CHAPTER 7
PHOTOVOLTAIC CELL USING POLYMER NANOCOMPOSITE

7.1 MATERIALS FOR FABRICATION OF DYE SENSITIZED SOLAR CELL

Materials used for building a photovoltaic cell and their major specifications are given below

Table 7.1 Material list for photovoltaic cell

<table>
<thead>
<tr>
<th>Materials</th>
<th>Basic description of the materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductive glass having ITO coating</td>
<td>Transparent and Conductive glass works as working and counter electrode</td>
</tr>
<tr>
<td>TiO₂ (Titanium dioxide powder)</td>
<td>Very thin and light white powder to make the conducting film</td>
</tr>
<tr>
<td>PVP</td>
<td>Polymer used as matrix for solid electrolyte</td>
</tr>
<tr>
<td>Salts and nano materials</td>
<td>Salts like KI, NaI, KOH and NH₄I and nano materials are added to form polymer nanocomposite for solid electrolyte</td>
</tr>
<tr>
<td>Distilled water</td>
<td>Pure water (solvent)</td>
</tr>
<tr>
<td>Ethanol</td>
<td>Pure ethanol (solvent), used for washing and cleaning.</td>
</tr>
<tr>
<td>Blackberry juice</td>
<td>Natural Dye. For Sensitizing the thin film of TiO₂</td>
</tr>
<tr>
<td>Graphite or Carbon</td>
<td>Preparation of counter electrode. A thin layer is applied on ITO glass</td>
</tr>
<tr>
<td>Iodine crystals</td>
<td>Black Crystals (solution is added to electrolyte)</td>
</tr>
</tbody>
</table>
Along with these ingredients some equipments were used for the fabrication of the Cell

7.2 EQUIPMENT USED TO BUILD DYE SENSITIZED SOLAR CELL

- Lab uniform to protect from expose to the chemicals
- Safety goggles to protect the eyes
- Glass stirring rod to mix the TiO\textsubscript{2} powder etc.
- Spatula for mixing PVP, Salts and nano powders
- Electrical balance to measure the quantity of PVP, Salts and nano materials before making paste
- Absorbent tissue paper to clean the conductive glass with ethanol
- Cotton waste to remove excessive electrolyte from the assembled cell
- Pipet to pour the electrolyte, dye, water and ethanol
- Heat source to sinter the TiO\textsubscript{2} thin film coated on conductive glass
- Tongs to hold the coated conductive glass
- Petri dish for dipping the glass in dye and for preparation of solid electrolyte
- Magnetic stirrer to stir the mixture of PVP, Salt, Iodine and nano materials
- Beaker for mixing TiO\textsubscript{2} and for washing and cleaning purposes
- Multimeter for identification the conductive side of glass, measurement of resistance, voltage and current
- Binder clips to hold the cell, these clips will also apply pressure on the cell
- Candle burning to coat the counter electrode
• Injector to put the electrolyte between two electrodes

• Variable Resistance or variable load used to measure the output parameters by varying the load (resistance)

• Hook-up wire to connect the alligator clip with multimeter and Variable Resistance

• Clamps, stand for positioning the solar cell in light source

• Scotch tape for holding the glass

7.3 DETAILED PROCEDURE

7.3.1 Preparation of Titanium dioxide paste

• Measure 2gm of titanium dioxide on the weighing dish and put it in a beaker for mixing (2-3 devices can be formed)
• Measure out 3ml of distilled water in the pipet
• Add about 1ml of distilled water to the titanium dioxide in the beaker
• Mix thoroughly until the mixture is free of lumps
• Repeat the steps and all the water taken
• Titanium dioxide paste is ready to pour on the glass

7.3.2 Identification of the Conductive Side of the ITO Glass

The ITO glass plates are only conductive on one side. The conductive side is first identified using multimeter. A multimeter set to measure resistance and tips of probes are placed on plate, the multimeter will read some resistance on conductive side. The resistance value may vary from glass to glass. The deposition of materials always is performed on the conductive side. The conductive coating has a rougher surface than bare glass. Further the edges of conducting glass are covered using scotch tape. On this setup the TiO\textsubscript{2} paste will be applied. ITO glass is used for preparation of working electrode and counter electrode.
7.3.3 Preparation of Polymer Nano composite (Electrolyte)

Required amount of PVP is measured and taken in a petridish. Suitable amount of water is mixed and stirred well. Care is taken to avoid cluster formation in the mixture. A magnetic stirrer is used for better mixing. Required amount of salt is taken in another petridish and solution with deionised water is made. Then it is poured into PVP solution and stirred thoroughly on magnetic stirrer. Iodine is taken as 12% of salt taken and it is also mixed to the same mixture. It is kept on magnetic stirrer about an hour. In case of nano composite composition nano particle are weighed accordingly and added to the above mixture and stirred about 45 minutes.

7.3.4 Deposition of Titanium dioxide on Glass (working electrode)

Conductive side facing up and apply two parallel strips of tape on the edges of the glass plate, covering about 6 mm of glass. On uncovered glass i.e. the middle of the glass the titanium is deposited. Edges masked by the tape will give room for future sealing and electrical contacts. This will prevent the plate from moving while making the deposition stroke. A portion of paste is applied near the top edge of the ITO glass between the two pieces of tape. With help of a glass rod the paste is spread across the plate with the support of the adhesive tapes on both sides. The gap between the strips of tape is filled with a layer of titanium paste. The operation is repeated until reasonably homogenous layer is obtained. Figure 7.1 Shows Titanium dye applied on ITO glass.

![Figure 7.1 Titanium paste applied on ITO glass](image)
7.3.5 Sintering the Titanium Layer

To ensures electrical contact between particles and good adhesion to the ITO glass substrate. Sintering is done by heating to 300˚C and for 30 to 45 minutes.

7.3.6 Preparation of Natural Dye and Staining the Titanium dioxide Film

Titanium dioxide is a semiconductor that doesn’t absorb visible light and it is necessary to sensitize the titanium electrode with a dye that can absorb as much light as possible in the visible light spectrum. Here blackberry juice is used as Natural Dye. The juice from the frozen fruit is extracted for sensitizing the thin film of Titanium dioxide. Place the fired electrode onto the fruit juice with the titanium surface facing down and apply slight pressure on the glass plate for titanium area to be soaked. Electrode is placed in dye for 3 hours for staining and afterwards rinsed it carefully with ethanol. Figure 7.2 Shows Stained TiO2 using natural dye black berry juice.

![Figure 7.2 Stained TiO₂ using natural dye black berry juice.](image)

7.3.7 Preparation of Counter Electrode

Hold the ITO glass piece on candle flame, conductive side facing down, about 10cm above the flame. The carbon from the combustion of wax is carried in the smoke which makes a black deposition on the conductive side of the ITO glass. Allow the glass plate to cool on a suitable surface before further processing. Figure 7.3 Shows Preparation of counter electrode using carbon black.
7.3.8 Assembly of Solar Cell

After the preparation of anode, cathode and electrolyte they have to be put together for the working. The active sides should face each other i.e. titanium should face carbon. The electrolyte is filled between two electrodes. The electrodes are pressed or using binder clips pressure is applied on electrodes such that electrolyte spreads everywhere, the excess electrolyte oozed out is wiped off. Allow the setup to dry around 12hrs. This type off approach is called as open cell approach. Anodes and cathodes are prepared simultaneously and stained titanium electrode is kept in the dye solution until the counter-electrode is ready. Figure 7.4 Shows Assembly of the Solar Cell. Once the solar cell is fabricated using multimeter, alligator clips measure the voltage output in working conditions.
7.4 PHOTOVOLTAIC RESULTS AND DISCUSSION

The characteristic values of each cell are measured and graphs are plotted for current and power according to change in voltage. Fill factor and efficiencies of each cell is calculated. Conclusions are made by the data obtained.

Figure 7.5 Circuit diagram for testing solar cell

Figure 7.5 shows the circuit diagram for testing of solar cells with variable resistance. Solar cell is kept under the direct sunlight. It is connected to a Variable resistance and an ammeter in series and a voltmeter in parallel as shown in the figure. Resistance is varied from zero to maximum and corresponding readings of voltage and current is tabulated.

Components we used for the testing

- Resistance: Variable resistance with range 0-1MΩ.
- Voltage: 1 multimeter.
- Current: 1 multimeter.
- Connections: wires and alligator clips.
7.4.1 Performance of Solar Cell

Open circuit voltage (Voc): The voltage between the terminals when no current is drawn (infinite load resistance) or open circuit voltage corresponds to the voltage drop across the diode (p-n junction). The condition for Voc is R infinity, I=0. Open circuit voltage is mathematical expressed as:

Short circuit current (Isc): The current when the terminals are connected to each other (zero load resistance) or it is the highest value of current generated in a cell. Short circuit condition is said when V=0.

Maximum power point: It is the operating point (Vmax, Imax) at which power dissipated in the resistance load is maximum.

\[ P_{\text{max}} = V_{\text{max}} \times I_{\text{max}} \]

Fill factor: The short-circuit current and the open-circuit voltage are the maximum current and voltage respectively from a solar cell. It is a ratio of the maximum power from the solar cell to the product of Voc and Isc.

Fill Factor, \( FF = \frac{I_{\text{m}} \times V_{\text{m}}}{I_{\text{sc}} \times V_{\text{oc}}} \)

Output Power Density, \( P_{\text{out}} = \frac{I_{\text{sc}} \times V_{\text{oc}} \times FF}{A} \)

Efficiency, \( \eta = \frac{P_{\text{out}}}{P_{\text{in}}} \times 100 \)

Where \( P_{\text{in}} \) is incident solar energy considered as 100 mW/cm²

The photovoltaic cell tested under Air mass 1.5 spectrum (AM1.5), Intensity of 100 mW/cm² (1 kW/m², one-sun of illumination) and Cell temperature of 25 °C
### 7.4.2 Photovoltaic Cell based on PVP+30%KI+4%Al₂O₃ Nanocomposite

Table 7.2 Characteristic values of photovoltaic cell

<table>
<thead>
<tr>
<th>Voltage (V in mV)</th>
<th>Current (I in mA)</th>
<th>Power (Pₜₒᵤₜ in mW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>38.4</td>
<td>0</td>
</tr>
<tr>
<td>75</td>
<td>38.0</td>
<td>2.85</td>
</tr>
<tr>
<td>150</td>
<td>36.8</td>
<td>5.52</td>
</tr>
<tr>
<td>250</td>
<td>34.4</td>
<td>8.60</td>
</tr>
<tr>
<td>350</td>
<td>32.0</td>
<td>11.20</td>
</tr>
<tr>
<td>400</td>
<td>24.0</td>
<td>9.60</td>
</tr>
<tr>
<td>430</td>
<td>18.0</td>
<td>7.74</td>
</tr>
<tr>
<td>460</td>
<td>8.4</td>
<td>3.86</td>
</tr>
<tr>
<td>480</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The above Table 7.2 shows the variation of voltage (V) and current (I) according to the change in resistance by a Variable Resistance. Resistance is varied from zero to maximum. And graphs of current versus voltage and power versus voltage graphs are plotted using the above readings. Figure 7.6 shows the variation of current according to voltage.

![Figure 7.6 I-V curve of Cell based on PVP+30%KI+4%Al₂O₃ nanocomposite](image-url)
Figure 7.7 P-V curve of Cell based on PVP+30%KI+4%Al₂O₃ nanocomposite

Figure 7.7 shows the change in the power according to change in voltage. From the study on photovoltaic cell following are determined:

Short circuit current \( I_{sc} = 38.4 \text{mA} \)

Open circuit voltage \( V_{oc} = 480 \text{mV} \)

Max current \( I_m = 32 \text{mA} \)

Max voltage \( V_m = 350 \text{mV} \)

Area \( A = 2.25 \text{cm}^2 \)

Fill Factor, \( FF = 0.61 \)

Output power density \( P_{out} = 4.99 \text{mW/cm}^2 \)

Efficiency \( \eta = 4.99 \% \)