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A Brief Review on the Polymer thin Film Solar Cells

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ABSTRACT

There has been considerable interest over the past few years in polymer thin film solar cell due to many benefits such as low fabrication cost, flexible devices and lightweight. The main objective of this paper to describe the fabrication of polymer solar cells in different growth conditions as reported by many researchers. Comparison of power conversion efficiency by using different active materials in solar cells was discussed. Lastly, the improvement of the efficiency as mentioned in their experimental results was reported.
Keywords: Polymer Solar Cells, Thin Films, Power Conversion Efficiency.

I. INTRODUCTION

Polymer thin film solar cells made with polymers, and can generate electricity from sunlight by the photovoltaic effect. Recently, they are gaining much important because of some advantages including flexibility (Lei et al., 2015), lightweight, low material cost (Rachel et al., 2012; Yip and Jen, 2012; Yeh and Yeh, 2013) and independence on scarce resources. The results obtained by researchers indicate that the power conversion efficiency of these solar cells have been increased in the past few years. There are a lot of efforts have been done in order to improve the device performance, so that they can meet the requirement for commercial application and also compete with the conventional inorganic solar cells. Currently, these inorganic solar cells are blooming and their market shares are increasing. Up-to-date, researchers have successfully deposited metal sulfide (Table 1), metal telluride (Table 2) and metal selenide (Table 3) semiconductor thin films which could be used to produce absorber materials in inorganic solar cells.

Table 1: Metal sulfide thin films

Thin films	References
NiS	Anuar et al (2011 a)
CdS	Taz et al (2015)
Cu_4SnS_4	Anuar et al (2009a)
$Cd_{1-x}Zn_xS$	Zhou et al (2015)
Cu_2S	Anuar et al (2011b)
$Cu_{1-x}Cd_xS_2$	Kumar et al (2015)
FeS_2	Anuar et al (2010a)
SnS	Safonova et al (2015) Anuar et al (2011c)
ZnS	Claudia et al (2015) Anuar et al (2010b)
MnS	Anuar and Ho (2010)
FeS	Muhammad et al (2015) Anuar et al (2010c)
CuS	Anuar et al (2011d)
ZnS:Ni	Reza and Soraya (2015)
$Ni_3Pb_2S_2$	Ho (2014)
In_2S_3	Mesa et al (2015)
MnS_2	Anuar et al (2010d)
Ag-Sn-S	Yeh and Cheng (2015)
PbS	Ersin et al (2015)

Table 2: Metal telluride thin films

Thin films	References
CdZnTe	Vidhya et al (2015)
CdTe	Douglas et al (1997)
CuTe	Fulari et al (2010)
Cu_2Te	He et al (2015)

ZnTe	Amutha et al (2007)

Table 3: Metal selenide thin films

Thin films	References
ZnSe	Anuar et al (2011e)
NiSe	Nader and Tahere (2015) Anuar et al (2009b)
PbSe	Anuar et al (2011f)
SnSe	Anuar et al (2012)
$CuInSe_2$	Pottier and Maurin (1989)
CdSe	Mahato and Kar (2015) Cephas et al (2015)

II. METHODS AND MATERIAL

In this work, polymer solar cells were fabricated using various methods as reported by many researchers from around the world. The power conversion efficiency was measured and reported. Also, the improvements of the solar cells were discussed and material requirements were investigated.

Literature Review

Chen et al. (2015) developed high speed rotating thermal decomposition technique to produce Ag_2S films on indium tin oxide substrate. In the scanning electron microscopy results, the surface of Ag_2S films are smooth, uniform and no agglomeration of nanoparticles is detected. The particle size is observed to be in the range of 15-70 nm. Furthermore, the film thickness and surface roughness were recorded about 287 nm and 10 nm, respectively. They claim that more Ag_2S particles are aggregated together with increasing cycles. Additionally, their experimental results show that the open circuit voltage and short circuit photocurrent of the ITO/Ag_2S/P_3HT:PCBM/MoO_3/Au solar cell increase with increasing cycle number from 10 (0.96%) cycles to 60 cycles (2.21%). They explain that the Ag_2S/P_3HT interfaces may provide more donor/acceptor area for exciton dissociation and charge transfer, eventually lead to the improvement of charge collection efficiency.

A series of experiments have been conducted by Lu et al. (2015) on the influence of solvent treatment on the performance of ITO/PEDOT:PSS/PTB7:$PC_{71}BM$ /Ca/Al solar cells. They observe the solar cells that experience methanol (7.74%), ethanol (7.63%), n-propanol (7.19%) and isopropanol (7.3%) treatment present higher conversion efficiency than without treatment of alcohol. It is due to the fact that solvent treatment promotes the separation of the photo generated excitons. On the other hand, according to atomic force microscopy results, the surface of active layer does not deteriorate after treating by these alcohols. Additionally, they observe that the alcohol treatment make the roughness of the corresponding surface lower than that of the reference surface.

Fu et al. (2015) reported the zinc oxide nanoarrays were synthesized using hydrothermal process. They compare the polymer solar cell performance according to different electron transport layer of bare zinc oxide nanoarrays (ZnO NA) and with CdS organic molecules sensitizers. The power conversion efficiency of 3.1% could be obtained for ZnO NA. After incorporation of cadmium sulfide (3.5%) and organic molecules such as TP-OH (4%), Py-OH (4.2%) and BP-OH (3.8%) onto zinc oxide nanoarrays, the efficiency could be increased significantly.

Wang et al. (2015) designed two spirobifluorene based isomeric acceptors, namely SBF1 and SBF2 in their research. They point out that the mobility of SBF2 higher than that of SBF1. They show that high electron mobility can ensure effective charge carrier transport to the electrodes, and then reduce the photocurrent loss in solar cell. As a result, they obtain power conversion efficiency of 0.17-0.63 % and 0.31-0.97% for SBF1 and SBF2, respectively.

Lei et al. (2015) prepared n-type Ag_3CuS_2 films on ITO substrate at room temperature. They found that the band gap about 1.25 eV with direct semiconductor in optical properties studies. Then, various types of solar cell were fabricated. The obtain results reflect that the Ag_3CuS_2/P3HT solar cells (0.79%) have higher power conversion efficiency if compared to Ag_3CuS_2/PTB7 devices (0.31%) under simulated illumination.

Jiangsheng et al. (2015) proposed a new strong electron deficient acceptor unit, namely TQxT in their experiments. Furthermore, three TQxT based new conjugated polymers have been successfully developed. They reveal that these polymers show absorption spectra beyond near infrared region. Photovoltaic behaviors of fabricated solar cells with different doping ratio of ultra-low band gap polymer were investigated. The results show that power conversion efficiency increases with increasing PBDTT-TQxP ratios from 3% (3.31%), 6% (3.5%) to 9% (3.58%), indicating that doping ratio could play an important role in optimizing photovoltaic performance.

Yu et al. (2015) synthesized P3HT/MWNT nanocomposites with various concentrations of multiwalled carbon nanotube (MWNT). They fabricated solar cell and claimed that the power conversion efficiency increases with the ratio of carbon nanotubes. For example, the conversion efficiency obtained using P3HT/MWNT ratio of 1:1, 1:0.5 and 1: 0.1 demonstrated conversion efficiency of 0.93%, 0.8% and 0.51%, respectively as shown in the solar cell prepared with no PEDOT:PSS layers. Meanwhile, the conversion efficiency was 1.01%, 1.18% and 2.16% for the solar cell using P3HT/MWNT ratio of 1:0.1, 1: 0.5 and 1:1, respectively. In another case, they point out that the solar cell with PEDOT:PSS layers displayed superior conversion rates to those with no PEDOT:PSS layers.

Zhao et al. (2015) reported the solar cell fabricated without hole transfer layer produces lower conversion efficiency of 2.34%, 4.34% and 4.71% in P3HT:PC61BM, PCDTBT:PC71BM, PTB7:PC71 BM, respectively. This is due to the reasons such as large series resistance and leakage current. They concluded that best power conversion efficiency of these solar cells which prepared under the optimized conditions reach up to 3.62%, 7.03% and 7.56%. They explain that an increase of the photo absorption of the photoactive layer and the conductivity, leads to the great improvement for the high efficiency of solar cells.

III. RESULTS AND DISCUSSION

Ti doped indium oxide (TlO) films have been produced using polymer assisted solution process by Sujaya et al. (2015). They suggest that the best growth conditions were 3% of Ti doping concentration and annealing temperature of 700 °C in order to produce the films display a sheet resistance of 330 Ω/sq and had a thickness of 130 nm. The obtained TlO films were applied as electrodes for the fabrication of solar cell consisting of glass/PAS-coated TlO/ZnO/PTB-7:PC_{71}BM/PEDOT:PSS/Ag. The lower conversion efficiency on this type of solar cell (4.6%) is due to the relatively high sheet resistance if compared to solar cell prepared on the commercial indium tin oxide (7.42%).

Polymer thin films solar cells have certain drawbacks such as low efficiency if compared to the crystalline silicon cells. In other words, they cannot replace for silicon cells in the energy conversion field. Also, this type of solar cell has short life time for large area devices as reported by Son et al. (2012). On the other hand, it has been reported by many researchers (Carsten and Vladimir, 2012; Blom et al., 2007) that the thickness of organic active layer is limited to a few hundred nanometers because of the intrinsically short exciton diffusion length of organic materials. As a result, this phenomenon leads to insufficient light harvesting of polymer solar cells.

IV. CONCLUSION

Polymer solar cells have drawn considerable interest by many researchers. They observe that the power conversion efficiency of these solar cells have been improved, and steadily increased in the past few years. Lastly, there is a very strong need for the development of polymer solar cells with low cost and high efficiency.

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VI. REFERENCES

[1]. Amutha, R., Subbarayan, A., Sathyamoorthy, R., Natarajan, K., Velumani, S. 2007. Conduction studies on ZnTe thin films. Journal of New Materials for Electrochemical Systems. 10: 27-31.

[2]. Anuar, K., Ho, S.M., Tan, W.T., Ngai, C.F. 2011a. Influence of triethanolamine on the chemical bath deposited NiS thin films. American Journal of Applied Sciences, 8: 359-361.

[3]. Anuar, K., Ho, S.M., Lim, K.S., Saravanan, N. 2011b. SEM, EDAX and UV-Visible studies on the properties of Cu_2S thin films. Chalcogenide Letters. 8: 405-410.

[4]. Anuar, K., Ho, S.M., Atan, S., Haron, M.J. 2011c. The effect of the pH value on the growth and properties of chemical bath deposited SnS thin films. Research Journal of Chemistry and Environment. 15:45-48.

[5]. Anuar, K., Ho, S.M., Tee, W.T., Lim, K.S., Saravanan, N. 2011d. Morphological characterization of CuS thin films by atomic force microscopy. Research Journal of Applied Sciences, Engineering and Technology. 3: 513-518.

[6]. Anuar, K., Ho, S.M., Tan, W.T., Kelvin, Saravanan, N. 2011e. Composition, morphology and optical characterization of chemical bath deposited ZnSe thin films. European Journal of Applied Sciences. 3: 75-80.

[7]. Anuar, K., Ho, S.M., Saravanan, N. 2011f. Preparation of lead selenide thin films by chemical bath deposition method in the presence of complexing agent (tartaric acid). Turkish Journal of Science and Technology. 6: 17-23.

[8]. Anuar, K., Saravanan, N., Tan, W.T., Atan, S., Kuang, Z., Haron, M.J., Ho, S.M. 2009a. Effect of Deposition Period and pH on Chemical Bath Deposited Cu_4SnS_4 Thin Films. Philippine Journal of Science. 138: 161-168.

[9]. Anuar, K., Tan, W.T., Abdullah, A.H., Jelas, M., Saravanan, N., Ho, S.M., Yazid, M. 2009b. Chemical bath deposition of NiSe thin films from alkaline solutions using triethanolamine as complexing agent. Oriental Journal of Chemistry. 25: 813-816.

[10]. Anuar, K., Tan, W.T., Jelas, M., Ho, S.M., Gwee, S.Y. 2010a. Effects of deposition period on the properties of FeS_2 thin films by chemical bath deposition method. Thammasat International Journal of Science and Technology. 15: 62-69.

[11]. Anuar, K., Saravanan, N., Ho, S.M., Noraini, K. 2010b. XRD and AFM studies of ZnS thin films produced by electrodeposition method. Arabian Journal of Chemistry. 3: 243-249.

[12]. Anuar, K., Ho, S.M., Atan, S., Saravanan, N. 2010c. X-ray diffraction and atomic force microscopy studies of chemical bath deposited FeS thin films. Studia Universitatis Babes-Bolyai, Seria Chemia. 55: 5-11.

[13]. Anuar, K., Abdullah, A.H., Ho, S.M., Saravanan, N. 2010d. Influence of deposition time on the properties of chemical bath deposited manganese sulfide thin films. Avances en Quimica. 5: 141-145.

[14]. Anuar, K., Ho, S.M., Tan, W.T., Ho, S.M., Saravanan, N. 2012. Temperature-dependent surface topography analysis of SnSe thin films using atomic force microscopy. Asian Journal of Research in Chemistry. 5: 291-294.

[15]. Anuar, K., Ho, S.M. 2010. Deposition and characterization of MnS thin films by chemical bath deposition method. International Journal of Chemistry Research. 1: 1-5.

[16]. Blom, P.W.M., Mihailetchi, V.D., Koster, L.J.A., Markov, D.E. 2007. Device physics of polymer: Fullerene bulk heterojunction solar cells. Advanced Materials. 19: 1551-1566.

[17]. Carsten, D., Vladimir, D. 2010. Polymer-fullerene bulk heterojunction solar cells. Reports on Progress in Physics. 73.

[18]. Cephas, A.V., Sartale, S.D., Patil, J.M., Ghoderao, K.P., Sawant, J.P., Kale, R.B. 2015. Room temperature chemical bath deposition of cadmium selenide, cadmium sulfide and cadmium sulfoselenide thin films with novel nanostructures. Solid State Sciences. 48: 186-192.

[19]. Chen, L., Wang, S., Han, C., Cheng, Y., Qian, L. 2015. Performance improvement of inverted polymer solar cells by incorporating Au and ZnO nanoparticles bilayer plasmonic nanostructure. Synthetic Metals. 209: 544-548.

[20]. Claudia, M.G., Luque, P.A., Beltran, A., Nestor, A.R., Lugo, E., Castillo, A., Lopez, M.A., Olivas, A. 2015. Study of morphology of ZnS thin films deposited on different substrates via chemical bath deposition. Scanning. doi: 10.1002/sca.21227.

[21]. Douglas, L.S., Martin, P., Doug, H.R., Ed, U., Andrew, F.C., David, W.N., Kim, M.J., Randy, J.E., Calvin, J.C., David, S.G. 1997. CdTe thin films from nanoparticle precursors by spray deposition. Chemistry of Materials. 9: 889-900.

[22]. Ersin, Y., Yasin, Y., Buse, B. 2015. Optimization of synthesis conditions of PbS thin films grown by chemical bath deposition using response surface methodology. Journal of Alloys and Compounds. 642: 63-69.

[23]. Fu, H., Li, B., Meng, X., Tan, L., Shen, X., Chen, Y. 2015. Interfacial engineering of ZnO nanoarrays as electron transport layer for polymer solar cells. Organic Electronics. 26: 487-494.

[24]. Fulari, V.J., Prakash, M.V., Gandawane, S.A. 2010. Measurement of properties of copper telluride thin films using holography. Progress in Electromagnetics Research. 12: 53-64.

[25]. He, W., Zhang, H., Zhang, Y., Liu, M., Zhang, X., Yang, F. 2015. Electrodeposition and characterization of CuTe and Cu2Te thin films. Journal of Nanomaterials. http://dx.doi.org/10.1155/2015/240525.

[26]. Ho, S.M. 2014. Influence of complexing agent on the growth of chemically deposited $Ni_3Pb_2S_2$ thin films. Oriental Journal of Chemistry. 30: 1009-1012.

[27]. Jiangsheng, Y., An, Q., Hai, J., Nie, X., Zhou, B., Zhang, F., Tang, W. 2015. Thiadiazole quinoxaline-based copolymers with 1.0 eV band gap for ternary polymer solar cells. Polymer. 79: 12-20

[28]. Kumar, V.N., Suryakarthick, R., Karuppusamy, S., Gupta, M., Hayakawa, Y., Gopalakrishnan, R. 2015. Effect of precursor concentration on the properties and tuning of conductivity between p-type and n-type $Cu_{1-x}Cd_xS_2$ thin films deposited by a single step solution process as a novel material for photovoltaic applications. RSC Advances. 5: 23015-23021.
[29]. Lei, Y., Yang, X., Gu, L., Jia, H., Ge, S., Xiao, P., Fan, X., Zheng, Z. 2015. Room temperature preparation of trisilver copper sulfide/polymer based heterojunction thin film for solar cell application. Journal of Power Sources, 280: 313-319.
[30]. Lu, S., Liu, K., Chi, D., Yue, S., Li, Y., Kou, Y., Lin, X., Wang, Z., Qu, S., Wang, Z. 2015. Constructing bulk heterojunction with componential gradient for enhancing the efficiency of polymer cells. Journal of Power Sources. 200: 238-244.
[31]. Mahato, S., Kar, A.K. 2015. Structural, optical and electrical properties of electrodeposited cadmium selenide thin films form applications in photo detector and photoelectrochemical cell. Journal of Electroanalyrical Chemistry. 742: 23-29.
[32]. Mesa, F., Chamorro, W., Hurtado, M. 2015. Optical and structural study of In_2S_3 thin films growth by co-evaporation and chemical bath deposition on Cu_3BiS_3. Applied Surface Science. 350: 38-42.
[33]. Muhammad, S.A., Asma, A., Mohammad, A.M. 2015. Synthesis of mackinawite FeS thin films from acidic chemical baths. Materials Science in Semiconductor Processing. 32: 1-5.
[34]. Nader, G., Tahere, A.B. 2015. Shapes alteration and optical band gap controlling in NiSe nanostructure thin films with deposition temperature changing. Optik-International Journal for Light and Electron Optics. 126: 4557-4560.
[35]. Pottier, D., Maurin, G. 1989. Preparation of polycrystalline thin films of $CuInSe_2$ by electrodeposition. Journal of Applied Electrochemistry. 19: 361-367.
[36]. Rachel, L., Nicholas, W., Nina, M., Daniel, H.R., Daniel, Q.N., Howard, E.K. 2012. Next generation polymer solar cell materials: Designed control of interfacial variables, ACS Nano, 6: 2865-2870.
[37]. Reza, S., Soraya, D. 2015. An investigation on optical characteristics of nanocrystalline ZnS:Ni thin films prepared by chemical deposition method. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 149: 941-948.
[38]. Safonova, M., Mellikov, E., Mikli, V., Revathi, N., Volobujeva, N. 2015. Chemical bath deposition of SnS thin films from the solutions with different concentrations of tin and sulphur. Advanced Materials Research. 1117: 183-186.
[39]. Son, H.J., Carsten, B., Jung, I.H., Yu, L.P. 2012. Overcoming efficiency challenges in organic solar cells: rational development of conjugated polymers. Energy & Environmental Science. 5: 8158-8170.
[40]. Sujaya, K.V., Jin, W.Y., Kang, J.W., Kim, J. 2015. Polymer assisted solution processing of Ti-doped indium oxide transparent conducting thin films for organic solar cells. Journal of Alloys and Compounds. 631: 67-71.
[41]. Taz, H., Ruther, R., Malasi, A., Yadavali, S., Carr, C., Nanda, J., Kalyanaraman, R. 2015. In situ localized surface plasmon resonance (LSPR) spectroscopy to investigate kinetics of chemical bath deposition of CdS thin films. The Journal of Physical Chemistry C, 119: 5033-5039.
[42]. Vidhya, S.N., Balasundaram, O.N., Chandramohan, M. 2015. The effect of annealing temperature on structural, morphological and optical properties of CdZnTe thin films. Optik-International Journal for light and Electron Optics. 126: 5460-5463. Yeh, L., Cheng, K. 2015. Preparation of chemical bath synthesized ternary Ag-Sn-S thin films as the photoelectrodes in photoelectrochemical cell. Journal of Power Sources. 275: 750-759.
[43]. Wang, J., Dai, S., Yao, Y., Cheng, P., Lin, Y., Zhan, X. 2015. Spirobifluorene-based acceptors for polymer solar cells: Effect of isomers. Dyes and Pigments. 123: 16-25.
[44]. Yeh, N., Yeh, P. 2013. Organic solar cells: their development potentials. Renewable and Sustainable Energy Review, 21: 421-431.
[45]. Yip, H., Jen, A.K.Y. 2012. Recent advances in solution-processed interfacial materials for efficient and stable polymer solar cells. Energy Environmental Science, 5: 5994-6011.
[46]. Yu, Y.Y., Chien, W.C., Ko, .Y.H, Chen, C.P., Chang, C.C. 2015. Preparation of conjugated polymer based composite thin film for application in solar cell. Thin Solid Films. 584: 363-368.
[47]. Zhao, Z., Chen, X., Liu, Q., Wu, Q., Zhu, J., Dai, S. 2015. Efficiency enhancement of polymer solar cells via zwitterion doping in PEDOT:PSS hole transport layer. Organic Electronics. 27: 232-239.
[48]. Zhou, L., Li, Y., Dong, Y. 2015. Preparation and characterization of $Cd_{1-x}Zn_xS$ thin films with chemical bath deposition. Advanced Materials Research. 1088: 86-90.