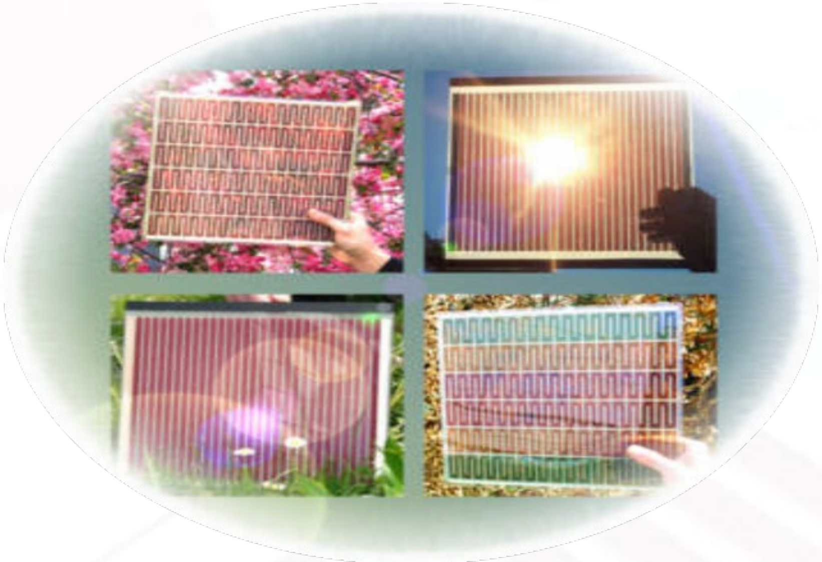
A Mixed Polymer Gel Electrolyte System for Dye Sensitized Solar Cells Based on Poly(methyl methacrylate) and Polyethylene Glycol with Nano-Porous TiO_2



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INTRODUCTION

Why the Energy from solar cells is the best?

- **Earth's oil reserves could run out during this century.**
- **The energy need of the planet is to double within the next 50 years.**
- **The pollution caused by fossil fuel.**

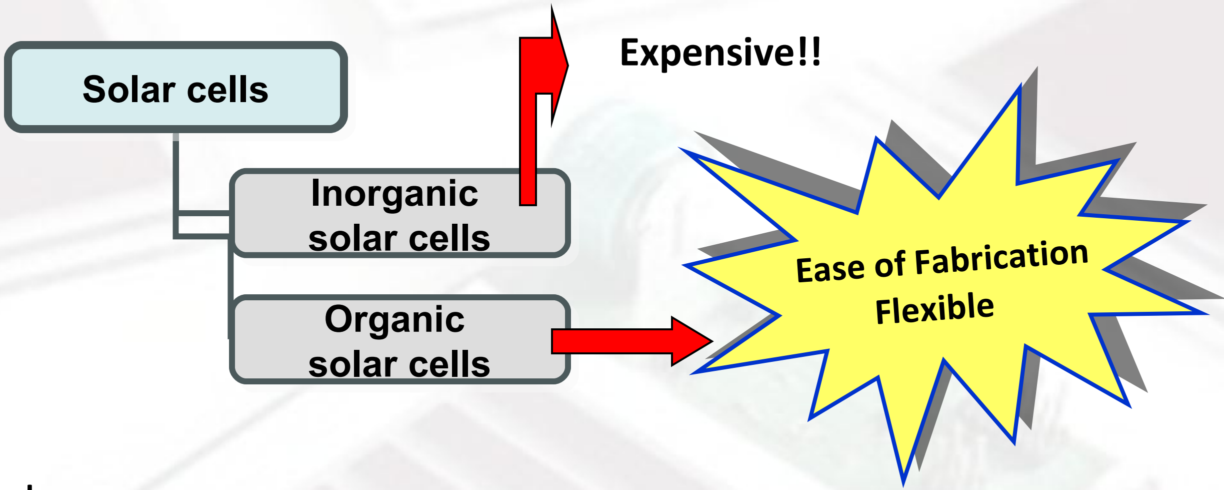
Energy from solar cells

- **Convert light energy directly into electricity.**
- **Do not require any cooling water system.**
- **Require little maintenance.**
- **Have no moving parts.**
- **Silent in operations.**
- **pollution free (Green) energy source.**

Organic Solar Cells

Main advantages of Organic solar cells over the Si devices are:

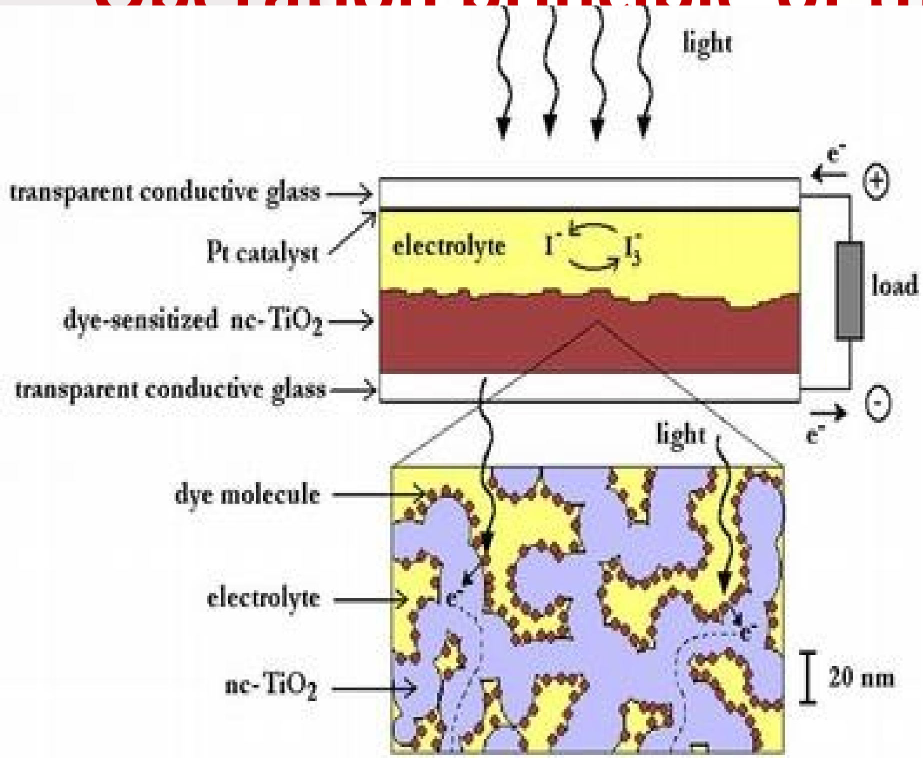
- Light in weight
- Low cost of production
- Very small thickness
- Flexible
- Ease of fabrication
- Can be fixed to any desired place



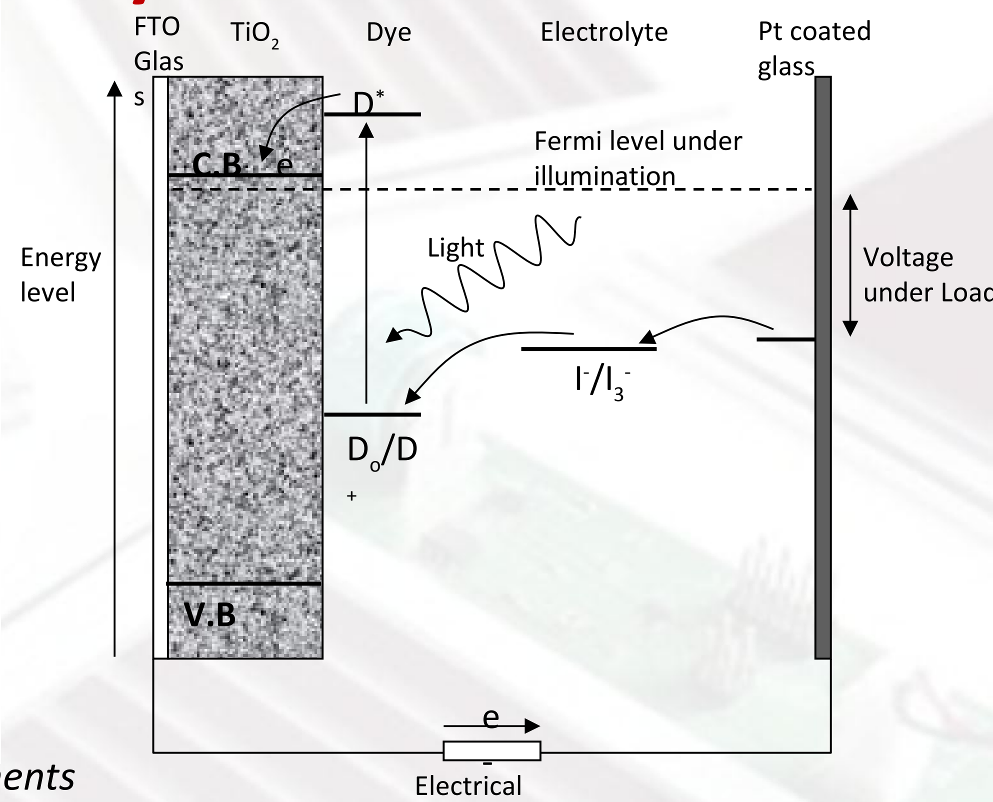
Organic Solar cells can be divided into four major classes

1. Dye sensitized nanocrystalline solar cells
2. Polymer blend solar cells
3. Molecular film solar cells
4. Hybrid polymer / nanocrystal solar cells

Operation principle of the Dye-Sensitized Solar cell



A schematic diagram of the structure and components of the dye-sensitized solar cell



The working principal of the dye-sensitized solar cell

Anode:

$D + h\nu \longrightarrow D^*$ Absorption of photon

$D^* \longrightarrow D^+ + e^- (TiO_2)$ Electron injection

$2D^+ + 3I^- \longrightarrow 2D + I_3^-$ Regeneration of dye

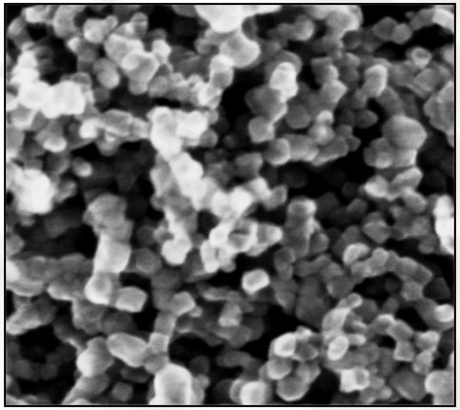
Cathode:

Materials & Methods

- **TiO_2**

Nanocrystalline TiO_2 has the following properties:

- Semiconductor transparent in the visible region of the spectrum.
- Particle size ranges from ~10 nm to ~100 nm.
- Highly porous material that provides strong enhancement of the surface area (~1000 times).
- High affinity of TiO_2 leads to easy surface modification.
- Low costs material, easy to produce in large quantities, chemically inert and non-toxic.



Magnified view of the nanocrystalline TiO_2

Preparation of TiO_2 paste

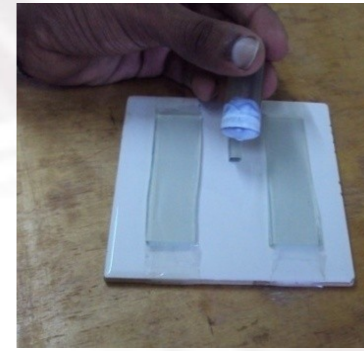
- 0.2 g of TiO_2 (particle size is 25 nm) was ground.
- 3 drops of Glacial acetic acid were added and mixed well.
- One drop of Triton X-100 with 3 drops of acetic acid was added into that mixture.
- Lastly, 6 drops of acetic acid and about 3ml ethanol were added and mixed until this becomes a creamy past.

Preparation of TiO_2 paste

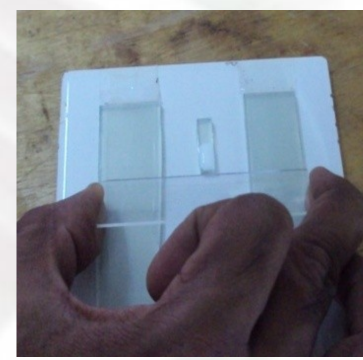
Preparation of TiO_2 film

Identify the conduction glass

Place the conducting glass Between two glass plates



Drop the TiO_2 paste



Spreading the TiO_2 paste

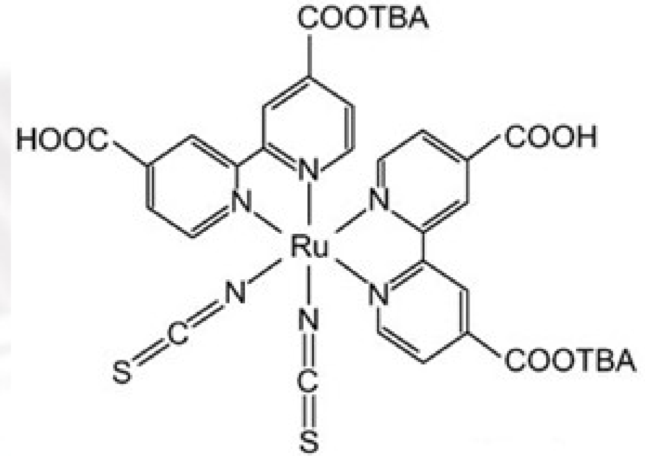
After Spreading

Sintering the TiO_2 film

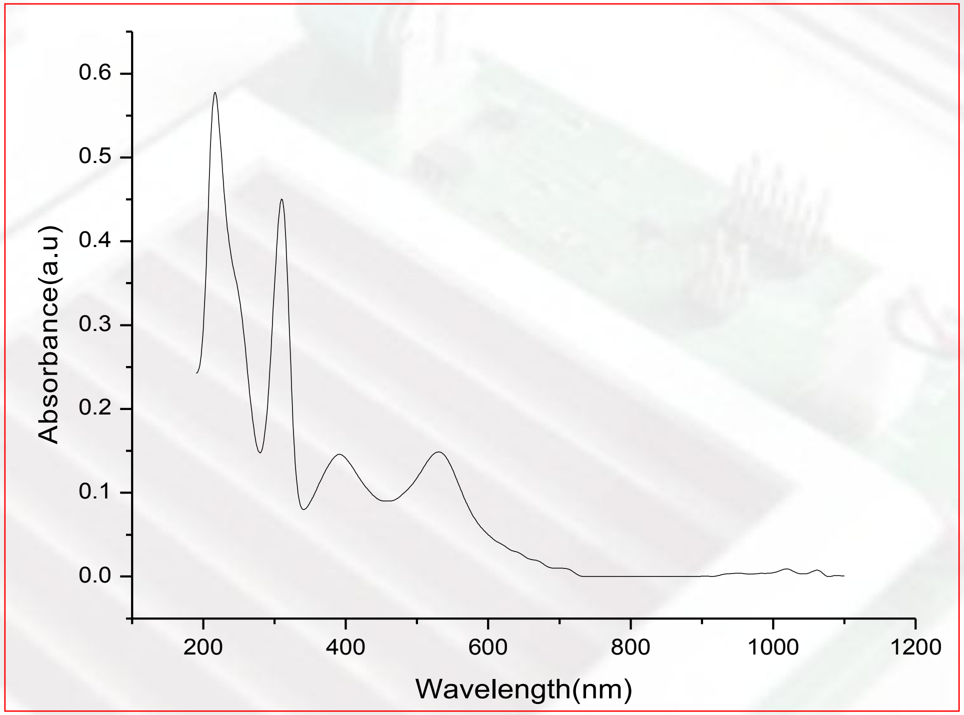
➢ Dye materials

Dye material is used as sensitizer, which absorb the photon from the incident light. The dye materials have the following properties:

- Large absorption coefficients
- Long chemical stability
- Broad absorption band in the visible region
- Wide availability
- High incident photon- to- current efficiency



Molecular structure of N719 dye



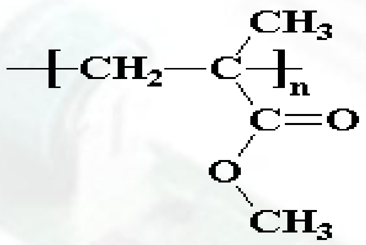
UV – Visible absorption spectrum of Ru dye N-719

Why polymers for electrolyte ?

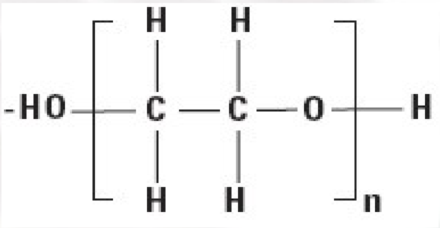
Conjugated polymers could be made electrically conductive.

Polymer electrolytes had played an important role due to their unique properties such as:

- Easy of fabrication into thin film with large surface area.
- Provide good electrode - electrolyte contact.
- Exhibited high ionic conductivity.
- Mouldability.
- Flexible nature.



Molecular structure of PMMA

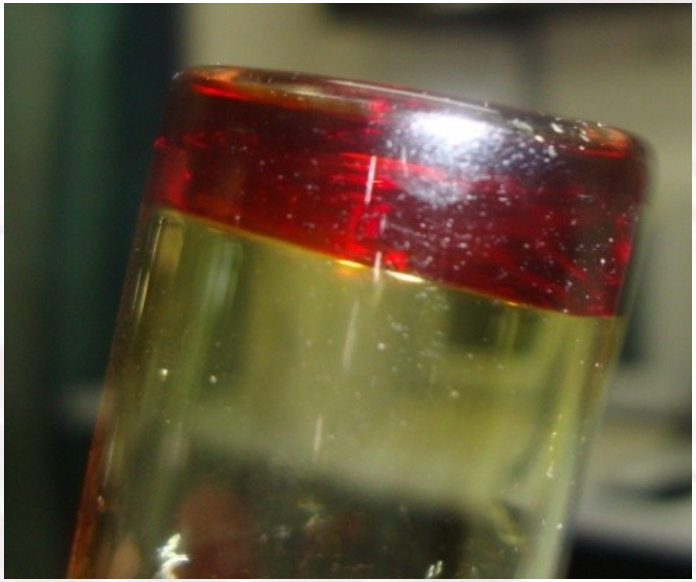


Molecular structure of PEG

➢ Quasi solid state electrolytes

The gel electrolytes have several advantages such as:

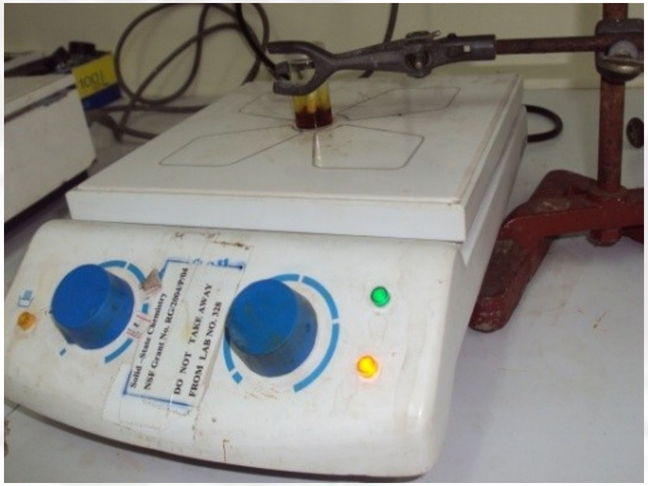
- low vapour pressure
- good long term stability
- excellent contacting and filling properties
- higher ionic conductivity



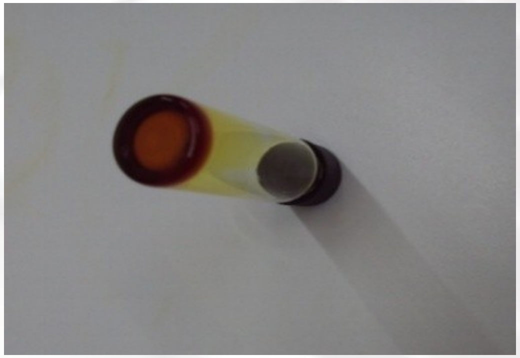
Gel electrolyte composition

Preparation of polymer electrolyte

- Appropriate amounts of EC, PC, PMMA and PEG were continuously stirred at 70◦C ~ 2 hours.
- I_2 and $Pr_4N^+I^-$ were added after the solution was cooled to room temperature.



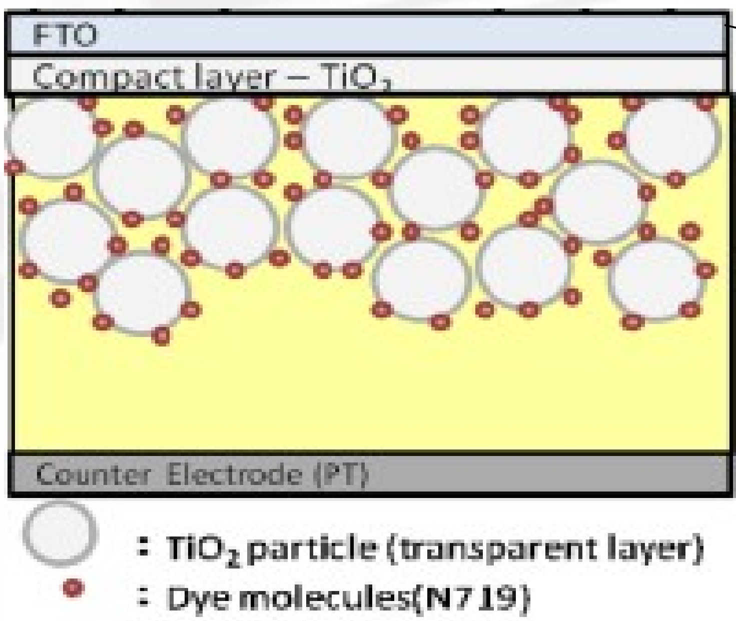
Stirring and heating the composition

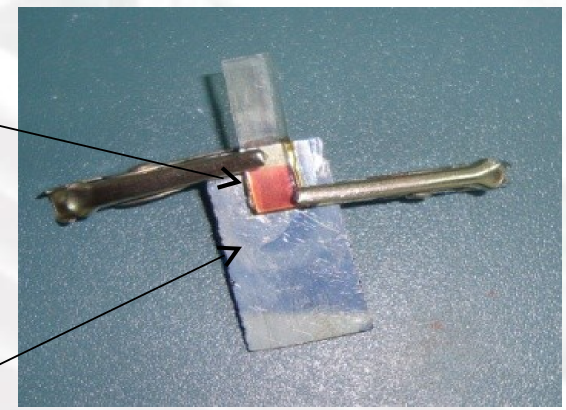


Gel type composition

Fabrication of the solar cells

DSSCs were fabricated by sandwiching the dye absorbed TiO_2 electrodes with a Pt coated FTO glass incorporating the polymer blend electrolyte.





Assembling of DSSC

Characterizations

➢ Current voltage characterization

- under the illumination of 1000 Wm^{-2}.
- Xenon 500 lamp was used with AM 1.5 filter.
- coupled with KEITHLEY 2000 multimeter into Galvanostat HA 301 via computer controlled software.

Experimental setup for I-V characterization of DSSC

➢ DC polarization

Understanding the transfer characteristic of ions in the electrolytes.

The value of Ionic transference number:

$$t_{ion} = \frac{i_t - i_e}{i_e}$$

i_t -Total current

i_e - Residual current (by the electrons)

The blocking electrodes were employed to determine the electronic transport.

DC polarization set- up

➢ UV-Vis Characterization

- UV/VIS absorption was taken for N719 Ruthenium dye .
- The absorbance spectrum was recorded in the range 190-1100 nm.

UV-Vis spectrophotometer UV-2450

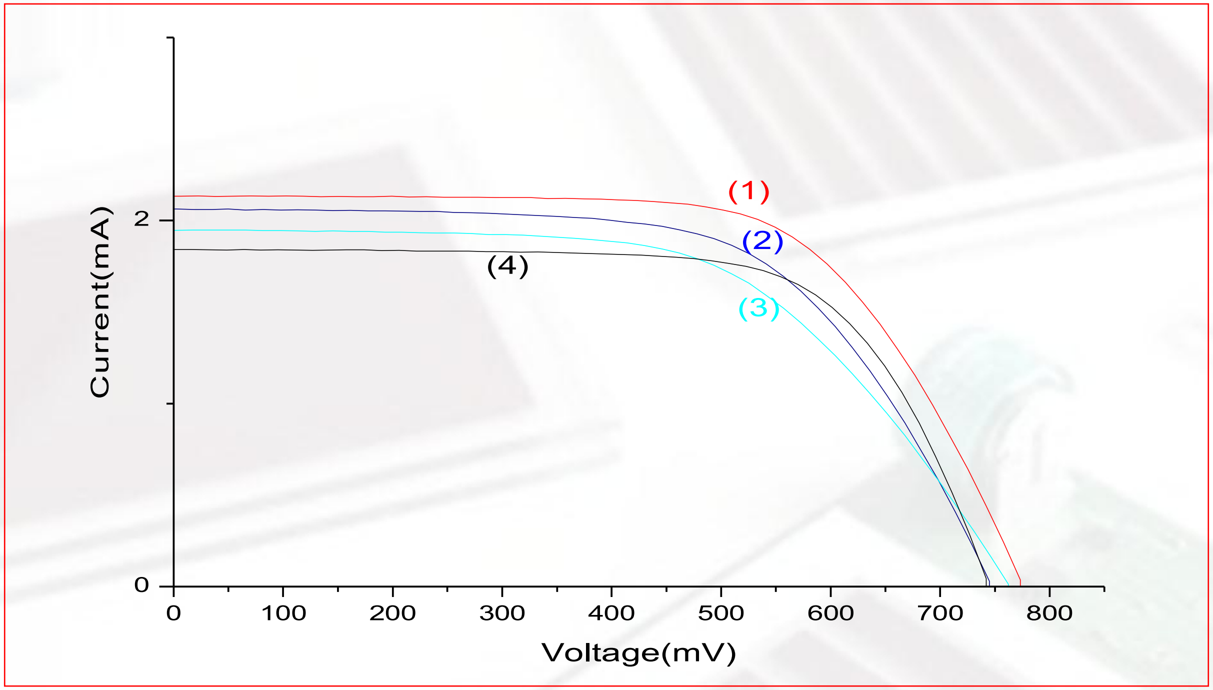
➢ FTIR Measurements

FTIR measurement was used to identify the functional group of the materials.

- The samples were prepared by mixing sample with dry KBr powder, having a ratio 1:5.
- scanning through 400 to 4000 cm^{-1}.

Nicolet 6700 FT-IR spectrometer

RESULTS



I-V characterization graph of DSSCs

Graph	PMMA (g)	PEG (g)	EC (g)	PC (g)	$Pr_4N^+I^-$ (g)	I_2 (g)
(1)	0.20	0.13	0.3	0.3	0.1388	0.0112
(2)	0.25	0.08	0.3	0.3	0.1388	0.0112
(3)	0.15	0.18	0.3	0.3	0.1388	0.0112
(4)	0.33	0	0.3	0.3	0.1388	0.0112

RESULTS

Graph	Jsc (mA cm^{-2})	Voc (mV)	FF (%)	η (%)
(1)	8.524	774.9	65.33	4.316
(2)	8.24	746.8	62.16	3.826
(3)	7.788	763	58.63	3.483
(4)	7.368	743.9	68.72	3.767

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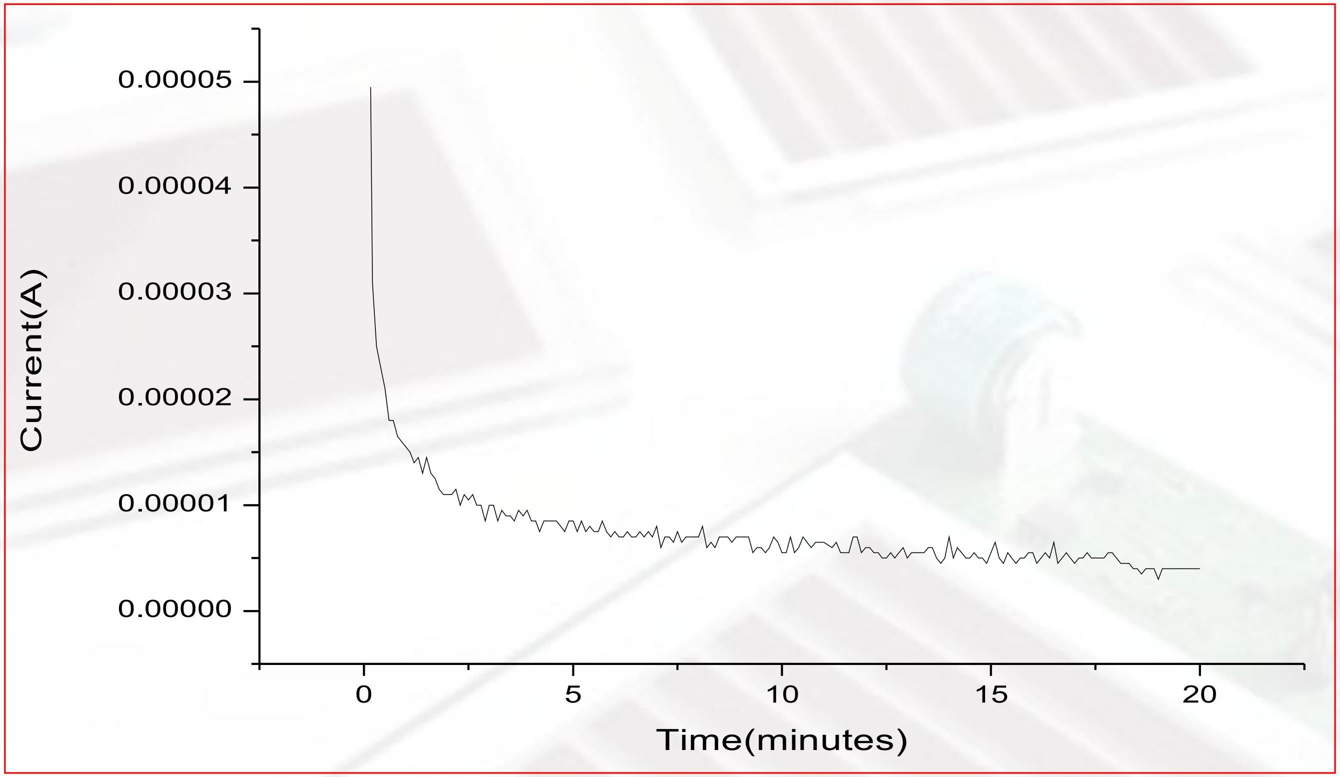
The charge transport of electrolyte

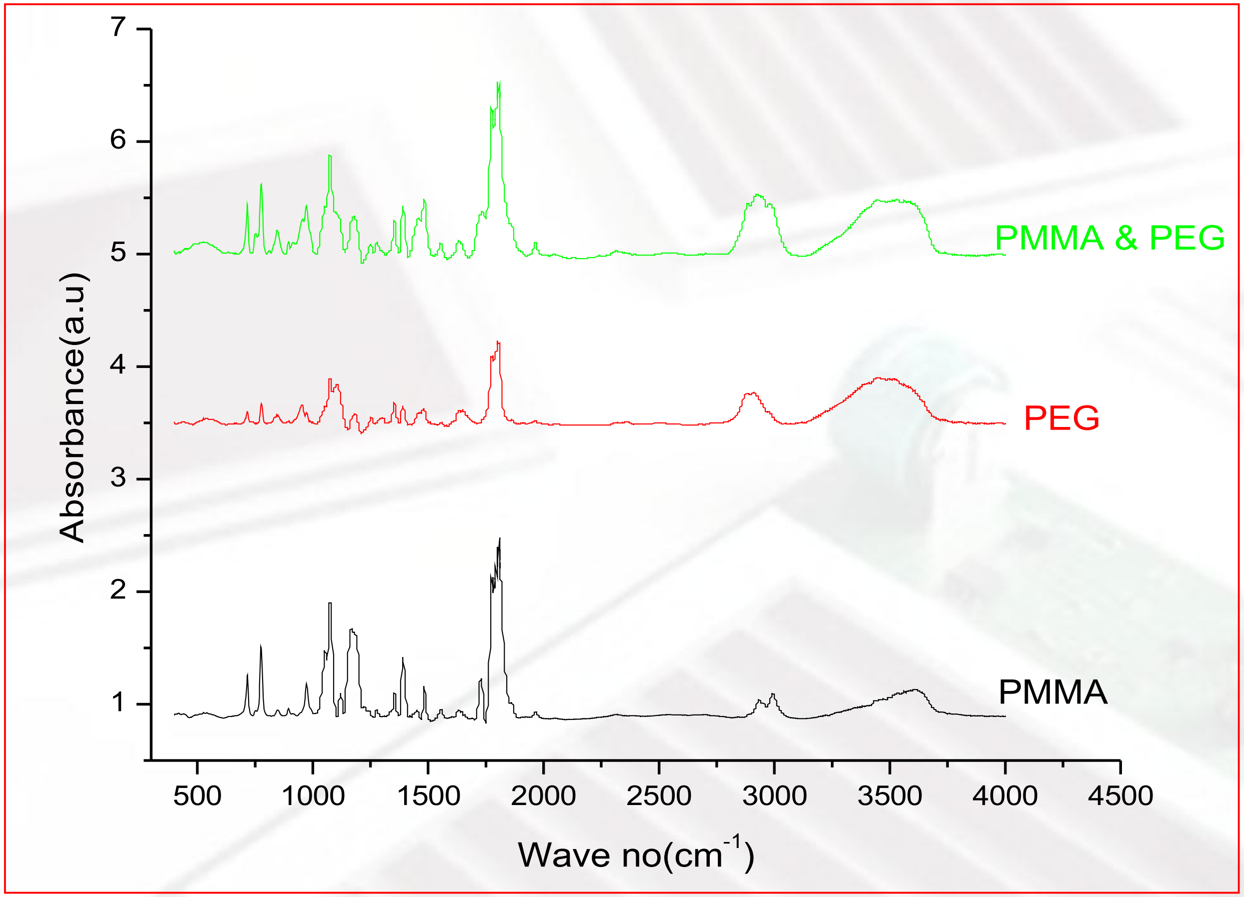


The current versus time graph of electrolyte

The ionic transference number of this electrolyte system was found to be ~ 0.92

This suggests that the conductivity of this electrolyte was predominantly due to ions and only negligible contribution came from electron.

FTIR spectrum



FTIR spectrum of PMMA, PEG & PMMA with PEG

The peaks are in the 3200-3800 cm^{-1} region, which refers to the presence of OH group which enhancing the power conversion efficiency of dye sensitized solar cells.

CONCLUSION

- The cell with PMMA electrolyte alone had an efficiency of 3.767% and the cell with PEG electrolyte had a very low efficiency as the electrolyte did not have a gel like nature but had a solid like behavior.
- Cell with the mixed polymer system PMMA:PEG (weight ratio) =20:13 gave an efficiency 4.3%.
- The high efficiency is quite likely due to the optimized composition of the **"gel"** electrolyte which gives the highest iodide ion conductivity resulting the highest Jsc.

Reference

- Gratzel M. (2001). Photoelectrochemical cells. *Journal of Nature* 414 (6861): 338-344.
- O'Regan B & Grätzel M. (October 1991). A low cost high-efficiency solar cell based on dye-sensitized colloidal TiO2 films, *Journal of Nature* **353**(24): 737-740.
- Wolfbauer G. (2001). A channel flow cell system specifically designed to test the efficiency of redox shuttles in dye sensitized solar cells. *Solar Energy Materials & Solar Cells* **70**:85-101.

Thank you