ABSTRACT

CdS and CdSe quantum dots (QDs) which have excellent optical properties were used as sensitizer for the application in solar cells. CdS and CdSe quantum dot-sensitized solar cells (QDSSCs) were fabricated and studied for determining the optimum preparation parameters that produce the best cell performance. CdS and CdSe QD-sensitized TiO_2 electrodes were prepared by successive ionic layer adsorption and reaction (SILAR) method. Three preparation parameters were optimized for QD fabrication: concentration of precursor solutions, number of dipping cycles and dipping time per cycle in each solution. CdS QDSSC achieved optimum performance when the QDs were prepared with preparation parameter of 0.10 M precursor solution concentration and 4 dipping cycles with 5 minutes dipping time in each solution. For CdSe QDSSC, optimum performance was achieved when QDs were prepared from 0.03 M precursor solution concentration and 7 dipping cycles with each dipping lasted for 30 seconds. The performance of CdSe QDSSC was further improved with an improved polysulfide electrolyte. A suitable polysulfide electrolyte for CdSe QDSSC composed of 0.5 M Na_2S, 0.1 M S and 0.05 M GuSCN. The effect of counter electrode materials were also explored. It was found that both CdS and CdSe QDSSCs performed best when carbon and commercial platinum catalyst were used as their counter electrodes respectively. When a passivation layer of ZnS was applied on the working electrode, a better performance was observed. However, other Zn chalcogenides (ZnSe and ZnTe) did not produce the same effect due to high electron recombination at the photoanode/electrolyte interface. The best CdSe QDSSC performance was obtained when a 24 μm thick TiO_2 was applied with ZnS passivation layer. Its efficiency was 3.05%. For CdS QDSSC, doping with Mn^{2+} and applied with ZnS passivation layer produced the best efficiency of 1.89%.

ABSTRAK

Titik-titik kuantum CdS dan CdSe yang memiliki sifat-sifat optikal yang baik telah digunakan sebagai sensitizer untuk applikasi sel solar. Sel-sel solar titik kuantum tersensitisasi (SSTKT) CdS dan CdSe telah direka dan dikaji untuk menentukan parameter penyediaan optimum bagi menghasilkan sel berprestasi tinggi. Titik kuantum CdS dan CdSe tersensitisasi elekrod TiO_2 telah disediakan melalui kaedah penjerapan dan tindak balas lapisan ionik berturutan. Tiga parameter penyediaan telah dioptimumkan untuk pembuatan titik kuantum: kepekatan larutan-larutan pendahulu, bilangan kitar celupan dan masa celupan dalam setiap larutan. SSTKT CdS mencapai prestasi optimum apabila titik-titik kuantumnya disediakan dengan 0.10 M kepekatan larutan pendahulu dan 4 kitar celupan dengan 5 minit masa celupan setiap larutan. Untuk SSTKT CdSe, prestasi optimum dicapai apabila titik-titik kuantumnya disediakan daripada larutan pendahulu berkepekatan 0.03 M dan 7 kitar celupan dengan 30 saat setiap celupan. Prestasi bagi SSKTK CdSe seterusnya dipertingkatkan dengan menggunakan elektrolit polisulfida yang telah ditambah-baikkan di mana komposisinya terdiri daripada 0.5 M Na_2S, 0.1 M S dan 0.05 M GuSCN. Kesan bahan-bahan elektrod kaunter yang berlainan juga diterokai. Didapati bahawa kedua-dua SSTKT CdS dan CdSe menunjukkan prestasi terbaik apabila karbon dan pemangkin platinum komersial digunakan sebagai elektrod kaunter masing-masing. Apabila lapisan pasivasi ZnS diterapkan ke atas elektrod kerja, prestasi sel solar yang lebih baik telah diperhatikan. Walau bagaimanapun, chalcogenide Zn yang lain (ZnSe dan ZnTe) tidak menunjukkan kesan yang sama disebabkan penggabungan semula elektron yang tinggi di antara muka fotoanod/elektrolit. SSTKT CdSe berprestasi tinggi telah diperolehi apabila TiO_2 berketebalan 24 μm digunakan dengan lapisan pasivasi ZnS. Kecekapan sel yang diperolehi ialah 3.05%. Untuk SSTKT CdS, Mn^{2+} “doping” dengan lapisan pasivasi ZnS telah menghasilkan kecekapan yang terbaik iaitu 1.89%.

LIST OF PUBLICATIONS

Articles published in ISI-cited journals which are related to this thesis:

- Jun, H.K., Careem, M.A., & Arof, A.K. (2014). Fabrication, characterization and optimization of CdS and CdSe quantum dot-sensitized solar cells with quantum dots prepared by successive ionic layer adsorption and reaction. *International Journal of Photoenergy*, Volume 2014, Article ID 939423, 14 pages.

- Jun, H.K., Careem, M.A., & Arof, A.K. (2014). Efficiency improvement of CdS and CdSe quantum dot-sensitized solar cells by TiO_2 surface treatment. *Journal of Renewable and Sustainable Energy*, 6, 023107.

- Jun, H.K., Careem, M.A., & Arof, A.K. (2014). Performances of some low-cost counter electrode materials in CdS and CdSe quantum dot-sensitized solar cells. *Nanoscale Research Letters*, 9, 69.

- Jun, H.K., Careem, M.A., & Arof, A.K. (2013). A suitable polysulfide electrolyte for CdSe quantum dot-sensitized solar cells. *International Journal of Photoenergy*, Volume 2013, Article ID 942139, 10 pages.

- Jun, H.K., Careem, M.A., & Arof, A.K. (2013). Quantum dot-sensitized solar cells – perspective and recent developments: A review of Cd chalcogenide quantum dots as sensitizers. *Renewable and Sustainable Energy Reviews*, 22, 148-167.

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- Jun, H.K., Buraidah, M.H., Noor, M.M., Kufian, M.Z., Majid, S.R., Sahraoui, B., *et al.* (2013). Application of LIBOB-based liquid electrolyte in co-sensitized solar cell. *Optical Materials*, 36, 151-158.

- Arof, A.K., Jun, H.K., Sim, L.N., Kufian, M.Z., & Sahraoui, B. (2013). Gel polymer electrolyte based on LIBOB and PAN for the application in dye-sensitized solar cells. *Optical Materials*, 36, 135-139.

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- Jun, H.K., Careem, M.A., & Arof, A.K. Performance of multilayered quantum dot-sensitized solar cells with different Zn chalcogenide passivation layers.

Papers presented:

- Jun, H.K., & Arof, A.K. (January 2014). *Efficiency improvement of CdS and CdSe quantum dot-sensitized solar cells by means of TiO_2 surface morphology alteration.* Poster presented at the International Conference on Science and Engineering of Materials, ICSEM – 2014, Greater Noida, India.

- Jun, H.K., Careem, M.A., & Arof, A.K. (August 2013). *Anthocyanin and quantum dots co-sensitized solar cells with a common cobalt-based electrolyte*. Poster presented at the 2nd International Conference on Solar Energy Materials, Solar Cells and Solar Energy Applications, Kuala Lumpur, Malaysia.

- Jun, H.K., Noor, M.M., Careem, M.A., & Arof, A.K. (June 2013). *A study on a natural dye-sensitized solar cell on co-sensitization with Cd chalcogenide quantum dots*. Poster presented at the 3rd International Conference on Semiconductor Sensitized and Quantum Dot Solar Cells, Granada, Spain.

- Jun, H.K., Careem, M.A., & Arof, A.K. (April 2013). *Efficiency improvement study of CdSe quantum dot-sensitized solar cell*. Poster presented at the 4th International Conference on Functional Materials & Devices 2013 (ICFMD-2013), Penang, Malaysia.

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ABBREVIATIONS

CB	Conduction band
CBD	Chemical bath deposition
$Cd(NO_3)_2$	Cadmium nitrate
CdS	Cadmium sulfide
CdSe	Cadmium selenide
CE	Counter electrode
Cu_2S	Copper sulfide
DSSC	Dye-sensitized solar cell
EDX	Energy dispersive x-ray
EIS	Electrochemical impedance spectroscopy
FESEM	Field emission scanning electron microscopy
FF	Fill factor
GuSCN	Guanidine thiocyanate
IPCE	Incident photon to current efficiency
J-V	Current density-voltage
J_{SC}	Short-circuit current density
KCl	Potassium chloride
MEG	Multiple exciton generation
Na_2S	Sodium sulfide
QD	Quantum dot
QDSSC	Quantum dot-sensitized solar cell
RGO	Reduced graphene oxide
RMS	Root mean square
SILAR	Successive ionic layer adsorption and reaction

TCO	Transparent conducting oxide
TEM	Transmission electron microscopy
TiO_2	Titanum dioxide
VB	Valence band
V_{OC}	Open-circuit voltage
ZnS	Zinc sulfide
ZnSe	Zinc selenide
ZnTe	Zinc telluride
η	Efficiency