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ISSN: 0976-3376

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

Asian Journal of Science and Technology
Vol. 07, Issue, 11, pp.3887-3890, November, 2016

RESEARCH ARTICLE

FABRICATION AND CHARACTERIZATION OF TIN SULPHIDE (SNS) BASED THIN FILM SOLAR CELLS

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ARTICLE INFO

Article History:
Received 18th August, 2016
Received in revised form
27th September, 2016
Accepted 16th October, 2016
Published online 30th November, 2016

Key words:
Tin sulphide,
Zinc sulphide,
Electro-deposition,
Characterization,
Solar cells.

ABSTRACT

This study reports fabrication and characterization of Tin sulphide (SnS) based thin film solar cells. The solar cell was fabricated using simple two electrodes electro-deposition technique to deposit window layer; Zinc sulphide (ZnS) and absorber layer; Tin sulphide (SnS) thin films on an Indium doped Tin oxide (ITO) coated glass slide and Silver paste was paste on the absorber layer (SnS) as back contact of the cell. Thus, a device structure of glass/ITO/ZnS/SnS/Ag solar cells is obtained. The active region SnS/ZnS hetero-junction was characterized using X-Ray diffractometer to reveals the presence of these phases. The device area is 1 cm^2 and was characterised using solar simulator at 1.5 AM with Keithley source metre coupled with interactive characterisation software to obtain both dark and illuminated I-V characteristic of the cell. From characteristic curves of the cell, the Voc is read to be 0.17 V; Isc to be -2.85x 10^{-8}A; Vmax to be 0.06 V and Imax to be -1.21x10^{-8}A. Thus, the fill factor (ff) was calculated to be 0.15 while the efficiency below 1 % was computed for the cell. The study therefore concludes that a SnS based thin film solar cell free of Cd is feasible and recommend further research to improve the efficiency of the cell.

INTRODUCTION

The world today is facing an increasing dilemma: On the one hand, the world population is growing and with a great part of this population striving to reach a standard of living comparable to that of the Western industrialized nations, the energy needs are increasing even faster. On the other hand, global warming (largely attributed to the burning of fossil fuels by mankind) and projections showing limited range of today's main sources of energy – coal, oil and gas –coupled with their non-uniform distribution in the world are warning signs that it would be disastrous to try and continue to me*et al*l the energy needs in conventional ways, causing severe environmental, economical and social problems. Hence, alternative and renewable ways to provide usable energy has to be developed. There are many options: wind energy, biomass, solar thermal energy, geothermal, hydrothermal, photovoltaic solar cells and using energy more efficiently, to name only a few examples. Schleußner, (2003) observe that, for the generation of electrical power, photovoltaic solar cells is arguably one of the most promising options. Since solar cell modules convert radiation energy from the sun directly into electrical energy, they do not cause any pollution in operation; they can be installed in many different ways (for instance on house roofs or on facades) and, even more importantly, photovoltaic can also be used in remote areas with no connection to power grids. A solar cell converts radiant energy into electrical energy. This conversion, which occurs in some semiconductors, is called the photovoltaic effect and was first observed in 1839 by Becquerel (Archer, 2001). Solar cells manufactured from wafers of crystalline or polycrystalline silicon are today the dominant technology in the commercial market and are so costly. Other technologies of producing solar cells such as Dye Sensitised Solar Cell (DSSC) and Organic Solar Cell have very low efficiency and degrade easily in ambient environment. Solar cells based on thin films of semiconductors are alternatives with prospects for high efficiency, stability and reduced cost. Tin sulphide (SnS) is a group IV–VI compound semiconductor material with an orthorhombic crystal structure with the optical band gap energy in the range of 1.1–1.3 eV (Nair and Nair, 1991). This is optimal for an absorber layer in solar cell devices.

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Moreover, it is optical absorption coef cient is (Reddy and Reddy, 2006). This is high enough to fabricate thin lm solar cells. Sinsermsuksakul *et al*. (2014) state that, tin (Sn) and sulphur (S) are abundant, non-toxic materials in nature, and are quite stable in an ambient environment. They state further that the theoretical maximum energy conversion ef ciency of SnS-based solar cells is about 25 % and has inherent p-type conductivity. Thus, SnS thin lms is a potential absorber materials for thin lm solar cells.

Similarly, ZnS is II-VI group semiconductor with a wide direct band gap of 3.5–3.7 eV (Vipin *et al*., 2008). This is a wide energy band gap which permit transmission of more high-energy photons to the junction and thus enhance the blue response of the photovoltaic cells. Murali and Kumaresan (2009) state that ZnS thin films have n-type conductivity and is nontoxic to human body, very cheap and abundant in nature. Thus, ZnS is a good candidate material that can replace CdS which is the widely used material for window layer in thin film solar cells. There are several attempts at fabricating SnS based thin films solar cells. Yue *et al*. (2012) report a record efficiency of 1.95% for SnS based thin film solar cells fabricated from p-n homojunction nanowires using boron and phosphorus as dopants. Furthermore, SnS-based solar cells have been reported using different n-type window layer such as SnS_2 (Sanchez-Juarez, Tiburcio-Silver and Ortiz, 2005), CdS (Reddy *et al*. 2006, Bashkrov, 2012), Cd1 xZnxS (Gunasekaran and Ichimura, 2007), ZnO (Ghosh, 2009) . Reddy *et al*. (2006) fabricate the best SnS based solar cells so far with CdS window layer achieving a power conversion efficiency (η) of 1.3%. Sinsermsuksakul *et al*. (2013) observe that the efficiencies achieved using heterojunctions of SnS with n-type materials other than CdS are extremely low (< 0.1%), mainly limited by low short-circuit current density (Jsc < 1.5 mA/cm^2). Vidal *et al*. (2012) opined that the poor Jsc is likely as a result of bulk recombination in SnS because of defects, e.g., grain boundaries, intrinsic point defects such as sulphur vacancies and/or impurities that arise from the preparation methods used to deposit the films. Sinsermsuksakul *et al*. (2014) in furthering their effort to improve the efficiency of SnS based thin film solar cells by addressing causes of its low efficiency such as: annealing to reduce recombination, optimizing the conduction band offset by tuning the composition of Zn(O,S) and others to obtain enhance efficiency of 4.36%. In all these SnS based thin film solar cells develop so far non-used n-type ZnS as window layer as well as non-have fabricated using electrodeposition technique to deposit both window and an absorber layer. This paper therefore reports the results of study on fabrication and characterization of all electrodeposited Tin sulphide (SnS) based thin film solar cells using ZnS as window layer.

EXPERIMENTAL PROCEDURE

Fabrication of the cell

The deposition of window (ZnS) and absorber (SnS) layer of the cell was done using simple two electrodes electro-deposition cell as earlier reported by Taleatu *et al.* (2014). The ZnS thin film was deposited on ITO coated glass from 25ml of 0.01M of Zinc acetate, 25ml of 0.25M of Sodium thiosulphate pental hydrate ($Na_2S_2O_3.5H_2O$) and 5 drops of 0.05M of H_2SO_4. A cathodic voltage of 0.9 V was applied, the starting current was observed to be 5.14 mA and the stopping current to be 0.99mA. The deposition period was measured to be 6.13minutes. The SnS thin film was then deposited on ZnS surface from 25ml of 0.01M of tin sulphate, 25ml of 0.05M of Sodium thio sulphate pental hydrate ($Na_2S_2O_3.5H_2O$) and 5ml of 0.05M of H_2SO_4. A cathodic voltage of 1.0 V was applied, the starting current was observed to be 2.28mA and the stopping current was observed to 0.72mA. The deposition period is measured to be 27:29 minutes. This process was repeated for five more rounds to increase the thickness of the absorber layer of the cell. The sample was remove and rinsed with distilled water and kept in sample holder. Thus, an ITO/ZnS/SnS heterojunction is obtained. The metallisation was done by pasting Silver paste on the surface of SnS to obtain a complete device of 1 cm^2 ITO/ZnS/SnS/Ag hetero-junction thin film solar cells.

Characterization of the cell

The active layer of the cell (ZnS/SnS hetero-junction) was characterised with XRD to study the structural phases that may be present in it. The efficiency of the tin sulphide based thin film solar cells was then determined at 1.5 AM by taken the I-V measurements of the solar cell under illumination and dark using the Model 4200-SCS Semiconductor Characterization System installed with interactive characterisation software.

RESULTS AND DISCUSSIONS

Structural Characterisation of ZnS/SnS hetero-structure

The structural phases present in the ZnS/SnS hetero-structure was studied using XRD. Fig.1 presents the XRD pattern of ZnS/SnS hetero-junction on ITO coated glass. The observed peaks are at 2θ equals 13.55, 21.29, 30.20, 34.40, 35.21, 37.41, 50.46 and 60.20°. These observed peaks can be index into Zincblend cubic structure of ZnS and orthorhombic structure of SnS thin films in addition to the cubic structure of the ITO glass.

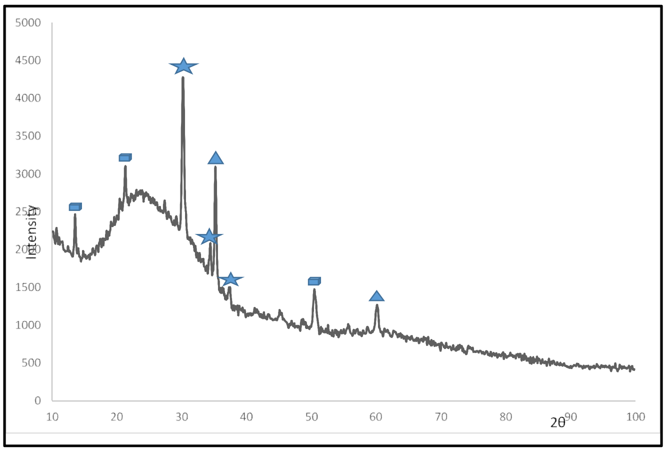

Fig. 1. XRD Pattern of ZnS/SnS heterojunction on ITO coated glass (SnS ZnS ITO)

Electrical characterisation of the cell (ITO/ZnS/SnS/Ag)

The device was characterised using solar simulator at 1.5AM with keithley source metre coupled with interactive characterisation software to obtain both dark and illuminated I-

V characteristic of the cell. The I-V characteristics of the device taken in the dark and under illumination are as shown in Fig.2 and 3 respectively.

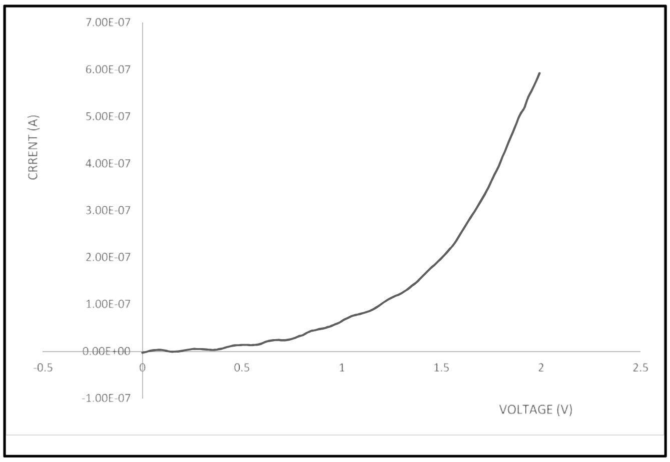

Fig. 2. I-V Characteristics of ITO/ZnS/SnS/Ag Solar cell (in the dark)

From the I-V characteristic taken in the dark, fig.2, a rectifying curve with very low reverse saturation current is observed which shows that hetero-junction is formed in the active layer of the cell. This is in line with result of Ghosh *et al*, (2010) who have found similar rectifying junction for ITO/CdS/SnS/In hetero-structure. This diode characteristics obtained in the dark is an evidence that a solar cell device structure have been fabricated.

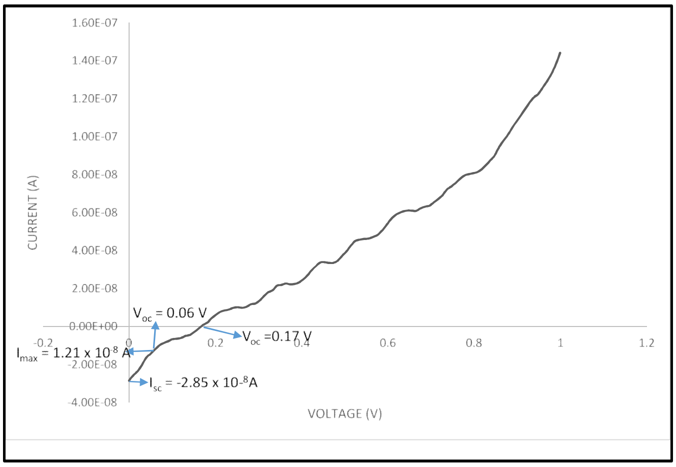

Fig. 3. I-V Characteristics of ITO/ZnS/SnS/Ag solar cell (under illumination)

From the illuminated I-V characteristics shown in fig.3, the following characteristics values of the cell can be deduce: The Voc is read to be 0.17 V; Isc to be -2.85x 10^{-8}A; V max to be 0.06 V and I max to be -1.21x10^{-8}A. The fill factor (ff) was calculated using:

$$ff = {Imax.Vmax}/_{Isc.Voc} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

which is the measure of the squareness of the I-V characteristics curve.

Thus, ff = -1.21x10^{-8}A X 0.06 V/ -2.85x 10^{-8}A X 0.17 V = 0.15. Thus, fillfactor (ff) was computed to be 0.15.

The efficiency of the cell was calculated using;

$$\eta = {Isc.Voc.ff}/_{P_{RAD}} \quad \ldots\ldots\ldots\ldots(2)$$

where P_{RAD} is the power of the incident radiation (100mW/cm^2). The area of the cell is 1 cm^2.

Thus, the efficiency η = (-2.85x 10^{-8}A X 0.17 V X 0.15)/100 mW/cm^2

= 7.27 x 10^{-10} / 100 mW = 7.27 x 10^{-9} % << 1%.

Thus, an efficiency of 7.27 x 10^{-9} % which is far below 1 % was computed for the cell. This is presumably due to presence of high number of trap states in the interface of active layer as a result of surface roughness which may reduce the diffusion length of minority carrier and high sheet resistivity of the electrodeposited ZnS layer. This efficiency notwithstanding, the result confirmed the observation of Sinsermsuksakul *et al*. (2013) that the efficiencies achieved using heterojunctions of SnS with n-type materials other than CdS (ZnS in this case) are extremely low (< 0.1%),

Conclusion

Though, a very low efficiency was found for the cell, the result of this study has demonstrated that it is possible to develop cadmium free, tin sulphide (SnS) based thin film solar cells using an all electrodeposited cheap and easier route. The study therefore recommend further study on an all electrodeposited SnS based thin film solar cells using ZnS as window layer. The trend of the study could follow the work of Sinsermsuksakul *et al*. (2014) done to improve the efficiency of their SnS based thin film solar cells.

Acknowledgement

The management and staff of Physics Advance Laboratory (PAL) of Sheda Science and Technology Complex (SHESTCO), Abuja are appreciated for permission to utilise their facilities for characterization.

REFERENCES

Archer, M. D. 200. Clean Electricity from Photovoltaics, edited by M. D. Archer, *Imperial College Press*, vol. 1, chap. 1

Bashkirov, S.A., V. F. Gremenok, V. A. Ivanov, V. V. Lazenka, and K. Bente. 2012. Tin sul de thin lms and Mo/p-SnS/n-CdS/ZnO heterojunctions for photovoltaic applications *Thin Solid Films* 520, 17, 5807-5810

Ghosh B, R. Roy, S. Chowdhury, P. Banerjee and S. Das 2010. Synthesis of SnS thin films via galvanostatic electrodeposition and fabrication of CdS/SnS heterostructure for photovoltaic applications. *Applied Surface Application*. 256, 4328-4333.

Ghosh, B, M. Das, P. Banerjee, and S. Das, 2009. Fabrication of the SnS/ZnO heterojunction for PV applications using electrodeposited ZnO films. *Semicond. Sci. Tech*. 24, 2, 025024.

Gunasekaran, M and M. Ichimura, 2007. Photovoltaic cells based on pulsed electrochemically deposited SnS and photochemicaly deposited CdS and Cd1-xZnxS. *Sol. Energ. Mat. Sol.Cells,* 91, 9, 774-778.

Jiang, F, H. L. Sh en, W. Wang, and L. Zhang, 2009. Preparation of SnS Film by Sulfurization and SnS/a-Si Heterojunction Solar Cells. *J. Electrochem. Soc*. 159, 3, H235-H238

Murali, K. R. and S. Kumaresan. 2009. Characteristics of Brush Plated ZnS Films. *J.Chalcogenide Letters*. 6, 1, 17 – 22

Nair M.T.S and P.K. Nair, 1991. Simpli ed chemical deposition technique for good quality SnS thin lms. *Semicond. Sci. Technol*. 6, 132–134

Reddy, K. T.R., N. K. Reddy, and R. W. Miles, 2006. Photovoltaic Properties of SnS based Solar *Cells. Sol. Energ. Mat. Sol.Cells*. 90, 18-19.

Reddy, N.K. and K.T.R. Reddy, 2006. Optical behaviour of sprayed tin sulphide thin lms. *Mater. Res. Bull.* 41, 414–422

Sanchez-Juarez, A., A. Tiburcio-Silver, and A. Ortiz, 2005. Fabrication of SnS_2/SnS heterojunction thin film diodes by plasma-enhanced chemical vapour deposition. *Thin Solid Films* 480, 452-456

Schleußner, S 2003. Cu(In,Ga)Se_2 Thin Film Solar Cells with ZrN as a Back Contact. Diplomarbeit von, Universität von Uppsala (Schweden)

Sinsermsuksakul, P., L. Sun, S.W. Lee, H.H. Park, S.B. Kim, C. Yang, R.G. Gordon, 2014. Overcoming ef ciency limitations of SnS based solar cells. *Adv. Energy Mater*. 4, 1400496.

Sinsermsuksakul, Prasert, Katy Hartman, Sang Bok Kim, Jaeyeong Heo, Leizhi Sun, Helen Hejin Park, Rupak Chakraborty, Tonio Buonassisi and Roy G. Gordon. 2013. Enhancing the efficiency of SnS solar cells via band-offset engineering with a zinc oxysulfide buffer layer. *Applied Physics Letters* 102, 5, 053901

Sugiyama, M, K. T. R. Reddy, N. Revathi, Y. Shimamoto, and Y. Murata, 2011 Band offset of SnS solar cell structure measured by X-ray photoelectron spectroscopy. *Thin Solid Films* 519, 21, 7429-7431

Taleatu, B. A., A. Y. Fasasi, G. Di Santo, S. Bernstorff, A. Goldoni, M. Fanetti, L. Floreano, P. Borghetti, L. Casalis, B. Sanavio, and C.Castellarin-Cudia, 2011. Electro-chemical deposition of zinc oxide nanostructures by using two electrodes. *AIP Advances* 1, 032147

Vidal, J., S. Lany, M. d'Avezac, A. Zunger, A. Zakutayev, J. Francis, and J. Tate. 2012. Band- structure, optical properties, and defect physics of the photovoltaic semiconductor SnS. *Appl. Phys. Lett.* 100, 3, 032104

Vipin, K., Sharma, M.K., Gaur, J., Sharma, T.P. 2008. Polycrystalline ZnS Thin Films By screen Printing Method And Its Characterization. *J chalcogenide Letters* 5, 11; 289 - 291.

Wang, Y, H. Gong, B. H. Fan, and G. X. Hu. 2010. Photovoltaic Behavior of Nanocrystalline SnS/TiO_2, *J. Phys. Chem.* C 114 (7), 3256-3259

Yue, G., Y. Lin, X. Wen, L. Wang, and D. Peng 2012. SnS homojunction nanowire based solar cells. *J. Mater. Chem*. 22, 32, 16437-16441

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