5

A SUITABLE POLYSULFIDE ELECTROLYTE FOR CdSe QDSSC[*]

5.1 Introduction

For a QDSSC to function efficiently, a good electrolyte with a redox mediator is required. The redox mediator regenerates the oxidized sensitizer by donating an electron. Unfortunately, there are not many electrolyte/redox mediator systems which can function in both DSSCs and QDSSCs. DSSCs work best with iodide based electrolyte systems [1]. However, in QDSSCs iodide based electrolytes produce very poor results [2-5]. Nevertheless, with appropriate coating on the QDs surface, a good efficiency result can be obtained with I^-/I_3^- redox electrolyte as shown by Shalom *et al.* [4] Therefore, the choice of electrolyte plays a major role in determining the QDSSCs' performance [5]. In general, polysulfide electrolytes have been used by many researchers as an electrolyte of choice for QDSSCs [6,7]. An optimized polysulfide

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electrolyte system has been reported for use in CdS QDSSCs by Lee *et al.* [8]. The same polysulfide electrolyte has been used in a QDSSC based on CdSe QD prepared from 6 SILAR cycles. Unfortunately, the cell showed a very low efficiency at 0.65%. There are many different polysulfide compositions reported in the literature which give reasonable efficiencies for CdSe QDSSCs [6,9-11]. The compositions reported range from pure aqueous solutions to solutions containing various amounts of additives. Lee *et al.* reported an efficiency of 2.9% in a CdSe QDSSC with electrolyte consisting of Na_2S, S and KCl in water/methanol mixture [6]. Meanwhile, Diguna *et al.* obtained an efficiency of 2.7% with just Na_2S and S as the liquid electrolyte [9]. On the other hand, a lower efficiency of 1.83% has been reported with an electrolyte composition of Na_2S, S and NaOH [10]. A somewhat lower efficiency was obtained by Salant *et al.* with an electrolyte composition of Na_2S, S and KOH [11]. The different conversion energy efficiencies ranging from 1.50% to about 3.00% reported by the above researchers may be due to different QDSSC systems involved such as variation in the electrolytes used, the way the QDs were prepared and the surface treatment of the photoanode. The discrepancies in the results reported has been a motivation to undertake a systematic study to find a suitable polysulfide electrolyte that can result in optimum performance of CdSe QDSSC.

In this study, CdSe QD-sensitized TiO_2 electrodes and counter electrodes where prepared as described in Chapter 3 with preparation parameters based on the optimization results from Chapter 4. The thickness of the TiO_2 layer was kept constant in all QDSSCs with no surface treatment. Various compositions of polysulfide liquid electrolyte were prepared and then tested in the QDSSCs to determine the optimum performing electrolyte. Materials for the preparation of polysulfide electrolyte like potassium chloride (KCl), sulfur (S), guanidine thiocyanate (GuSCN) and TiO_2

nanoparticles powder were all procured from Sigma-Aldrich while sodium sulfide nonahydrate ($Na_2S.9H_2O$) was supplied by Bendosen, Germany. The polysulfide electrolyte solution was prepared in water-ethanol mixture. The concentration of each material in the electrolyte is given in detail in the results and discussion section. The performance of the QDSSC with the optimized polysulfide electrolyte was then evaluated over two hours to assess the stability of the cell. So far, there is no report in the literature on the optimization of polysulfide electrolyte for use in CdSe QDSSC prepared from SILAR method. Hence the outcome of this study may lead to a basis of a polysulfide electrolyte system for the application in CdSe QDSSC.

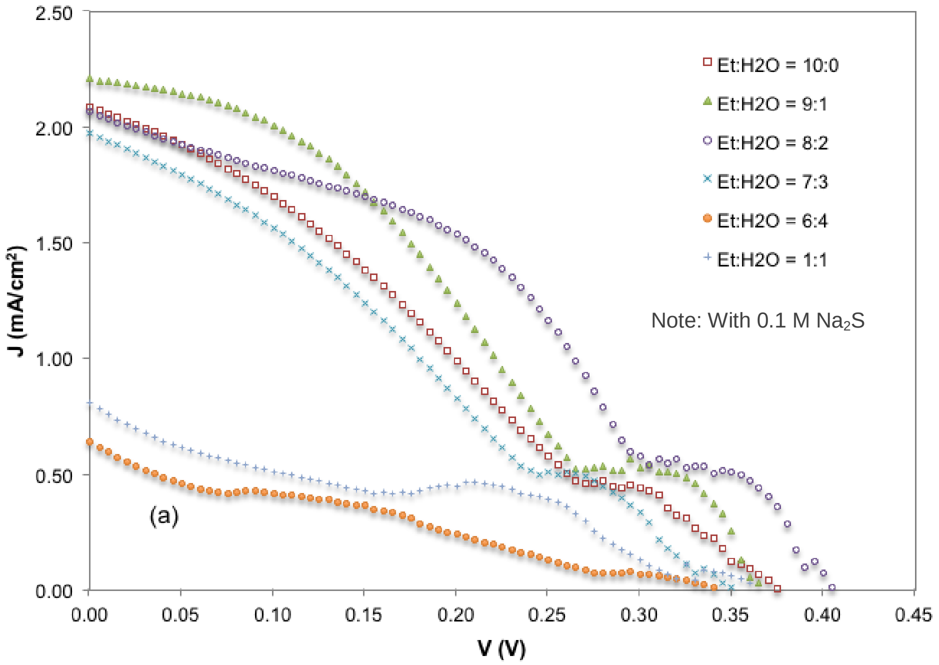
5.2 Results and discussion

5.2.1 Optimum solvent for the electrolyte

Most of the polysulfide electrolytes were prepared as aqueous solutions. However, recently Lee *et al.* proposed to mix methanol with water for the electrolyte preparation [8]. The use of alcohol was suggested to reduce the high surface tension of the aqueous solution. High surface tension will result in a low penetration and poor wetting of the solution in the mesoporous TiO_2 film. To overcome this problem, alcohol (methanol or ethanol) solution is used as co-solvent for the electrolyte solution.

The study started by comparing pure alcohol and aqueous solution as a solvent for the electrolyte. An appropriate amount of Na_2S only was used to prepare the 0.1 M electrolyte solution. Figure 5.1(a) shows the *J-V* curves of QDSSCs fabricated with electrolytes having selected ratio of co-solvents and Figure 5.1(b) shows the variation of efficiencies and fill factors of all cells investigated with the ethanol/water ratio in the electrolyte. Table 5.1 shows the summary of the performance parameters of all cells investigated, which were prepared with electrolytes having different ratios of co-solvents.

With the pure water aqueous electrolyte solution (water 100%), the efficiency of the QDSSC is found to be 0.19% with a short-circuit photocurrent density of 2.09 mA/cm^2. However, with pure methanol electrolyte solution (methanol 100%), the solar cell does not perform. The efficiency is only 0.02% with a short-circuit photocurrent density of 0.2 mA/cm^2. Both solutions produce an open-circuit voltage above 0.3 V. Fill factor is rather low i.e. 23% for the water solution and 16% for the methanol solution. With another alcohol-based solution, pure ethanol solution (ethanol 100%), a cell efficiency of 0.21% with a short-circuit photocurrent density of 2.09 mA/cm^2 is observed. Ethanol seems to be a better solvent compared to methanol as it yields a better fill factor value of 27%. Ethanol has a surface tension of 21.82 mN/m at room temperature compared with 22.51 mN/m of methanol [12]. However, surface tension is only part of the contributing factors for the solar cell performance. The ethanol can also serve as a sacrificial hole scavenger that allows easy hole transfer from the excited CdSe QDs and prevents the recombination of the charge carriers [13]. Therefore, a mixture of water and ethanol is chosen as the solvent in the subsequent investigations. The ratio of ethanol and water is varied to prepare the co-solvent solution for the electrolyte.



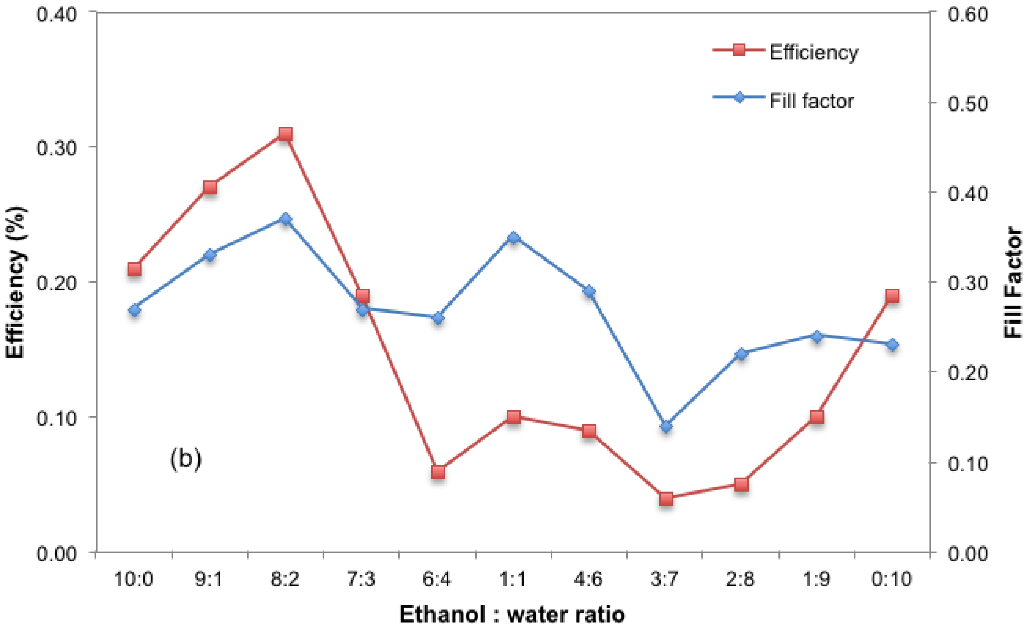


Figure 5.1: (a) *J-V* curves of CdSe QDSSCs with 0.1 M Na_2S electrolyte having various solvent ratios. (b) Variation of efficiency and fill factor of the cells with different solvent ratios in the electrolyte.

Table 5.1: Performance parameters of CdSe QDSSCs with 0.1 M Na_2S electrolytes having various solvent ratios.

Solution composition of the electrolyte	J_{SC} (mA/cm^2)	V_{OC} (V)	Fill factor (%)	Efficiency, η (%)
Methanol 100%	0.42	0.305	16.0	0.02
Ethanol 100%	2.09	0.375	27.0	0.21
Ethanol:Water = 9:1	2.21	0.365	33.0	0.27
Ethanol:Water = 8:2	2.07	0.405	37.0	0.31
Ethanol:Water = 7:3	1.97	0.350	27.0	0.19
Ethanol:Water = 6:4	0.65	0.340	26.0	0.06
Ethanol:Water = 1:1	0.81	0.360	35.0	0.10
Ethanol:Water = 4:6	0.85	0.345	29.0	0.09
Ethanol:Water = 3:7	0.82	0.340	14.0	0.04
Ethanol:Water = 2:8	0.62	0.360	22.0	0.05
Ethanol:Water = 1:9	1.21	0.340	24.0	0.10
Water 100%	2.09	0.395	23.0	0.19

From the results, it is clear that the best cell performance is obtained when the solution consists of ethanol/water ratio of 8/2 (by volume). The cell with this electrolyte has the best efficiency of 0.31% with a short-circuit photocurrent density of 2.07 mA/cm^2. This result is better than the results obtained for cells with single solvent-based electrolytes. This cell also has the highest fill factor (37%) among the cells prepared with other electrolyte solutions. As the ratio of the ethanol part in the electrolyte solution decreases, efficiency of the cell is found to decrease. It is clear that electrolytes having ethanol content greater than 70% give better performance. This indicates the importance of ethanol in making the electrolyte penetrate deep into the mesoporous TiO_2 film and wet the pores. The penetration and wetting depends on the combination of viscosity and surface tension of the electrolyte solution. As the maximum performance is obtained with the electrolyte having ethanol/water ratio of 8/2, this composition is used for further studies to enhance the performance of the QDSSCs. It is interesting to note that QDSSCs work without S in the Na_2S electrolyte but the J-V curves of the cell appear to be different in that the curves levels off at higher applied voltage in the range 0.25 – 0.35 V before eventually dropping to zero photocurrent density. The author attributes this effect to the absence of regenerative species of S_x^{2-} in the electrolyte and the hole scavenging effect from alcohol which results in non-regenerative cells [13-15]. The use of alcohol in the solar cell electrolyte will lead to alcohol oxidation at the photoanode and at the same time it itself is a sacrificial donor by scavenging photogenerated holes. It is therefore of great importance to further optimize the Na_2S concentration as well as the inclusion of regenerative species S_x^{2-} in the optimized solvent of ethanol/water (8/2 by volume). Further investigations are necessary to understand the exact reasons for the unusual shape of the *J-V* curves when S is absent in the electrolytes.

5.2.2 Optimum Na_2S salt concentration for the electrolyte

As the efficiency of the cell obtained with 0.1 M Na_2S electrolyte is low, it is imperative to optimize the Na_2S concentration in the electrolyte solution. The amount of Na_2S is varied in the solution having ethanol/water: 8/2 (by volume) to obtain electrolyte solutions of different concentrations ranging from 0.1 to 1.0 M. The corresponding *J-V* curves of the cells having different concentrations of Na_2S are shown in Figure 5.2(a) while the variation of the efficiencies and fill factors with the concentrations are shown Figure 5.2(b). Table 5.2 summarizes the performance parameters of the cells prepared with electrolytes having different concentrations of Na_2S. From the results, optimum performance is obtained for the cells with an electrolyte having 0.5 M of Na_2S. This cell has an efficiency of 0.71% with an improved short-circuit photocurrent density of 4.26 mA/cm^2 as well as a better open circuit voltage of 0.46 V. However, there is not much change in the fill factor value.

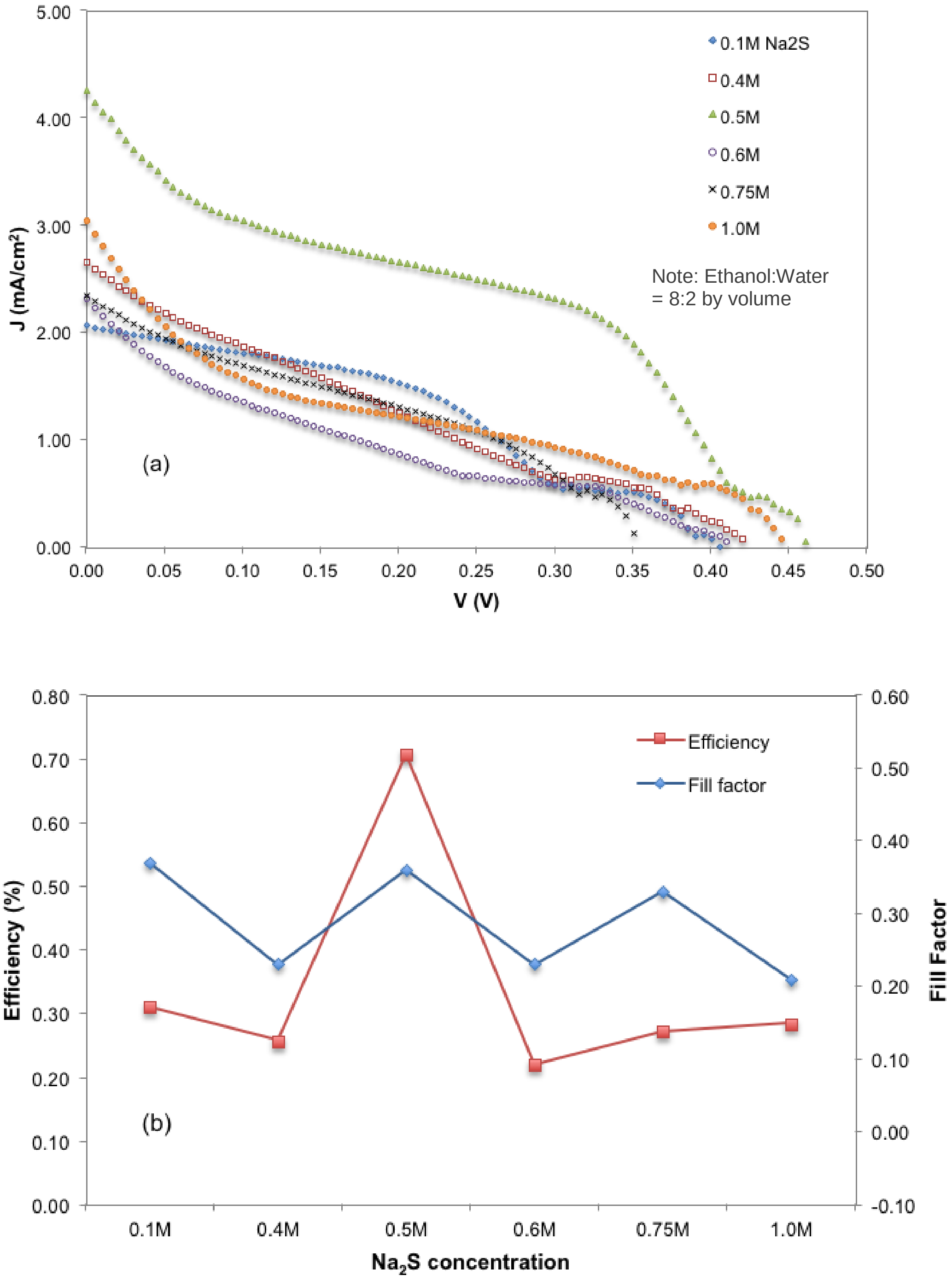


Figure 5.2: (a) *J-V* curves of CdSe QDSSCs with electrolytes having various amounts of Na_2S. (b) Variation of efficiency and fill factor of the cells with the amount of Na_2S in the electrolyte.

Further increase of Na_2S in the electrolyte solution above 0.5 M does not improve the cell performance. It should be noted that Na_2S is only slightly soluble in alcohol but very soluble in water. As such, higher concentrations of salt may not incur full solubility in the co-solvent. The results obtained suggest that for the best performance of the QDSSC the electrolyte must have an optimum Na_2S concentration of 0.5 M. With higher salt concentration, charge recombination at the photo-electrode and electrolyte interface is enhanced as evidenced by the low fill factor value. This also implies a slow hole recovery rate from the oxidized QD by the high concentration electrolytes. It is interesting to note that the QDSSC works with only Na_2S in the electrolyte but the *J-V* curves have somewhat irregular shapes (Fig. 5.1 (b)). The absence of regenerative S species in the electrolyte may have resulted in these irregular shapes as indicated in section 5.3.1. This problem can be mitigated by the addition of sulfur to form the polysulfide redox couple (see section 5.3.3 below). It should be noted that without the sulfur in the electrolyte the QDSSCs will not function continuously.

Table 5.2: Performance parameters of CdSe QDSSCs with electrolytes having various amounts of Na_2S in ethanol/water (8:2 by volume) solution.

Na_2S concentration in the electrolyte	J_{SC} (mA/cm^2)	V_{OC} (V)	Fill factor (%)	Efficiency, η (%)
0.1 M	2.07	0.405	37.0	0.31
0.4 M	2.66	0.420	23.0	0.26
0.5 M	4.26	0.460	36.0	0.71
0.6 M	2.32	0.410	23.0	0.22
0.75 M	2.35	0.350	33.0	0.27
1.0 M	3.04	0.445	21.0	0.28

5.2.3 Sulfur content needed for the best performance of the cells

In order to obtain a regenerative redox couple, a second element is needed to couple with S^{2-} from the Na_2S. In most studies, sulfur is added to the sulfide salt to form a polysulfide (S^{2-}/S_x^{2-}) redox couple. From the perspective of chemical reaction, oxidation occurs at the photoanode-electrolyte interface according to [16]†:

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† For details of reaction mechanism, please refer to Chapter 2.

$$S^{2-} + 2h^{+} \rightarrow S \quad (5.1)$$

$$S + S_{x-1}^{2-} \rightarrow S_{x}^{2-} \text{ (x = 2 to 5)} \quad (5.2)$$

At the counter electrode, reduction occurs where S_x^{2-} is reverted back to S^{2-}:

$$S_x^{2-} + 2e^{-} \rightarrow S_{x-1}^{2-} + S^{2-} \quad (5.3)$$

This chemical reaction is thought to enhance the hole recovery rate which results in a higher performance of solar cell [17]. Ardoin and Winnick suggested that the active species at the photoanode would be the disulfide ion [18].

In this study, sulfur has been added into the 0.5 M Na_2S solution. The amount of sulfur added is varied and the efficiency of the cell utilizing each electrolyte is obtained. Due to limited solubility of sulfur in alcohol, the amount of the sulfur added is limited to 1.0 M. The performance trend along with *J-V* curves of cells having different amount of S are shown in Figure 5.3 and the performance parameters of the cells are summarized in Table 5.3. The results show that addition of 0.1 M of sulfur to the electrolyte enhances the cell efficiency to a best value of 1.32% and produce the best fill factor of 43%. Photocurrent density is also improved to a higher value of 7.08 mA/cm^2. The overall efficiency has more than 80% improvement which is largely attributed to the enhancement of photocurrent density. This shows that addition of sulfur in small amounts up to 0.1 M concentration increases the cell performance. However, further increase of sulfur amount does not yield better performance. The author attributes this to the solubility limit of sulfur in the solvent. Note that with the addition of sulfur in the electrolyte, the *J-V* curves take a more regular shape.

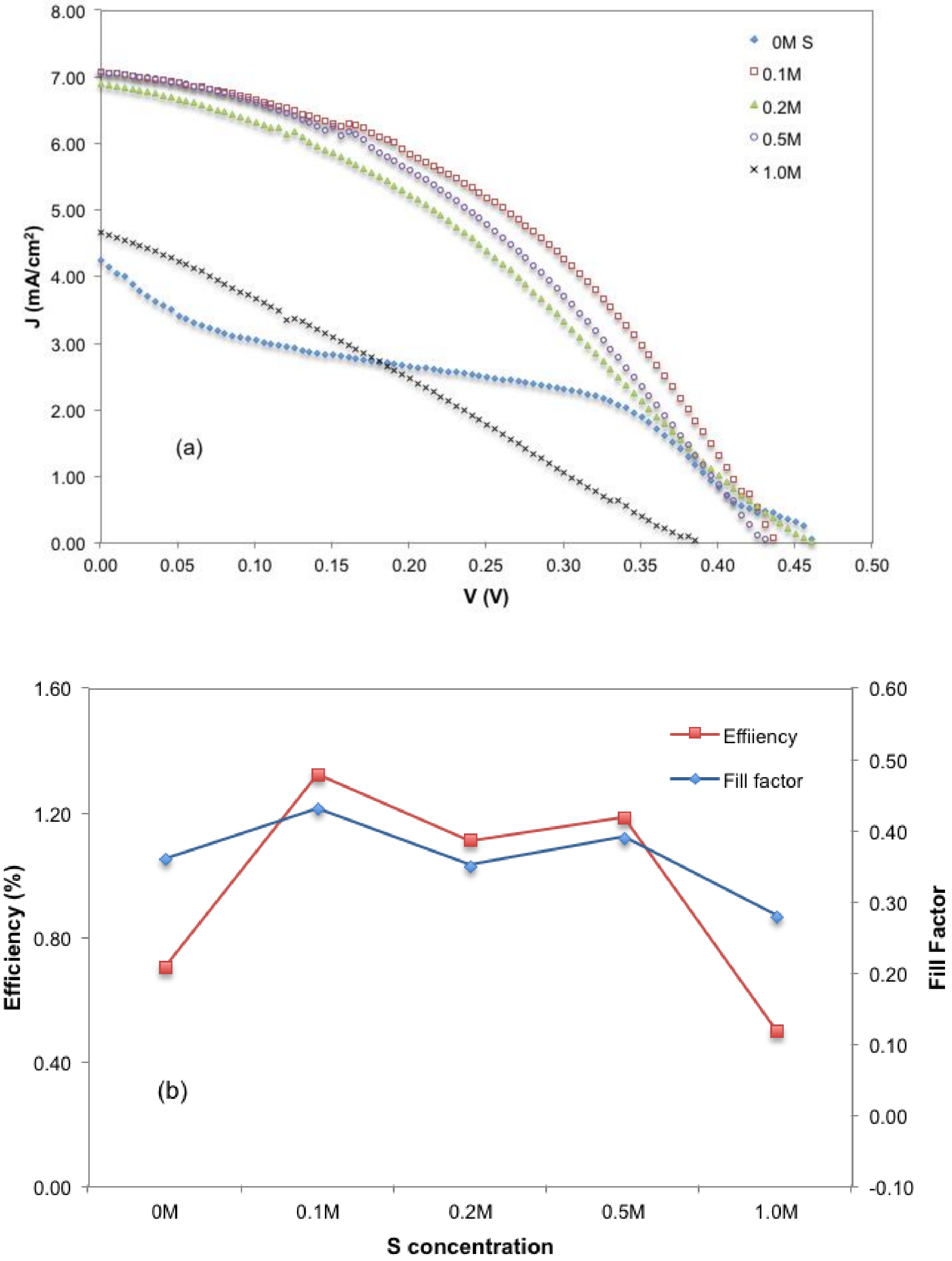

Figure 5.3: (a) *J*-*V* curves of CdSe QDSSCs with electrolytes having various amounts of S. (b) Variation of efficiency and fill factor of the cells with the amount of S in the electrolyte. The electrolyte used: 0.5 M Na_2S in ethanol/water (8:2 by volume).

Table 5.3: Performance parameters of CdSe QDSSCs with electrolytes having various amounts of S. The electrolyte used: 0.5 M Na_2S in ethanol/water (8:2 by volume).

S concentration in the electrolyte	J_{SC} (mA/cm^2)	V_{OC} (V)	Fill factor (%)	Efficiency, η (%)
0 M	4.26	0.460	36.0	0.71
0.1 M	7.08	0.435	43.0	1.32
0.2 M	6.91	0.460	35.0	1.11
0.5 M	7.08	0.430	39.0	1.19
1.0 M	4.66	0.385	28.0	0.50

5.2.4 Additives needed for optimum performance of the cells

The introduction of additives to the electrolyte has been shown to enhance the photocurrent generated and thereby improve the performance of QDSSCs [8,19]. Lee *et al.* has added KCl to the electrolyte to further enhance the performance of CdS QDSSCs [8]. The presence of KCl increased the performance of the cell as well as the electrolyte solution conductivity. In the present study, the author has added different amounts of KCl to the optimized 0.5 M Na_2S and 0.1 M S solution. However, it was noticed that the performance of the cells did not improve. The electrolyte without KCl appears to be superior in this case (see Figure 5.4(a)). Addition of KCl actually decreased the photocurrent density in contradiction to Lee *et al.* work. The difference may be due to different solvent mixtures as they have used a mixture of methanol and water as co-solvent. The author opined that the presence of anion Cl^- in the electrolyte may have altered the CdSe QDs-sensitized TiO_2 surface state which could have resulted in a lower cell performance. At the time writing, the mechanism of the Cl^- effect is not well understood.

Replacement of KCl with NaOH also did not produce any improvement either in the performance of QDSSCs (see Figure 5.4(a)). This is expected as KCl is known to be more electropositive than NaOH. Thus the conductivity of the electrolyte with added NaOH should be lower compared with that of the electrolyte with added KCl. The performance parameters of CdSe-sensitized solar cells with electrolytes having KCl or NaOH additive are summarized in Table 5.4. Figure 5.4(a) shows the corresponding *J-V* curves and the trend of the variation of parameters with KCl additive is shown in Figure 5.4(b).

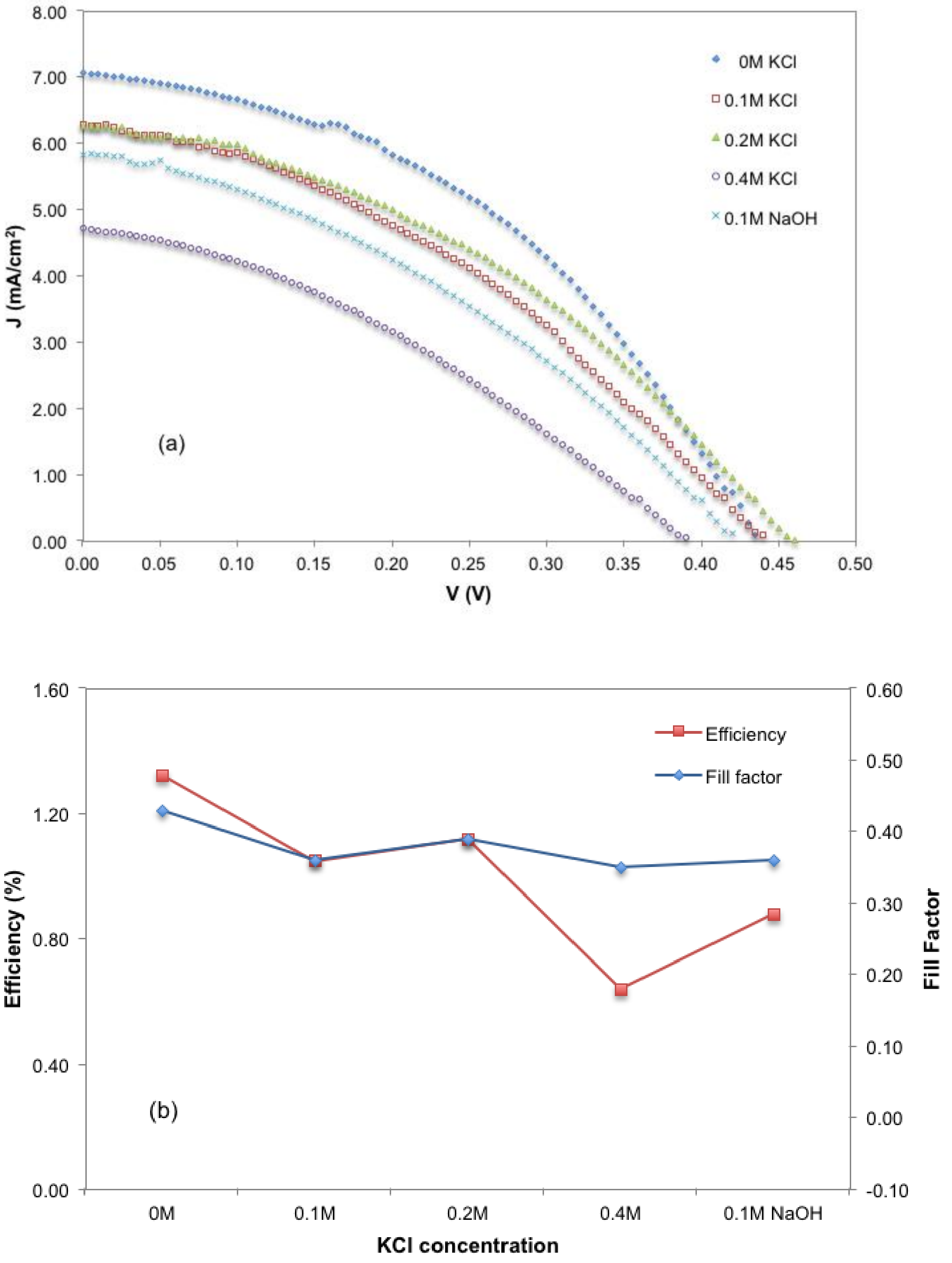

Figure 5.4: (a) *J-V* curves of CdSe QDSSCs with electrolytes having various amounts of KCl additive. (b) Variation of efficiency and fill factor of the cells with the amount of KCl in the electrolyte. Electrolyte used: 0.5 M Na_2S, 0.1 M S in ethanol/water (8:2 by volume).

Table 5.4: Performance parameters of CdSe QDSSCs with electrolytes having various amounts of KCl additive. Electrolyte used: 0.5 M Na_2S, 0.1 M S in ethanol/water (8:2 by volume).

KCl concentration in the electrolyte	J_{SC} (mA/cm^2)	V_{OC} (V)	Fill factor (%)	Efficiency, η (%)
0 M	7.08	0.435	43.0	1.32
0.1 M	6.60	0.440	36.0	1.05
0.2 M	6.27	0.460	39.0	1.12
0.4 M	4.22	0.390	35.0	0.64
0.1 M NaOH	5.83	0.420	36.0	0.88

In a DSSC work reported by Zhang *et al.*, guanidine thiocyanate (GuSCN) was added to the I^-/I_3^- electrolyte system for the improvement of performance and stability [20]. Following this report, Chou *et al.* tried adding GuSCN in CdS QDSSC and obtained enhancement in current density and efficiency [19]. In order to try this additive to the CdSe QDSSC, the author has added different amounts of GuSCN into the optimized electrolyte solution having 0.5 M Na_2S and 0.1 M S in ethanol/water (8/2 by volume). The presence of GuSCN decreases the photocurrent density but increases the open-circuit voltage in contrast to the significant improvement in photocurrent density reported by Chou *et al.* [19]. This difference could be attributed to the different electrolyte compositions and QD-sensitized photoanodes involved. Only a small amount of GuSCN is required to enhance the polysulfide electrolyte. In this case, 0.05 M of GuSCN can boost the cell performance to an efficiency of 1.41% with fill factor of 44% and open-circuit voltage of 0.470 V (see Table 5.5). The performance parameters of the cells with electrolytes having various amounts of GuSCN are summarized in Table 5.5 and the *J-V* curves of the cells and performance trend are shown in Figure 5.5(a) and 5.5(b). It should be noted that the addition of GuSCN did not result in a distinct improvement on the cell performance. An initial increase of GuSCN concentration produces a slight improvement on the cell performance as the additive assists in decreasing the interfacial recombination at the photoanode by patching up the TiO_2

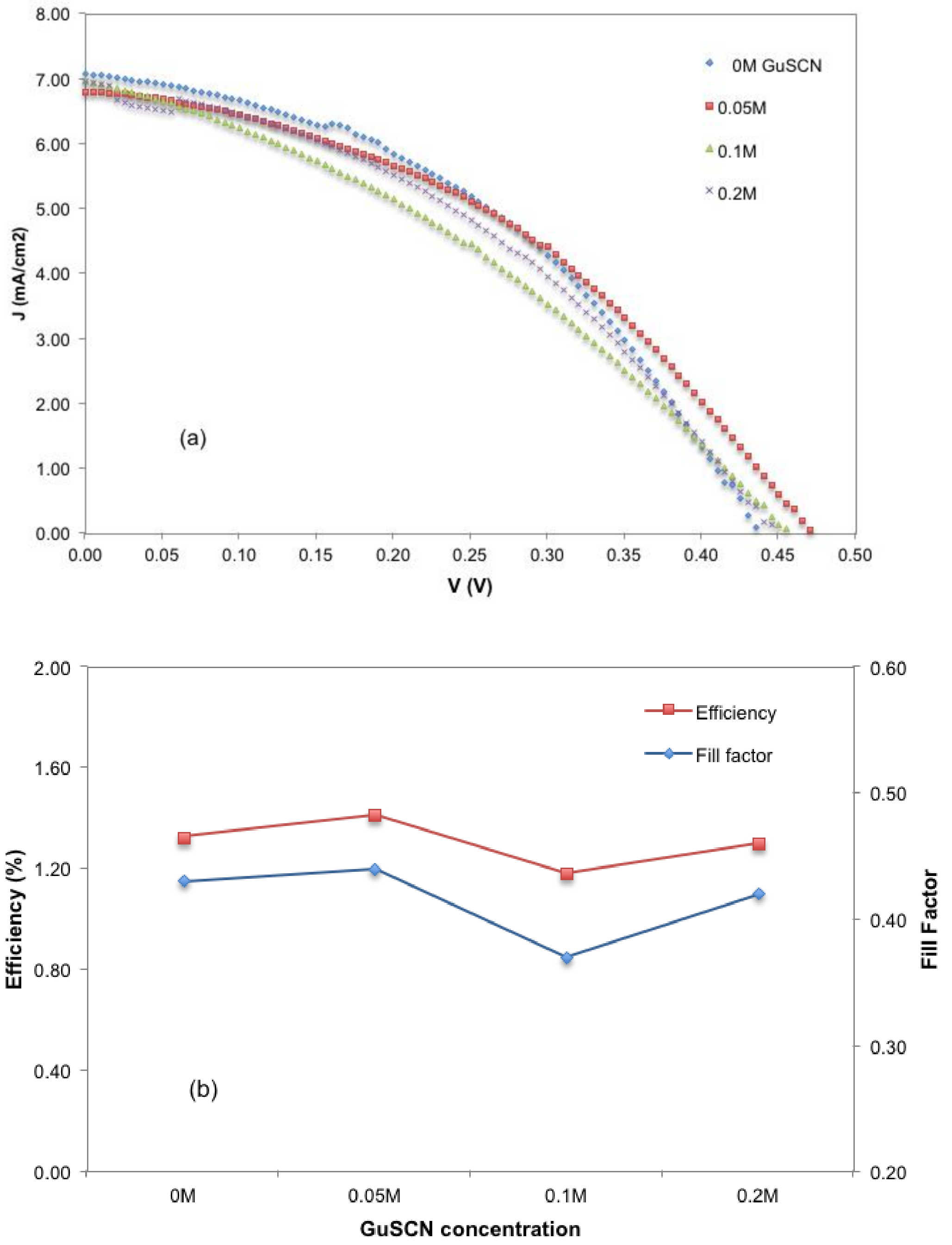

Figure 5.5: (a) *J-V* curves of CdSe QDSSCs with electrolytes having various amounts of GuSCN additive. (b) Variation of efficiency and fill factor of the cells with the amount of GuSCN in the electrolyte. Electrolyte used: 0.5 M Na_2S, 0.1 M S in ethanol/water (8:2 by volume).

surface not covered by the QDs. It also shifts the conduction band of TiO_2 to more positive potentials [20]. However, at higher concentration of GuSCN, cyanide may have adsorbed strongly on the CdSe QDs surface. This phenomenon may have negative effect on the electrolyte regenerative cycle though the precise mechanism may need to be further investigated [21].

Table 5.5: Performance parameters of CdSe QDSSC with electrolytes having various amounts of GuSCN additive. Electrolyte used: 0.5 M Na_2S, 0.1 M S in ethanol/water (8:2 by volume).

GuSCN concentration in the electrolyte	J_{SC} (mA/cm^2)	V_{OC} (V)	Fill factor (%)	Efficiency, η (%)
0 M	7.08	0.435	43.0	1.32
0.05 M	6.80	0.470	44.0	1.41
0.1 M	6.98	0.455	37.0	1.18
0.2 M	6.95	0.445	42.0	1.30

So far, the author is able to reproduce the performance of the optimized electrolyte by using few similar cell assemblies with performance variance of ±0.05%. The author’s optimized polysulfide electrolyte composition is different from that of Lee *et al.* as they have obtained an optimized polysulfide electrolyte consisting of 0.5 M Na_2S, 2 M S and 0.2 M KCl in methanol/water (7:3 by volume) solution [8]. It should be noted that their electrolyte is efficient in CdS QDSSCs. When the same electrolyte was applied in CdSe QDSSC (as in this study), the efficiency did not match with what has been reported. Clearly both electrolytes are sensitive to the material type involved. It is also noted that the efficiency obtained in this study for CdSe QDSSCs is lower compared to the values reported in the recent literatures where efficiency of more than 2.0% was obtained [22-24]. Beside different polysulfide electrolyte composition, the performance differences are largely due to different photoanode configuration, surface treatment, QD deposition method and type of counter electrode. It is acknowledged the best result from this work is lower as the photoanode has not been fully optimized. A better result is anticipated if all the photoanode parameters are optimized (i.e. TiO_2 film thickness, ZnS passive layer, scattering layer, and volume and size of QD deposited.). The choice of counter electrode also plays an important role in the cell performance. Commonly used platinum electrode may not be suitable with polysulfide electrolyte as the S compound will adsorb on the surface affecting the electrode performance [25].

The alternative will be Cu_2S electrode which has better catalytic activity for the reduction of S_x^{2-} species [10,23].

5.2.5 Stability of the electrolyte

From author's study as discussed in previous sections, the optimum polysulfide electrolyte for CdSe QDSSC consists of 0.5 M Na_2S, 0.1 M S and 0.05 M GuSCN in ethanol/water solution (8/2 by volume). To improve the stability of the electrolyte, the author has added 1 wt% of TiO_2 nanoparticles (< 400 nm) into the solution. TiO_2 is usually used as a filler in the preparation of stable high conducting polymer electrolytes. The author has investigated the performance of CdSe QDSSCs having electrolytes with and without TiO_2 nanoparticles under continuous soaking of light for two hours with a light intensity of 100 mW/cm^2. Initially the cell with the electrolyte having added TiO_2 shows an efficiency of 1.39% which is slightly lower than that of the cell without TiO_2 added (refer Table 5.6). Nevertheless, it has an improved photocurrent density of 7.70 mA/cm^2. When the illumination is continued, the efficiencies of both cells decrease with time. The efficiency of the cell using polysulfide electrolyte without added TiO_2 appears to decrease at a faster rate compared to that of the cell using electrolyte with added TiO_2. After two hours, the former reaches an efficiency of 0.72%, a decrease of about 50% from initial value. For the cell using polysulfide electrolyte with added TiO_2, the efficiency obtained after two hours of continuous light soaking is 1.02%. This translates to about 27% decrease from initial value. The decrease in performance is also noted and this can be attributed to the decrease of photocurrent density and open-circuit voltage. With the addition of TiO_2 to the electrolyte solution, stability of the cell has improved substantially presumably due to enhanced stability of the electrolyte. The efficiency variation of the two cells in the two-hour light soaking period is presented in

Figure 5.6. The presence of TiO_2 is thought to have adsorbed on the QD surface and thus passivating the QD surface states which in turn decreasing the recombination of electrons from the photoanode into the electrolyte [4]. Thus, an improved performance and better stability are achieved. Although the mechanism involved in the stability improvement of the cell due to addition of TiO_2 in the polysulfide electrolyte needs further investigation to understand, this method seems noteworthy for improving the stability of the QDSSCS using polysulfide liquid electrolytes.

When a CdSe-sensitized photoanode is dipped in the optimized polysulfide electrolyte solutions, UV-vis spectra obtained for the CdSe-sensitized photoanode before and after dipping into the electrolyte did not show any deviation. The results obtained are shown in Figure 5.7. There is no significant change of absorbance before and after dipping of the electrode. The CdSe-sensitized TiO_2 film appears to be having the same colour of dark brown before and after dipping (see inset in Figure 5.7). This signifies that no major chemical reaction occurs in the CdSe-sensitized TiO_2 film upon exposure to polysulfide electrolyte. These results emphasize that polysulfide electrolytes are a better choice for CdSe QDDSSCs as the electrolyte do not produce any serious deterioration of the QDs.

Table 5.6: Performance parameters of CdSe QDSSCs with and without TiO_2 nanoparticles in the electrolyte. Electroyte used: 0.5 M Na_2S, 0.1 M S, 0.05 M GuSCN in ethanol/water (8:2 by volume).

Composition	Time (min)	J_{SC} (mA/cm^2)	V_{OC} (V)	Fill factor (%)	Efficiency, η (%)
0.5M Na_2S + 0.1M S + 0.05M GuSCN	0	6.80	0.470	44.0	1.41
	120	4.36	0.40	41.0	0.72
0.5M Na_2S + 0.1M S + 0.05M GuSCN + 1wt% TiO_2	0	7.70	0.475	38.0	1.39
	120	5.27	0.430	45.0	1.02

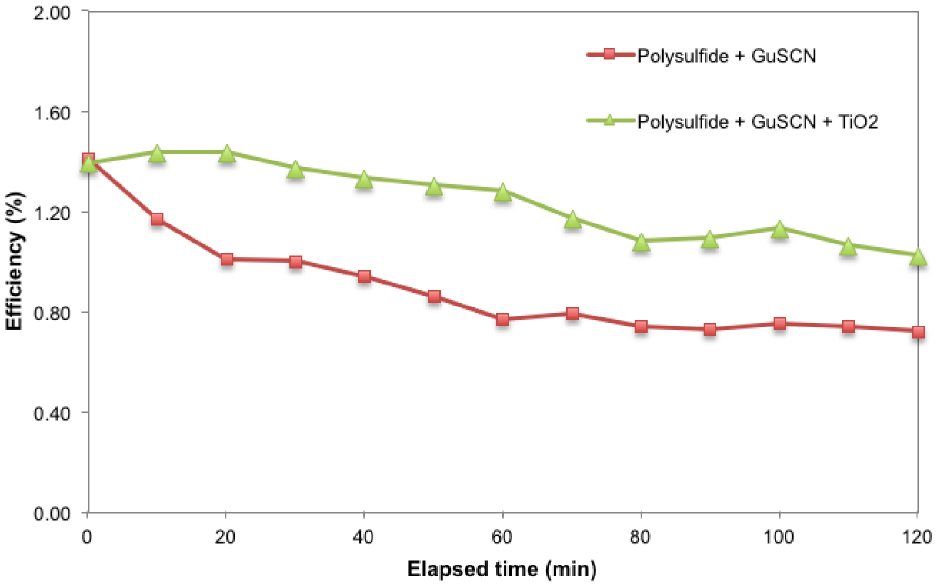

Figure 5.6: Efficiency variation of CdSe QDSSCs with time under two-hour light soaking. The polysulfide electrolytes used in the cells were with and without added TiO_2 nanoparticles.

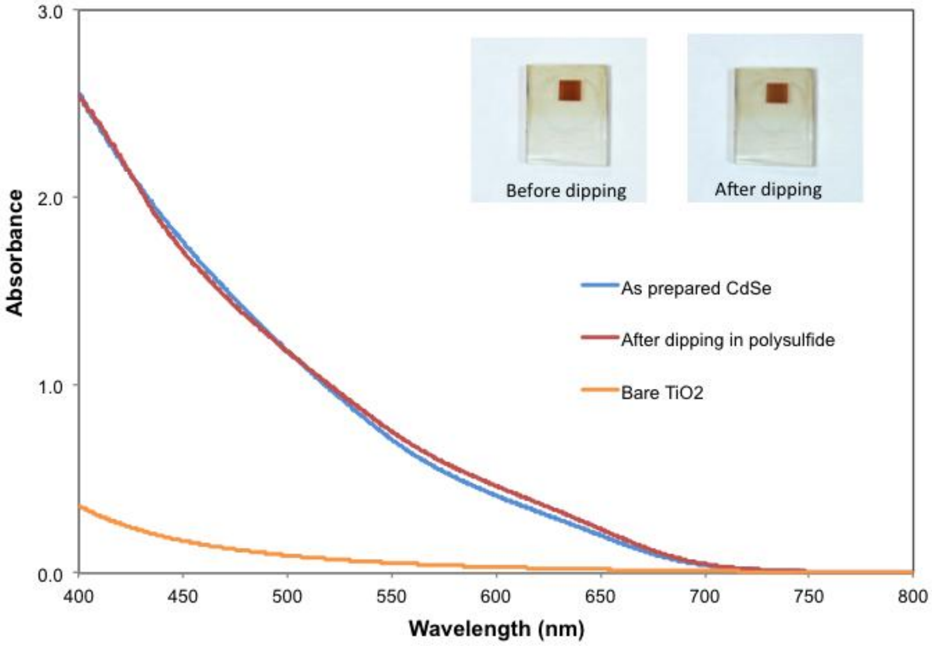

Figure 5.7: UV-vis spectra of CdSe-sensitized TiO_2 electrodes before and after dipping in polysulfide electrolytes (Inset: Photograph of CdSe-sensitized electrodes before dipping and after dipping in polysulfide electrolyte).

5.3 Summary

A suitable polysulfide electrolyte has been investigated for use in CdSe based QDSSCs. The optimum cell performance was obtained with polysulfide electrolyte consisting of 0.5 M Na_2S, 0.1 M S and 0.05 M GuSCN in ethanol/water (8/2 by volume) solution. The CdSe QDSSC with this optimized polysulfide electrolyte has an efficiency of 1.41%, a short circuit current density of 6.80 mA/cm^2, an open circuit voltage of 0.47 V and a fill factor of 44%. With the addition of TiO_2 nanoparticles to the electrolyte, the stability of the cell is enhanced. A higher photocurrent density was also obtained with the inclusion of TiO_2 nanoparticles. The polysulfide electrolyte has the potential to give good long term stability for the CdSe QDSSCs as the QDs do not appear to undergo any serious deterioration.

5.4 References

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