Chapter - 6

Surface Passivation of SnO$_2$ Photoanode Films through MgO Coating and Its Influence on the Performance of Dye Sensitized Solar Cells

This chapter describes the surface modification of SnO$_2$ electrodes coated with MgO for dye-sensitized solar cells. Such a modification would be helpful for improving the solar light harvesting and photon-to-electron conversion efficiency. Sol-gel-derived Mg(OH)$_2$ gel was coated onto SnO$_2$ nanoparticles by dip coating technique. The MgO-coated SnO$_2$ electrode had been characterized by x-ray diffraction (XRD), energy-dispersive x-ray spectroscopy (EDS), scanning electron microscopy (SEM) and UV–vis spectrophotometer. The study reveals that the modification in SnO$_2$ by MgO coating increases dye adsorption, decreases trap states and suppresses interfacial recombination losses. The effects of precursor concentration and MgO coating for different times on the performance of DSSCs were investigated. It has been found that, MgO coating for 90 s on SnO$_2$ improves all photovoltaic parameters, resulting in increasing the efficiency from 1.11% to 1.54%.
6.1: Introduction

The performance of DSSCs is significantly influenced by the morphology and optical properties of nanocrystalline oxide films [1-4]. As a key component of DSSCs, the photoelectrode should have high surface area for maximum dye loading, which facilitates efficient light harvesting [5]. As discussed earlier, SnO$_2$ has a deeper conduction band than TiO$_2$ and the bulk SnO$_2$ has a mobility of up to 240 cm$^2$/Vs, which is 100 times that of TiO$_2$. Because of these properties, SnO$_2$ in principle should facilitate efficient charge injection and transfer, making it a promising candidate for high performance of the devices. Moreover, in the previous reports for DSSCs based on “bare” metal oxide films including SnO$_2$ and liquid electrolyte, it was observed that the recombination of conduction band electrons with oxidized dye is faster than the regeneration of the oxidized dye [6-9]. The charge recombination occurs at the electrode/electrolyte interface. This affects open-circuit photovoltage by changing the Fermi energy level. Such a decrease in an open-circuit voltage upsets the overall performance of the device [10, 11]. Thus to decrease the recombination loss certain modification in the device structure become a challenge to further increase in its photovoltaic performance.

Surface modification of oxide film is considered as one of the important approach to enhance the device performance and stability [11, 12]. The conversion efficiency of the cell is improved by employing an ultra-thin layer of wide band gap material over it [7, 13]. The improvement in photovoltaic parameters attributed to the following two factors: First, the wide band gap insulating layers with high conduction band(CB) edge retards the back transfer of electrons from CB of SnO$_2$ to the oxidized species of electrolyte and thus decreases the charge recombination loss [14]. Second, the surface coating also enhances the dye adsorption, leading to improved light harvesting efficiency [13]. The isoelectric point (IEP) i.e. the pH of oxide material decides its basicity, greater value of which enhances its surface adsorption capabilities. Dye molecules are adsorbed more easily on to the surface through their anchoring carboxyl groups because of more basic property of the wide band gap coating material layer than SnO$_2$ [15]. Several wide band gap materials such as ZnO [16], ZrO$_2$ [17], Al$_2$O$_3$ [18, 19], MgO [20], Nb$_2$O$_5$ [21], CaCO$_3$ [9] and SiO$_2$[14] have been used for this purpose.
Among all these, MgO is of particular interest for coating over SnO$_2$ photoelectrode. This is because the conduction band edge for MgO is negative to both the SnO$_2$ conduction band edge and excited state oxidation potential of Eosin Y dye. Such an energy band position indicates that MgO can be used as a surface passivation layer (SPL) to enhance the performance of DSSC [14, 22, 23, 11]. Furthermore, the higher IEP of MgO \((IEP \sim pH 12)\) as compared to SnO$_2$ \((IEP \sim pH 5.5)\) favors stronger dye adsorption and thus better light harvesting [7]. Previous studies on MgO coated SnO$_2$ have shown improvement in both the short circuit density \((J_{sc})\) and open circuit voltage \((V_{oc})\), resulting in the enhancement of photoconversion efficiency of DSSCs [7, 8, 24]. These cells based on bare SnO$_2$ have efficiencies of the order of 1%, while after MgO coating the efficiencies enhanced and is of the order 7% [8, 24]. Kumara et al. [25] and Taguchi et al. [26] reported that the ultra-thin layer of MgO seems to acts as a barrier, preventing the back transfer of injected electrons to the oxidized species of the electrolyte. It is found that compared to the TiO$_2$ based DSSCs, the MgO/SnO$_2$ based DSSC is less sensitive to degradation of the dye and the electrolyte by UV light [8]. Furthermore, the improvement in device performance requires the optimization of the thickness and the evenness of the MgO layer. Also the specific surface area of the MgO layer can be increased significantly by controlling its preparation route [6, 8, 27]. For coating of SPL on metal oxide film various modification methods have been applied, such as dip-coating in a solution [14, 21, 28, 29], spin-coating a solution [30, 31] and electrochemical deposition [32, 33]. Fig. 6.1 shows the schematic of working mechanism of DSSC based on SnO$_2$ photoelectrode with and without MgO coating.

Fig. 6.1: Schematic of working mechanism of DSSC based on SnO$_2$ and MgO-coated SnO$_2$ electrodes.
In the light of the above discussion, MgO-coated SnO₂ electrodes were fabricated by dip coating technique. An attempt has been made to investigate the influences of MgO coating for different times and precursor concentration on absorption properties, dye adsorption, micrograph and the performance of Eosin Y sensitized SnO₂ based DSSCs.

6.2: Experimental details

6.2-1: Materials

Magnesium acetate-tetra-hydrate, Mg(OOCCH₃)₂ 4H₂O and ethanol were purchased from SDFCL for the preparation of MgO SPL on SnO₂ films. For porous layer of photoanode, the SnO₂ paste was prepared as per the procedure described in chapter No 3. Eosin-Y (2-(2,4,5,7-tetrabromo-6-oxido-3-oxo-3H-xanthen-9-yl) benzoate, C₂₀H₆Br₄Na₂O₅) dye was purchased from HIMEDIA. FTO glass substrates were pre-cleaned ultrasonically in distilled water, acetone and alcohol for 10 minutes each as per the procedure given in section-2.4.

6.2-2: Preparation of SnO₂ porous layer films

The porous SnO₂ photoanode film of 8 µm thickness (named as PA4 in chapter 4), which showed optimal photovoltaic performance has been used for over coating of MgO. The hydrothermally synthesized photoanodes prepared with 4, 12 and 24 h reaction time (named as HPA-1, HPA-2 and HPA-3 in chapter 5) were also used for over coating of MgO.

6.2-3: Preparation of surface passivation layer of MgO on SnO₂ films

The experiment was performed into two parts:

Part I: The PA4 as mentioned above was further used for MgO coating initially. The SPL of MgO was deposited on SnO₂ by dip-coating method to fabricate MgO coated SnO₂ (MgO/SnO₂) electrodes. Magnesium acetate was selected as a precursor material. MgO sol was then prepared for coating layer using Magnesium acetate in ethanol solvent. PA4 was dip coated for some time ‘t’ in prepared sol of defined concentration ‘C’. The coated electrodes were further annealed at 450 °C for 30 min. Different thicknesses of MgO were deposited on PA4 by varying ‘t’ and ‘C’. The detailed experimental parameters and the nomenclature of MgO coated photoanodes are presented in Table-6.1. The procedure is explained with flowchart in Fig. 6.2.
Table 6.1: Preparation parameters and identifications for MgO/ SnO$_2$ electrodes prepared at different precursor concentration and coating time.

<table>
<thead>
<tr>
<th>Concentration of Mg(OOCCH$_3$)$_2$ ‘C’ (mM)</th>
<th>Coating time ‘t’ (s)</th>
<th>Photoanode nomenclature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>90</td>
<td>M1</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>M10A</td>
</tr>
<tr>
<td>10</td>
<td>90</td>
<td>M10B</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>M10C</td>
</tr>
<tr>
<td>100</td>
<td>90</td>
<td>M100</td>
</tr>
</tbody>
</table>

Fig. 6.2: Flowchart for the SPL of MgO coating on SnO$_2$ photoelectrode.

Part II: Based on the photovoltaic performance of DSSCs with MgO coated SnO$_2$ electrodes, the optimized parameters related to coating of SPL of MgO on PA4 were also used for HPA-1, HPA-2 and HPA-3 using same procedure. The detailed experimental parameters and the nomenclature are given in Table-6.2.
Table 6.2: Preparation parameters and identifications for MgO coated hydrothermally synthesized HPA-1, HPA-2 and HPA-3 SnO\textsubscript{2} electrodes

<table>
<thead>
<tr>
<th>Concentration of Mg(OOCCH\textsubscript{3})\textsubscript{2} 'C' (mM)</th>
<th>Coating time 't' s</th>
<th>Photoanode nomenclature</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>90</td>
<td>MHPA-1</td>
</tr>
<tr>
<td>10</td>
<td>90</td>
<td>MHPA-2</td>
</tr>
<tr>
<td>10</td>
<td>90</td>
<td>MHPA-3</td>
</tr>
</tbody>
</table>

6.2-4: DSSC fabrication

Eosin Y dye is used as sensitizer in this experiment. The prepared SnO\textsubscript{2} and MgO/ SnO\textsubscript{2} electrodes were immersed in an Eosin Y dye solution (0.3 mM in ethanol solution) for 24 h to adsorb dye molecules on to the photoelectrode surface. To fabricate the solar cell, the sensitized SnO\textsubscript{2} and MgO/ SnO\textsubscript{2} photoelectrodes were assembled into sandwich-type cells using Pt- FTO as counter electrodes and few drops of electrolyte solution (iodine/iodide in acetonitrile) were added between them.

6.3: Characterization

The crystal structure, and elementary analysis of the photoelectrode films were characterized by X-ray diffractometer (XRD, Rigaku “D/B max-2400”, \(\lambda = 1.54 \text{ Å}\)), scanning electron microscopy (SEM, JEOL-JSM 6360-A) and energy-dispersive X-ray spectroscopy (EDS) respectively. Profilometery (KLA Tencor P_16+) was used to determine thickness of the photoelectrode films. Diffuse reflectance and optical absorption spectroscopic studies were conducted for both unsensitized and dye sensitized photoanode films using JascoV-670 spectrometer. All the cells were tested under AM 1.5 solar simulator equipped with a 450W xenon lamp at 100 mW/cm\textsuperscript{2} (Model Sol 2A, Newport).

6.4: Results and discussion

6.4-1: The phase identification or phase crystal structure of SnO\textsubscript{2} and MgO/SnO\textsubscript{2} photoelectrodes

Fig. 6.3(a & b) shows the XRD pattern of “bare” SnO\textsubscript{2} and MgO/SnO\textsubscript{2} photoelectrodes. All the peaks in the patterns correspond to the rutile structure of SnO\textsubscript{2} (space group: \(P4_2/mnm, a=4.7, c =3.18 \text{ Å}\), JCPDS file No. 41-1445). No characteristic peaks for MgO are observed, in XRD pattern because of thin coating of MgO. As observed in Fig.
6.3(a), there is no change in the nature of diffraction peaks. However, the diffraction peaks corresponding to MgO coated hydrothermal photoanodes observed in Fig. 6.3(b), are broadened probably due to the induced strain by the over layer coating.

![Fig. 6.3: (a) XRD pattern of SnO$_2$ (PA4), MgO/SnO$_2$ photoanodes.](image)
Fig. 6.3: (b) XRD pattern of hydrothermally synthesized SnO₂ photoanodes with and without MgO coating.

6.4-2: Surface morphological analysis

Fig. 6.4 shows scanning electron micrographs of the SnO₂ films before and after MgO coating for various precursor concentration and coating time. The micrographs show that the surface structure of the SnO₂ mesoporous photoelectrode films have not
varied much with coating of SPL of MgO. This can be attributed to a very thin MgO layer formation on SnO₂ photoelectrode. This also means that most of the MgO sol in the electrode was soaked into the mesoporous SnO₂ layer to overcoat the individual nanoparticles. It is observed that, the sample possesses network of small agglomerated sub-micron sized particles with spherical morphology and with pores in between them. Such a network will allow the dye solution to go inside the photoelectrode film, which will be helpful for maximum dye molecule adsorption on the SnO₂ surface. To further confirm the formation of MgO on SnO₂, EDS measurements are carried out.

Fig. 6.4: SEM images of the bare SnO₂ and MgO coated SnO₂ for different concentration and time.

6.4-3: Energy dispersive X-ray spectroscopic (EDS) analysis

In order to confirm the formation of SPL of MgO on SnO₂ photoelectrodes, the films are subjected to EDS spectroscopic experimental analysis. Fig. 6.5 shows the EDS spectra of “bare” SnO₂ and MgO/SnO₂ films and is composed of Sn, O and Mg elements. It is observed from the figure that the Mg peak appears in all MgO/SnO₂ photoelectrodes. The chemical atomic wt% composition analysis for tin, magnesium and oxygen estimated from the EDS spectra is shown in Table 6.3.
Table 6.3: Atomic wt % composition analysis for tin, magnesium and oxygen estimated from the EDS spectra.

<table>
<thead>
<tr>
<th>Photoanode</th>
<th>tin</th>
<th>magnesium</th>
<th>oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare SnO₂</td>
<td>6.22</td>
<td>0.0</td>
<td>93.76</td>
</tr>
<tr>
<td>M1</td>
<td>14.39</td>
<td>0.18</td>
<td>85.43</td>
</tr>
<tr>
<td>M10A</td>
<td>12.74</td>
<td>0.23</td>
<td>87.03</td>
</tr>
<tr>
<td>M10B</td>
<td>4.38</td>
<td>0.48</td>
<td>95.15</td>
</tr>
<tr>
<td>M10C</td>
<td>4.45</td>
<td>0.79</td>
<td>94.76</td>
</tr>
<tr>
<td>M100</td>
<td>3.95</td>
<td>0.86</td>
<td>92.96</td>
</tr>
<tr>
<td>MHPA-3</td>
<td>5.05</td>
<td>0.53</td>
<td>94.42</td>
</tr>
</tbody>
</table>

Fig. 6.5: EDS spectra of the bare SnO₂ and MgO coated SnO₂ for different concentration and time.
With increasing concentration of the precursor and by keeping coating time constant to 90 s, an increased Mg % is observed. Among these three photoanodes, M1, M10B and M100, M100 shows maximum Mg %. Therefore the precursor concentration after certain limit forms a thick MgO coating. Furthermore, by keeping precursor concentration constant and varying coating time, among M10A, M10B and M10C, M10C with coating time 150 s, shows maximum Mg %. This fact also allows to conclude that, for optimized precursor concentration the coating time after certain limit also forms a thick MgO coating. Fig. 6.5 also shows the EDS spectra of HPA-3 SnO\textsubscript{2} photoelectrodes with and without MgO coating. The optimized precursor concentration and coating time is used for coating of SPL of MgO on hydrothermally synthesized SnO\textsubscript{2} photoelectrodes. It is seen from the figure that, the Mg peak appears in MgO/SnO\textsubscript{2} MHPA-3 photoelectrode.

6.4-4: Optical absorption spectra of SnO\textsubscript{2}, EY-sensitized SnO\textsubscript{2} and MgO/SnO\textsubscript{2} electrodes:

![Absorption spectra](image)

**Fig. 6.6: Absorption spectra of the bare SnO\textsubscript{2} and sensitized MgO coated SnO\textsubscript{2} photoelectrodes.**

**Fig. 6.6** shows the optical absorption spectra of bare SnO\textsubscript{2}, EY sensitized M1, M10A, M10B, M10C and M100 photoelectrodes with different MgO coating conditions. It is seen from the Fig. 6.6 that, the absorption for all sensitized SnO\textsubscript{2} photoelectrodes is extended to visible region as compared to un-sensitized photoelectrode(PA4). The
absorption maximum for all sensitized photoelectrodes matched with that of Eosin Y dye in solution. With increasing concentration of the precursor and by keeping coating time constant to 90 s, an increased absorbance in the 400-600 nm regions is observed for M10B as compared to M1. Among these three photoanodes, M1, M10B and M100, EY sensitized M100 shows decrease in absorption in dye region. Therefore, the precursor concentration after certain limit forms a thick MgO coating, which will not be helpful for sufficient dye loading. Furthermore, by keeping precursor concentration constant and varying coating time, among M10A, M10B and M10C, EY sensitized M10C with coating time 150 s, shows decrease in absorption in dye region. This fact also forces to conclude that, for optimized precursor concentration, the coating time after certain limit also forms a thick MgO coating, which will not be helpful for sufficient dye loading. Therefore from the absorption spectra of the sensitized photoelectrode, it is observed that EY sensitized M10B photoelectrode with sufficient thin coating of MgO have maximum absorbance in the dye region, which will be helpful to enhance light harvesting efficiency (LHE) and photocurrent density of SnO\textsubscript{2} based DSSCs.

**Fig. 6.7** shows the optical absorption spectra of EY sensitized HPA-1, HPA-2 and HPA-3 SnO\textsubscript{2} photoelectrodes with and without MgO coating. The optimized precursor concentration and coating time in the above study are used in coating of SPL of MgO on hydrothermally synthesized SnO\textsubscript{2} photoelectrodes. It is seen from the figure that, the absorption for all sensitized SnO\textsubscript{2} photoelectrodes is extended to visible region. The absorption maximum for all sensitized photoelectrodes matched with that of Eosin Y dye in solution.

For MgO/SnO\textsubscript{2} photoelectrodes, MHPA-1, MHPA-2 and MHPA-3, an increased absorbance in the 400-600 nm regions is observed. Among these three photoanodes, EY sensitized MHPA-3 shows maximum absorption in dye region. MHPA-3 comprises MgO coated closely connected SnO\textsubscript{2} nanoflowers. Greater the IEP of MgO is better increasing the dye loading through their high basicity. Such a maximum dye loading will be helpful to enhance light harvesting efficiency and photocurrent density.
Chapter - 6

Surface Passivation of SnO₂ Photoanode Films through MgO Coating and Its Influence on the Performance of Dye Sensitized Solar Cells

Fig. 6.7: Absorption spectra EY sensitized HPA-1, HPA-2 and HPA-3 SnO₂ photoelectrodes with and without MgO coating.

6.5: Solar cell characterization

6.5-1: DSSC based on EY-sensitized SnO₂ photoelectrodes: effect of surface passivation

Fig. 6.8 shows the photo-current density - photovoltage (J-V) characteristics of DSSCs based on EY sensitized “bare” SnO₂ and M1, M10A, M10B, M10C and M100 photoelectrodes with different MgO coating conditions. The photovoltaic parameters namely, open-circuit voltage (Voc), short-circuit photocurrent density (Jsc), fill factor (FF) and photovoltaic efficiency (η) for DSSCs with different photoelectrodes are summarized in Table 6.4. It is clearly seen from the Fig. 6.8 that, compared with SnO₂, the MgO/SnO₂ electrode M1, M10A, M10B and M10C gives higher Jsc, open-circuit photovoltage Voc and fill factor FF. This means that the SPL of MgO coating helps to enhance the solar cell performance with sensitized MgO/SnO₂ photoelectrodes. With increasing concentration of the precursor and by keeping coating time constant to 90 s, increased photovoltaic parameters are observed for M10B as compared to M1 and M100. Among these three photoanodes, M1, M10B and M100, EY sensitized M100 shows decrease in solar cell performance as compared to DSSC with “bare” SnO₂ (Fig. 6.9). The DSSC with M1 shows enhancement in the photovoltaic parameters as compared to that of bare SnO₂. Such an enhancement is attributed to the increase in dye adsorption. Whereas, in case of M100,
higher precursor concentration causes thick MgO coating formed over SnO₂, which will not be helpful for sufficient transfer of electrons from the dye to CB of SnO₂. Such a thick layer then will act as a barrier for transport of charges hence $J_{sc}$ decreases. Furthermore, by keeping precursor concentration constant and varying coating time, among M10A, M10B and M10C photoelectrodes, increased photovoltaic parameters are observed for DSSC based on M10B. The DSSC with M10A shows poor performance as compared to M10B due to insufficient coating of MgO over SnO₂. But it shows the enhancement in the photovoltaic parameters as compared to only SnO₂. Such an enhancement is attributed to the increase in dye adsorption. Whereas, because of prolonged coating time, a thick MgO coating formed over SnO₂ in case of M10C, which is not helpful for sufficient transfer of electrons from the dye to CB of SnO₂. Such a thick layer acts as a barrier for transport of charges hence $J_{sc}$ decreases. Therefore from J-V characteristics of the DSSCs based on all sensitized photoelectrode, it is observed that DSSC based on EY sensitized M10B photoelectrode with sufficient thin coating of MgO have shown better photovoltaic characteristics. The efficiency is significantly enhanced from 0.54 to 0.73% in case of DSSC with M10B photoelectrode (Fig. 6.10).

The increase in $J_{sc}$ is due to the enhancement in light harvesting efficiency. The coating of the MgO layer apparently increases the amount of adsorbed dye molecules [8]. In addition to the enhanced $LHE$, the charge recombination due to back electron transfer is also retarded. Such retardation can contribute to the increase in the $V_{oc}$ and hence better solar cell performance [13, 34, 35]. These results confirm that the enhanced dye adsorption and the retardation of the interfacial recombination are responsible for the enhanced solar cell performance.

Table 6.4: Photovoltaic parameters of EY sensitized SnO₂ and MgO/SnO₂ photoelectrodes

<table>
<thead>
<tr>
<th>Photoanode</th>
<th>$V_{oc}$ (V)</th>
<th>$J_{sc}$ (mA.cm⁻²)</th>
<th>FF (%)</th>
<th>η (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only SnO₂(PA4)</td>
<td>0.35</td>
<td>2.91</td>
<td>52.7</td>
<td>0.54</td>
</tr>
<tr>
<td>M1</td>
<td>0.36</td>
<td>2.97</td>
<td>60.8</td>
<td>0.64</td>
</tr>
<tr>
<td>M10A</td>
<td>0.37</td>
<td>3.35</td>
<td>54.2</td>
<td>0.67</td>
</tr>
<tr>
<td>M10B</td>
<td>0.38</td>
<td>3.70</td>
<td>52.0</td>
<td>0.73</td>
</tr>
<tr>
<td>M10C</td>
<td>0.35</td>
<td>2.57</td>
<td>53.2</td>
<td>0.48</td>
</tr>
<tr>
<td>M100</td>
<td>0.33</td>
<td>2.45</td>
<td>54.1</td>
<td>0.45</td>
</tr>
</tbody>
</table>
Fig. 6.8: Photo-current density - photovoltage (J-V) characteristics of DSSCs based on EY sensitized “bare” SnO$_2$ and M1, M10A, M10B, M10C and M100 photoelectrodes.

Fig. 6.9: Variation of short circuit current density ($J_{sc}$) and open circuit photovoltage ($V_{oc}$) of DSSCs based on EY sensitized “bare” SnO$_2$ and M1, M10A, M10B, M10C and M100 photoelectrodes.
Fig. 6.10: Variation of photoconversion efficiency of DSSCs based on EY sensitized “bare” SnO$_2$ and M1, M10A, M10B, M10C and M100 photoelectrodes.

6.5.2: DSSC based on EY – sensitized HPA-1, HPA-2 and HPA-3 SnO$_2$ photoelectrodes: effect of surface passivation

Fig. 6.11 shows the J-V characteristics of DSSCs based on EY sensitized HPA-1, HPA-2 and HPA-3 SnO$_2$ photoelectrodes with and without MgO coating. The photovoltaic parameters namely, $V_{OC}$, $J_{SC}$, $FF$ and $\eta$ for DSSCs with different photoelectrodes are summarized in Table 6.5.

<table>
<thead>
<tr>
<th>Photoanode</th>
<th>$V_{OC}$ (V)</th>
<th>$J_{SC}$ (mA.cm$^{-2}$)</th>
<th>$FF$ (%)</th>
<th>$\eta$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPA-1</td>
<td>0.33</td>
<td>2.45</td>
<td>54.04</td>
<td>0.45</td>
</tr>
<tr>
<td>MHPA-1</td>
<td>0.38</td>
<td>2.94</td>
<td>56.97</td>
<td>0.64</td>
</tr>
<tr>
<td>HPA-2</td>
<td>0.39</td>
<td>2.73</td>
<td>57.53</td>
<td>0.62</td>
</tr>
<tr>
<td>MHPA-2</td>
<td>0.44</td>
<td>3.27</td>
<td>60.00</td>
<td>0.87</td>
</tr>
<tr>
<td>HPA-3</td>
<td>0.43</td>
<td>4.36</td>
<td>59.29</td>
<td>1.11</td>
</tr>
<tr>
<td>MHPA-3</td>
<td>0.47</td>
<td>5.23</td>
<td>61.58</td>
<td>1.54</td>
</tr>
</tbody>
</table>
Chapter - 6

Surface Passivation of SnO₂ Photoanode Films through MgO Coating and Its Influence on the Performance of Dye Sensitized Solar Cells

Fig. 6.11: photo-current density - photovoltage (J-V) characteristics of DSSCs based on hydrothermally synthesized SnO₂ photoelectrodes with (MHPA-1, MHPA-2 and MHPA-3) and without (HPA-1, HPA-2 and HPA-3) MgO coating.

It is clearly seen from the Fig. 6.11 that compared with hydrothermally synthesized HPA-1, HPA-2 and HPA-3 SnO₂ photoelectrodes, performance of MgO coated MHPA-1, MHPA-2 and MHPA-3 SnO₂ photoelectrodes have shown better performance in DSSC. It is observed that from MHPA-1 to MHPA-3, both Voc and Jsc increases. The better performance is observed for EY sensitized MHPA-3 based DSSC with Voc, Jsc and η % about 0.47 V, 5.23 mA/cm² and 1.54 %, respectively. As already discussed, HPA-3 with SnO₂ nanoflowers offers maximum surface area to adsorb sufficient dye molecules [36]. The MgO coating helps to adsorb more dye molecules, which contributes to light harvesting efficiency. Also, due to MgO coating, the back electron transfer from SnO₂ to the oxidized species of electrolyte is retarded, which contributes to enhancement in photovoltaic parameters namely, V_oc and FF.

6.6: Conclusions

A surface passivation layer of MgO is successfully coated on SnO₂ films by dip coating method. The coating of an MgO improves the performance of the SnO₂ photo electrode based DSSCs. The surface modification of SnO₂ electrodes with a thin layer of MgO is found to improve dye adsorption and thus increases the sensitized photocurrent. The
increase in the short circuit current indicates that the high specific surface area and more basic nature of the MgO, as compared to SnO\textsubscript{2}, favoring more dye adsorption through its carboxylic acid groups. In addition to \( J_{SC} \), the photovoltage and fill factor of the DSSCs are strongly enhanced because of SPL formation. Such an enhancement in MgO/SnO\textsubscript{2} based DSSCs is due to suppression of electron back transfer from CB of SnO\textsubscript{2} to the oxidized species of the redox electrolyte.

However, the optimum enhancement in device performance is critically sensitive to the thickness of the MgO barrier. The maximum efficiency 1.54 % is obtained for DSSC based on SnO\textsubscript{2} with optimum coating of MgO with 10mM precursor concentration and 90 s coating time. Such an enhancement suggests that electron transfer from the LUMO of dye to the CB of SnO\textsubscript{2} occurs by tunneling through the SPL of MgO. Thicker layers act as barrier, and hence results in an observed decrease in photocurrent. These results clearly establish the possibility of using SnO\textsubscript{2} electrodes for DSSCs with certain surface modification and may open new possibilities for light harvesting in IR region using dyes having absorbance in longer wavelength region.
Chapter 6

Surface Passivation of SnO₂ Photoanode Films through MgO Coating and Its Influence on the Performance of Dye Sensitized Solar Cells

References:


