© 2016 IJSRST | Volume 2 | Issue 3 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

Optimization of CdS Layer on TiO_2 Nanoparticles for Efficient CdS/CdSe Co-Sensitized Solar Cell

T. T. Ha

Faculty of Physics, DongThap University, DongThap Province, Vietnam

ABSTRACT

In this work, we have studied the optical of the different electrodes through the UV-Vis and the Photoluminescense spectra (PL). The results show that the best electrons transport path is from the conduction band of CdSe to that of CdS, and finally, to TiO_2 films. Thus, the PL of TiO_2/CdS/CdSe was quenched. In addition, we have prepared the quantum dots solar cells with the power conversion efficiency of 1.21 %.

Keywords: Passivation, Solar Cells, Quantum Dots.

I. INTRODUCTION

Recently, the scientists in the world have interested in the quantum dots solar cells (QDSSCs) based on the TiO_2 subtrate. The QDSSCs based on the QDs have more advantages than the Dye sensitized solar cells (DSSCs) based on the molecules for some reasons: (1) the molecules only absorb the light in visible, (2) and are unstable in the air enviromental. Beside the disadvantages of the moleccules, the QDs has some advantages such as quantum confinement effect, the higher coefficients than the dyes, the generation of multiple electron – hole pairs by a single incident photon [1-2]. Moreover, the tunable adsorption band of the QDs can be perform by the changed their size for the light harvesters in QDSSCs [3].

For those reasons, the QDSSCs were promised to become the candidate for the high efficiency. Firstly, Vogel and colleagues prepared the QDSSCs based on CdS QDs and obtained the low efficiency [4]. In 2008, many scientists only studied the single QDs as CdS, CdSe, PbS… for the application in the QDSSCs. Therefore, the results obtained the low efficiency. For the next years, the series articles focus on the improving efficiency of the QDSSCs with the subject such as: to improve the adsorption of the photoanodes [5], [6]; to use the different methods such as chemical bath deposition (CBD), successive ionic layer adsorption and reaction (SILAR)... [7]; to apply the core – shell QDs to reduce the surface states in the QDs [8]. However, the efficiency of the QDSSCs was still lower than the efficiency of the DSSCs at the present due to the high surface states at the TiO_2/QDs contact and the large diffusion resistance in the TiO_2 film.

In this work, we have studied the optical of the different electrodes through the UV-Vis and the Photoluminescense spectra (PL). The results show that The best electrons transport path is from the conduction band of CdSe to that of CdS, and finally, to TiO_2 films. Thus, the PL of TiO_2/CdS/CdSe was quenched. In addition, we have prepared the quantum dots solar cells with the power conversion efficiency of 1.21 %.

II. METHODS AND MATERIAL

EXPERIMENT

The films were coated with TiO_2 layers by silk-screen printing, and were then annealed at 500°C for 30 minutes. Their sizes ranged from 10 nm to 30 nm. The thickness of the TiO_2 films was approximately 4 µm, as measured by a stylus. Then, the films were dipped in 40 mmol $TiCl_4$ solution for 30 minutes at 70°C and sintered at 500°C for 30 minutes.

TiO_2/CdS/CdSe/ZnS films were synthesized using the SILAR and colloidal synthesis methods. First, the TiO_2 film was dipped in 0.5 M Cd^{2+}-ethanol solution for 1

minute and rinsed with ethanol. Then, the film was dipped for 1 minute in 0.5 M S^{2-}-methanol solution and rinsed with methanol after being dried in air (a SILAR cycle). The number of CdS QDs increased by repeating the assembly cycles with three cycles. Second, the TiO_2/CdS assembly was immersed in CdSe solution (size ~3 nm) for 20 hours before being dried at room temperature. For the ZnS passivation layers, TiO_2/CdS/CdSe photoanodes were dipped into 0.1 M Zn^{2+} and 0.1 M S^{2-}-solutions for 1 minute and rinsed with pure water between the two dips (a total of two cycles). Finally, the films were annealed in a vacuum environment at 300°C to prevent oxidation. The TiO_2/CdS/CdSe/ZnS thickness was measured using a stylus. The average thickness of CdS (3 cycles), CdSe (20 hours), and ZnS (2 cycles) were 351.9 nm, 80 nm and 257.8 nm respectively.

Fabrication of QDSSCs

The structure of the QDSSCs was designed using a Surlyn between the photoanodes and counter electrodes at 170°C. The electrolyte was filled from a hole made on the counter electrode. The active area of the QDSSCs was 0.38 cm^2. The polysulfide electrolyte consisted of 0.5 M Na_2S, 0.2 M S and 0.2 M KCl in Milli-Q ultrapure water/methanol (7:3 by volume).

Characterization

The morphologies of the samples were investigated using transmission electron microscopy (TEM). The crystal structure was analyzed using an X-ray diffractometer (Philips, PANalytical X'Pert, CuKα radiation). The absorption properties of the samples were investigated using a diffuse reflectance UV–vis spectrometer (JASCO V-670). Photocurrent voltage measurements were performed on a Keithley 2400 source meter using a simulated AM 1.5 sunlight with an output power of 100 mW/cm^2 produced by a solar simulator (Solarena, Sweden).

III. RESULT AND DISCUSSION

To investigate the change of the tructural TiO_2 electrodes after annealing treatment, the Raman analysis was performed. Figure 1 shows the raman of different photoanodes such as: without annealing and annealing at 200^0C and 300^0C. The peaks at 145cm^{-1}, 395cm^{-1}, 518cm^{-1}, 639cm^{-1} is the oscillation modes correspond to the TiO_2 anatase and the oscillation modes 1LO (205 cm^{-1}), and 2LO (410cm^{-1}) the CdSe cubic. In addition, The sample at 300^0C appeared a 280 cm^{-1} peak correspond to –Se-Se- oscillation mode of CdS_xSe_{1-x} ligands. So, from results of the raman, we noted that the CdSe QDs loaded on the TiO_2 film.

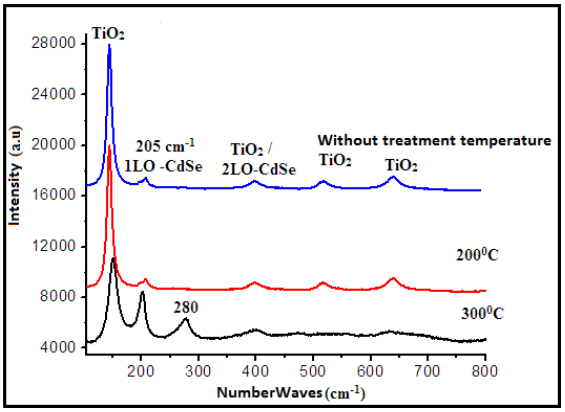


Figure 1. The Raman of the TiO_2/CdSe photoanode.

Figure 2a shows the UV−vis absorption spectra of CdS/CdSe/TiO_2 films with different thickness of CdS QDs. In order to remove the light scattering effect of TiO_2 films, the spectra curves were obtained by deducting the absorbance of TiO_2 films with different thickness. It is found that the absorption of the films increases with the increasing film thickness, indicating that the amount of CdS QDs increases accordingly. The shift of absorption edges from the short to long wavelength with the increase of the film thickness suggests that CdS QDs get larger with an increasing film thickness. The size of CdS QD can be estimated using the UV−visible absorption spectrum. It is not the intention of this paper to discuss the size of CdS, because the CdS layer serves as the seed layer to enhance the CdSe growth rate and is surrounded by CdSe.

Figure 2b shows the PL of different photoanodes that their thickness is changed by the CdS cycles SILAR. After the CdS and CdSe QDs are sequentially deposited onto the TiO_2 film, a cascade type of energy band structure is constructed for the co-sensitized photoanodes (Figure 3a). The best electrons transport path is from the conduction band of CdSe to that of CdS, and finally, to TiO_2 films. Thus, the PL of TiO_2/CdS/CdSe was quenched (displayed in Figure 2b). This reveal that TiO_2 film serve as effective quenchers of excited CdS and

CdSe QDs. The thickness photoanodes quenches more efficiently than films.

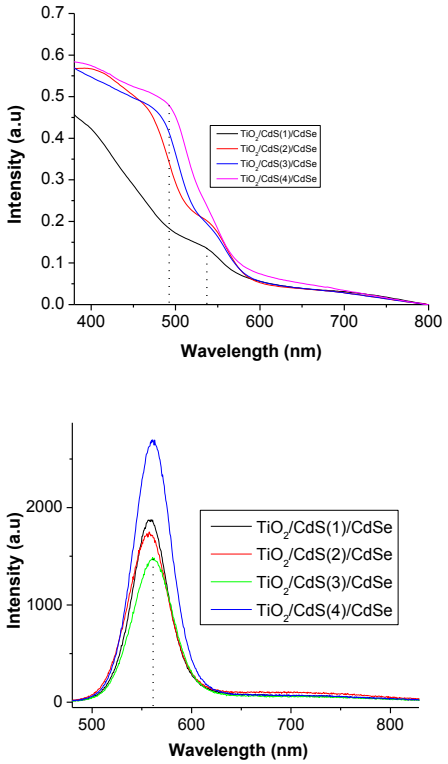
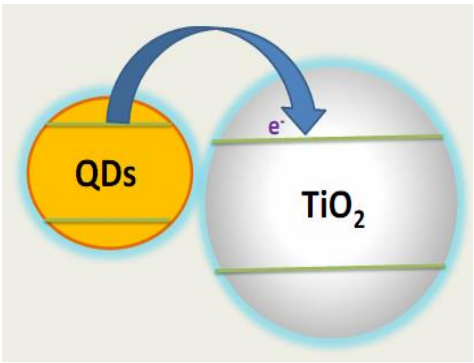


Figure 2. (a) The UV-Vis and (b) the PL spectra of the QDSSCs based on the different photoanodes.



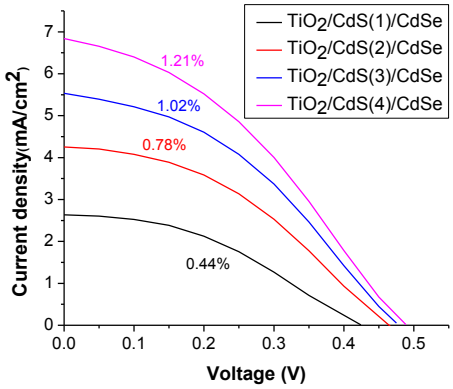


Figure 3. (a) The schematic of energy band levels in the QDSSCs and (b) the I-V curves of the QDSSCs

Table 1. Photovoltaic performance parameters of the QDSSCs

Solar Cells	J_{SC} (mA/cm^2)	V_{OC}(V)	Efficiency η(%)
TiO_2/CdS(1)/CdSe	2.6	0.4	0.44
TiO_2/CdS(2)/CdSe	4.3	0.5	0.78
TiO_2/CdS(3)/CdSe	5.5	0.5	1.02
TiO_2/CdS(4)/CdSe	5.5	0.49	1.21

The TiO_2/CdS/CdSe photoelectrode films were as a function of CdS thickness in the quantum dots solar cells. Figure 3b shows the photocurrent voltage (I−V) curves for the solar cells measured under the illumination of 1 sun (AM 1.5, 100 mW/cm^2). The performance parameters of the solar cells, including open circuit potential (V_{oc}), short circuit current (J_{sc}) and power conversion efficiency (η), are listed in Table 1. It can be seen that J_{sc} increases with the increasing of CdS thickness from 1 to 4 layers. The increasing of J_{sc} is mainly caused by the increasing of CdSe amount for more optical absorption. From the results shown in Table 1, we can also see that V_{oc} also increases light continuously as increasing film thickness. This further evidences the existence of charge recombination, which is related to the electrons diffusion. A thicker film results in longer electron diffusion distance and therefore higher recombination rate. This eventually results in lower open circuit voltage. In our study, the highest efficiency, ~1.21 %, was obtained when the layers were 4 in thickness. This can be explained by the inhomogeneous distribution of QDs in the TiO_2 nanocrystalline film, which mainly concentrates at the top layer in the region of 4 layers.

IV. CONCLUSION

The QDSSCs based on the TiO_2/CdS/CdSe photoanodes with the different CdS QDs thicknesses. The results show that The best electrons transport path is from the conduction band of CdSe to that of CdS, and finally, to TiO_2 films. Thus, the PL of TiO_2/CdS/CdSe was quenched.

In addition, we have prepared the quantum dots solar cells with the power conversion efficiency of 1.21 %.

V. ACKNOWLEDGMENTS

The author would like to thank Ho Chi Minh city of Science and Dong Thap university, Vietnam.

VI. REFERENCES

[1] Nozik, A, J (2005), Exciton Multiplication and Relaxation Dynamics in Quantum Dots: Applications to Ultrahigh-Efficiency Solar Photon Conversion. Inorg. Chem. 44, 6893-6899.

[2] Wu. Jiang, Wang. Zhiming M. (2014), Quantum Dot Solar Cells. Springer-Verlag New York, Volume 15.

[3] Guyot-Sionnest, P (2008), Colloidal Quantum Dots. C. R. Physique. 9, 77-787.

[4] Vogel R, Pohl K, Weller H. (1990), Sensitization of highly porous polycrystalline TiO2 electrodes by quantum sized CdS, Chem Phys Lett,174,241-6.

[5] Lee Y. L, Lo Y. S. (2009), Highly efficient quantum-dot-sensitized solar cell based on co-sensitization of CdS/CdSe, Advanced Functional Materials, 19, 604–609.

[6] Zhang Q, Zhang Y, Huang S, Huang X, Luo Y, Meng Q, Li D. (2010), Application of carbon counterelectrode on CdS quantum dot-sensitized solar cells (QDSSCs), Electrochemistry Communications,12, 327–30.

[7] Chen J, Zhao DW, Song JL, Sun XW, Deng WQ, Liu XW, Lei W. (2009), Directly assembled CdSe quantum dots on TiO2 in aqueous solution by adjusting pH value for quantum dot sensitized solar cells, Electrochemistry Communications, 11, 2265–7.

[8] Yu X-Y, Lei B-X, Kuang D-B, Su C-Y. (2012), High performance and reduced charge recombination of CdSe/CdS quantum dot-sensitized solar cells, J Mater Chem, 22, 12058–63.