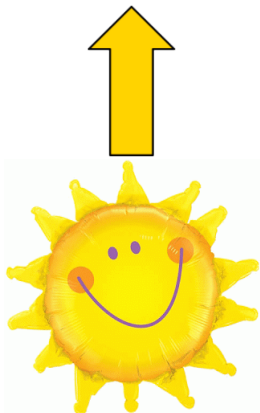
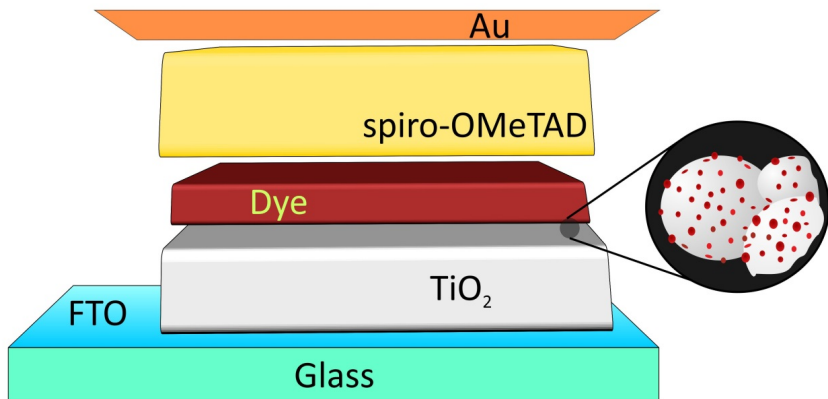


<http://actu.epfl.ch/news/epfl-s-campus-has-the-world-s-first-solar-window/>

Hybrid Solar Cell (HSC)

$$\text{Overall cost} = \frac{\text{fabrication cost}}{(\text{efficiency} \times \text{lifetime})}$$

Solid state dye-sensitized solar cell (ss-DSC) structure



Park et al., J. Phys. Chem. Lett., 2013, 4 (15), 2423

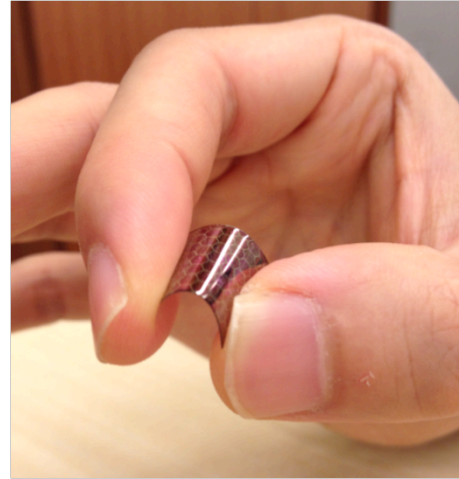
15.4%

Liu et al., Nature 501, 395 (2013)

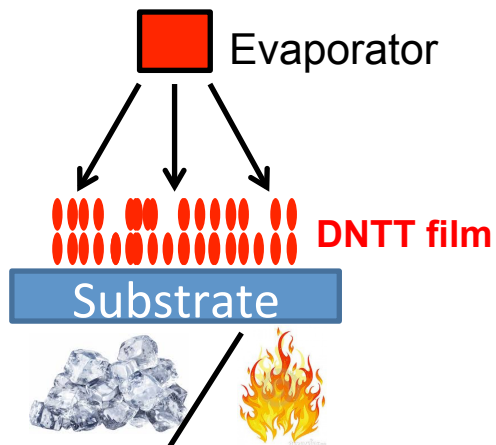
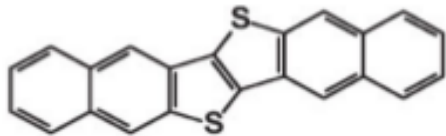
Summary

Overall cost = **fabrication cost** / (**efficiency** × **lifetime**)

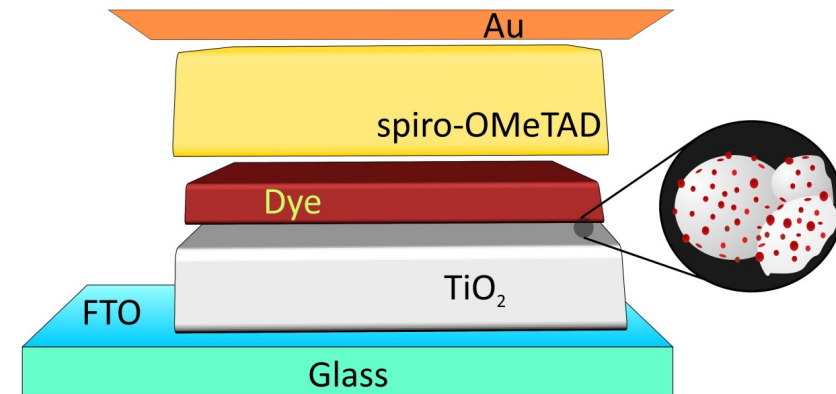
Flexible electrode for
Low-**cost** solar cells

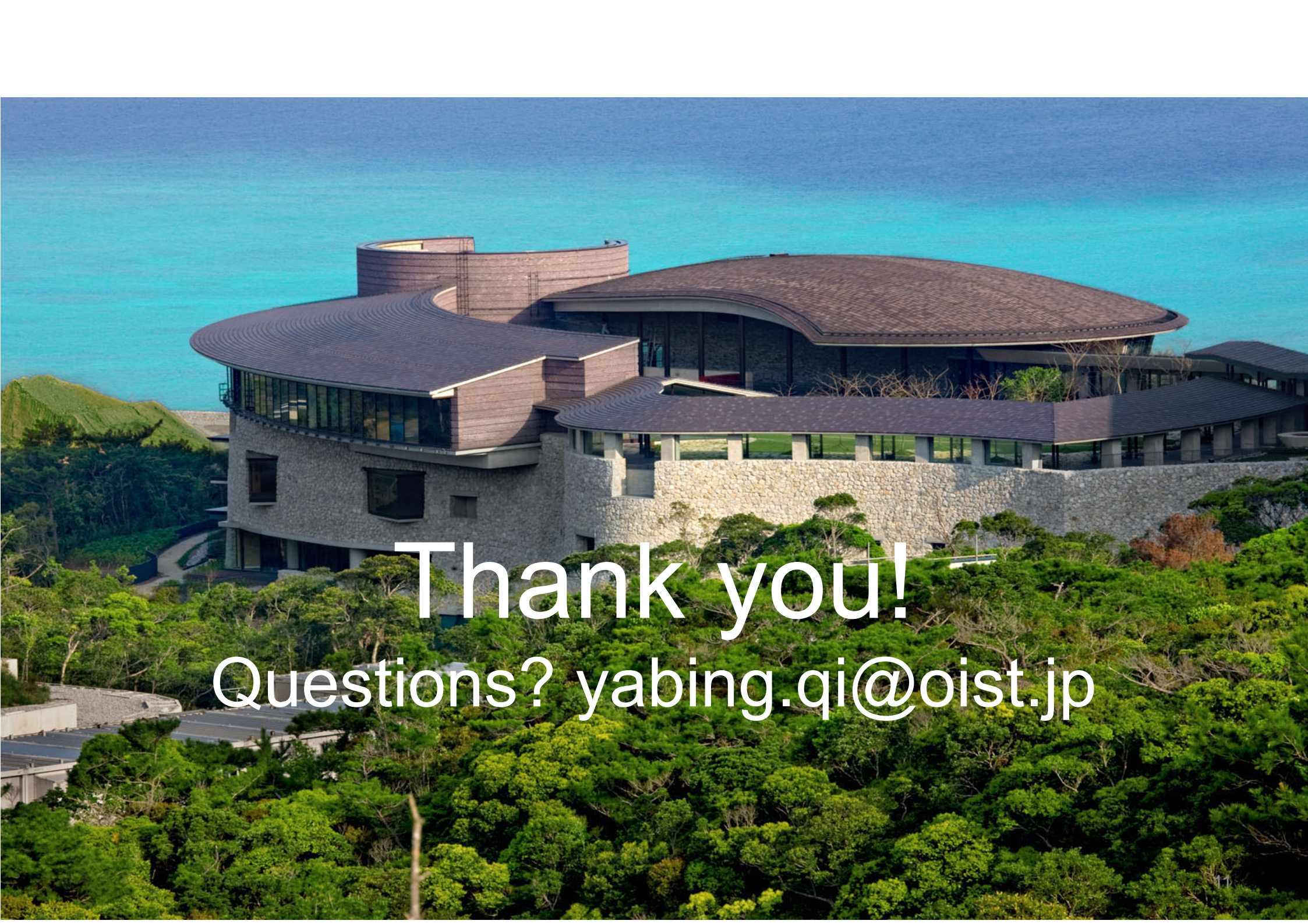


High performance materials
→ improve **efficiency** and **lifetime**.



Solid state dye-sensitized solar cell (ss-DSC) → high **efficiency** and low-**cost**.





Thank you!
Questions? yabing.qi@oist.jp