# Fabrication procedure of dye-sensitized solar cells

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Materials

- ITO(Indium doped Tin Oxide) glass (2 x 2 cm, 2 slides for 1 cell)
- Dye (Eosin Y, Eosin B, etc.)
- Ethanol
- $TiO_2$ paste
  - ➤ Suspend 3.5g of $TiO_2$ nano-powder P25 in 15ml of ethanol.
  - ➤ Sonicate it at least for 30 min.
  - ➤ Add 0.5ml of titanium(IV) tetraisopropoxide into the suspension.
  - ➤ Mix until the suspension is uniform.

  (D.S. Zhang, T. Yoshida, T. Oekermann, K. Furuta, H. Minoura, *Adv. Functional Mater.*, **16**, 1228(2006).)
- Spacer
  - ➤ Cut a plastic film (like as Parafilm or Scotch tape) having dimensions of 1.5 cm by 2 cm.
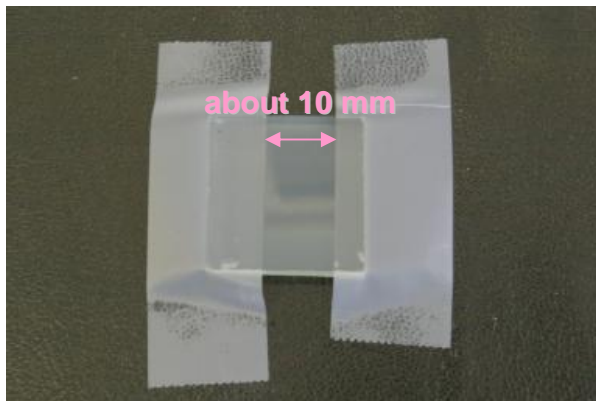  - ➤ Make a hole(s) on the film.
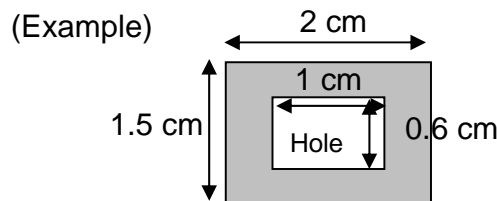


- Liquid electrolyte
  - ➤ 0.5M lithium iodide and 0.05M iodine in acetonitrile. $\gamma$-Butyrolactone or 3-methoxypropionitrile is also recommended as a solvent to improve its volatility.
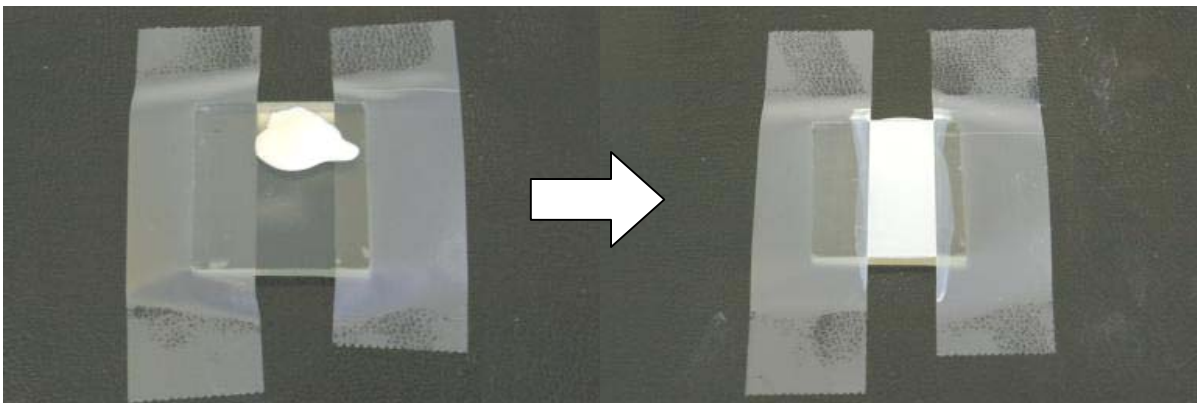- Binder clips (small, 2 pieces for 1 cell)

Tools

- Hot plate
- Pipets
- Tweezers
- Spatulas
- Scotch tape

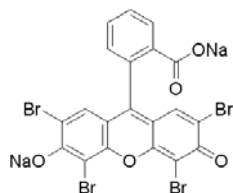1. Put Scotch tape on the conducting side of ITO glass.



about 10 mm

2. Put TiO$_2$ paste and flatten it with a razor blade on the same side of the ITO glass.



3. Put this electrode on top of a hot plate and heat it at approximately 150 °C for 10 min.

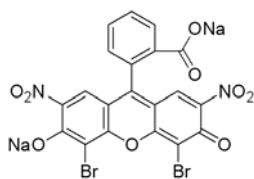4. Prepare a dye solution. (Ex. 20mL of 1 mM eosin Y in ethanol)



Eosin Y
(Mw=691.85)

Eosin B
(Mw=624.06)

Eosin B in ethanol

5. Dip the TiO$_2$ electrode into the dye solution for 10 min. (The dipping time can be varied depending upon the selected dye. The solution can be heated it up mildly (60-80 °C) if the coloration is too slow.)

6. Put graphite with a dark pencil on the conducting surface of another ITO glass as a counter electrode. Pt plate or Pt deposited ITO electrode (see below) is an alternative option in case photocurrent or fill-factor is too low.



Pt deposited ITO electrode
- Prepare 5mM H$_2$PtCl$_6$ in 2-propanol.
- Put some drops of the solution on ITO glass.
- Heat it up to 350-400°C for 1h.
- Let it cool down.
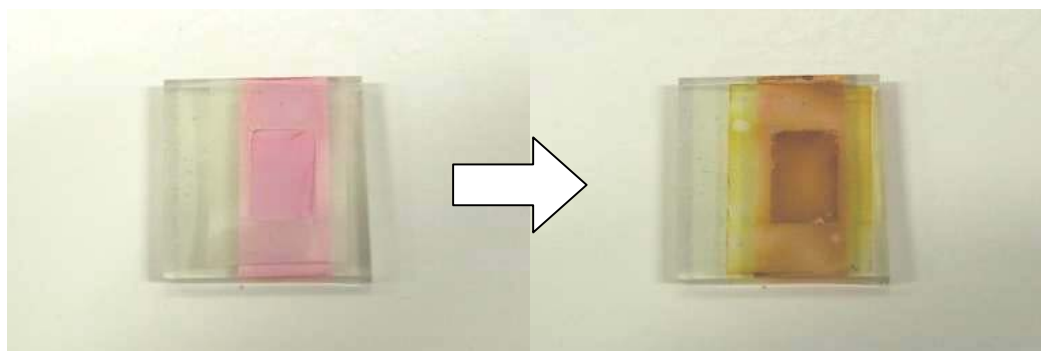- It will look almost transparent.

7. Take out the TiO$_2$/dye electrode from the dye solution and wash it with fresh ethanol.
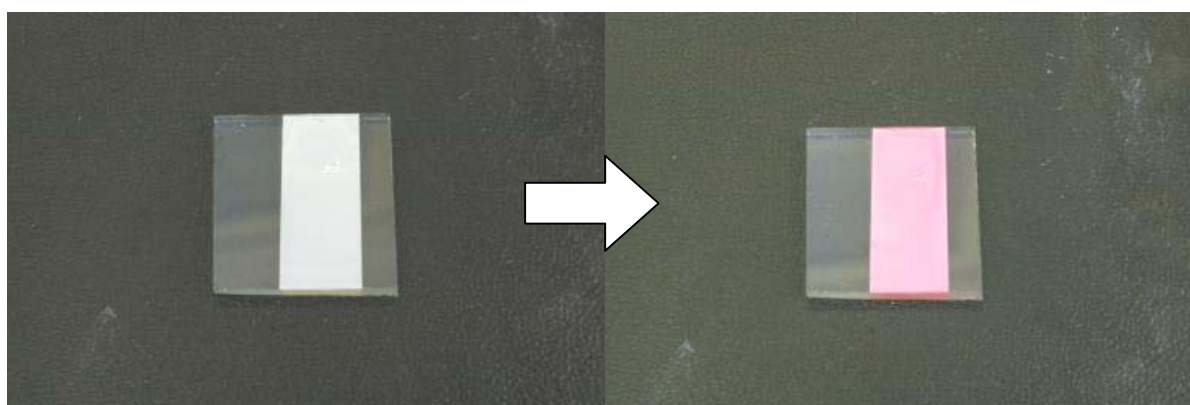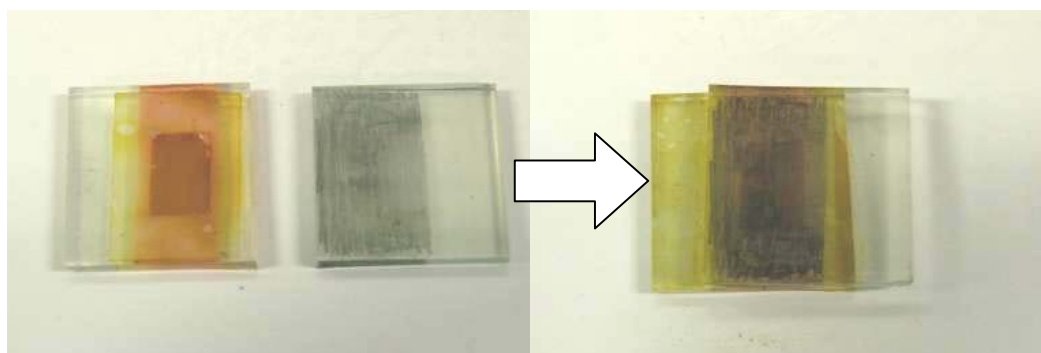


before dipping

after dipping

8. Place the spacer on the TiO$_2$/dye electrode and put some drops of the electrolyte solution into the hole(s). This and next step should be done quickly to prevent the solvent (acetonitrile) from drying out.
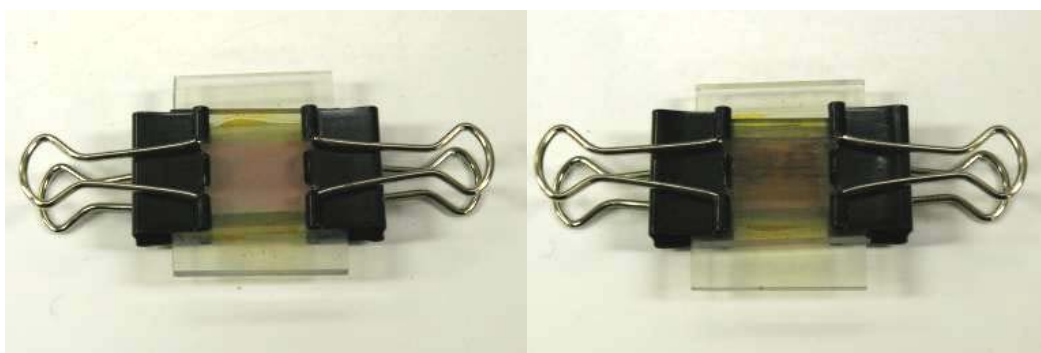


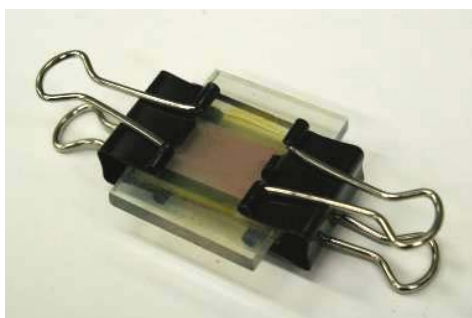9. Combine them with counter electrode to face them each other.



Important; Let all bubbles out of the hole(s).

10. Fix them with binder clips.



Front side (TiO$_2$/dye electrode)            Back side (counter electrode side)
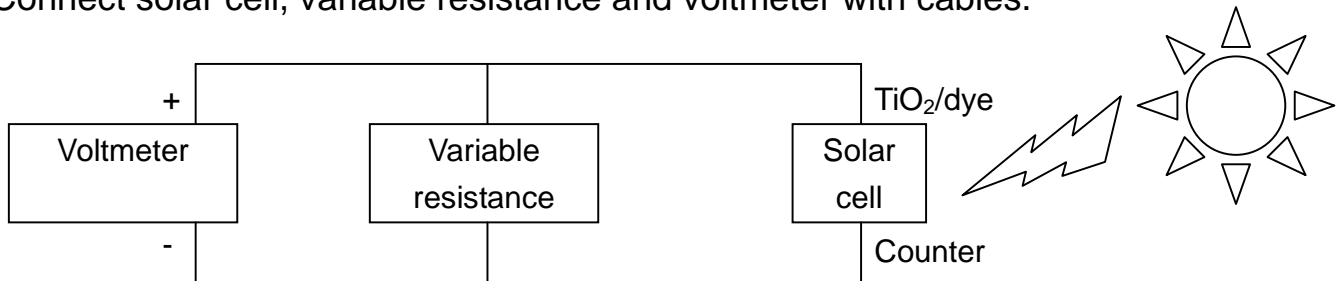
# Evaluation of dye-sensitized solar cells

Equipment
- Light source (OHP, Halogen lamp, Xe lamp, etc.)
- Cables
- Variable resistance
  (or switchable fixed resistances
  ex. 50, 100, 200, 500, 800, 1k, 2k, 5k, 10k, 20k, 40k, 80k, 100k, 200k, 400k and 800k$\Omega$)
- Voltmeter

1. Connect solar cell, variable resistance and voltmeter with cables.

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        +  ┌─────────────┐              ┌──────────┐  TiO₂/dye
 ┌───────┐ │             │  ┌──────────┐│          │
 │Voltmeter│            └──│ Variable  ││  Solar   │
 │         │                │ resistance││   cell   │
 └───────┘                 └──────────┘│          │
        -  └─────────────┘              └──────────┘  Counter
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2. Shine the light from the side of $TiO_2$/dye electrode.
   (Note; Light intensity has to be known in advance to calculate power conversion efficiency.
   It can be measured by a power meter or a calibrated photodiode.)
3. Set the resistance at maximum value and record voltage.
4. Decrease the resistance and record voltage.
5. Repeat 4 until the voltage reaches nearly zero and turn the light off.
6. Calculate corresponding current at each recorded point.
$$I = V/R$$

7. Plot voltage (X-axis) vs current (Y-axis).
8. Plot voltage (X-axis) vs power (Y-axis) to find Pm (see next page).
9. Calculate fill-factor (ff).

$$ff = \frac{Im \times Vm}{Isc \times Voc} = \frac{Pm}{Isc \times Voc}$$

10. Calculate power conversion efficiency ($\eta$).

$$\text{power conversion efficiency } (\eta) = \frac{\text{Output power}}{\text{Input power}} \times 100 \ (\%)$$

$$= \frac{Pm \ (mW/cm^2)}{\text{Light intensity } (mW/cm^2)} \times 100 \ (\%)$$

$$= \frac{Isc \ (mA/cm^2) \times Voc \ (V) \times ff}{\text{Light intensity } (mW/cm^2)} \times 100 \ (\%)$$

(Note; Current and power have to be normalized by electrode's active area (=hole area))
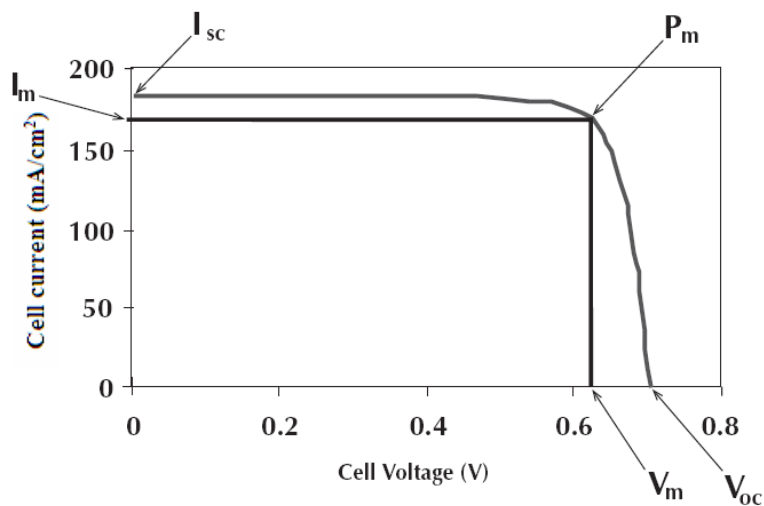


I-V characteristics of a typical solar cell

Voc; open circuit voltage, Isc; short circuit current.
Im and Vm are the maximum cell current and voltage respectively at the maximum power point,
 Pm = Im x Vm