FABRICATION AND CHARACTERIZATION OF COST-EFFICIENT SNS/SI COMPOSITE FOR PHOTOVOLTAIC APPLICATION.

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Abstract:

The present work we are synthesize the SnS-SiO2 composite incorporate with SiO2 by using the silicic acid by chemical oxidation rout. oxidation of silicic acid to silicon dioxide and formation of composites between of SnS and silicic acid takes place simultaneously. Fabricate the PV cell in structure ITO/SnS-SiO2/Al for Photovoltaic application. PV performance of the composite was analyzed with the 10 wt% ratio of SnS and silicic acid by measuring and calculating PV parameter. The performance reflecting parameters like open circuit voltage, short circuit current, Fill factor and efficiency have been calculated. The value of efficiency of solar cell was found to be 2.5%. The obtained results were discussed reconfirmation of SnS as an absorber for the fabrication of low-cost solar cells.

Keyword: Photovoltaic; FF; Voc; Isc.

Introduction

In recent years, solar energy conversion was taking a major interest of many researchers in worldwide. In PV applications, solar cells based on Si have been used and still heavily in use for solar energy conversion. SnS has gained much attention as a promising inorganic material for solar cell [1,2]. SnS is non toxic and its electrical conductivity is easily control by addition of doping element [3]. This type of materials has the wide absorption range and low band gap. M. X. Wang reported that SnS nano wires show strong absorption in the visible and near infrared spectral region, and the direct energy band gap of SnS nano wire is 1.46 e, which is suitable for solar cell application [4,5]. The fabrication of cubic SnS films by chemical bath deposition technique and investigated that, band gap of SnS decreases with increase in bath temperature. Now a day research works have focus towards heterojunction structures of SnS [6]. Depending on the type of conductivity of SnS layer has, a layer of opposite conductivity is chosen [7]. The literature survay reports the performance of various heterojunction solar cells for example CdS/SnS[8], ZnO/SnS [9] and SnS/PbS[10] transparent conducting oxides (TCO) are crucial in amorphous/crystalline silicon heterojunction solar cells performance as they have to be highly conductive to ensure the transport of photogenerated charges while remaining highly transparent to the sun spectrum [11, 12, 13].

In the present work we have synthesized SiO_2 rich SnS composites to study I-V characteristics in view of solar cell for photovoltaic application. The composite was prepared by incorporation of 10 wt % concentration of SnS in SiO_2. In this work, SnS nanoparticles were synthesized by chemical route. For incorporation of SnS in SiO_2, solid state diffusion route was adopted. The as-obtained composites further investigated for photovoltaic application. The significant power conversion efficiency was extracted from the prepared materials systems. As-prepared SnS-SiO2 was characterized using X-ray diffractions (XRD), scanning electron microscopy (SEM) and photovoltaic response measurements.

Experimental

AR grade (SD fine, India) chemicals were used for synthesis of SnS/Si composite without any further purification. In the present work, SnS nanoparticles were synthesized by chemical route method. The Tin chloride ($SnCl_2$) and sodium sulfide (Na_2S) were used as starting chemicals for the synthesis of SnS nanoparticles. Both chemicals $SnCl_2$ and Na_2S were mixed in distilled water in 1:2 ratio respectively. As-obtained SnS nanoparticles were used to prepare composite with SiO_2.

The solid state diffusion method was used to prepare composite between SnS and SiO_2. For this silicic acid was utilized as source of SiO_2. The heating of silicic acid above 800 °C, results in oxidation of silicic acid. By considering this principle, for fixed value of silicic acid, prepared SnS added in silicic acid in 10 wt.%. The mixture between silicic acid and SnS nanoparticle was homogenized by addition of acetone and rigorous magnetic stirring. Prepared mixture was kept for 24 h to evaporation of acetone. Subsequent to this step, the obtained fine powder heated at 50°C for the complete removal of acetone. After this, as-obtained fine power heated in step wise pattern. For each step powder heated at 200, 400, 600, 800, and 1000 °C in vacuum for three hours. In this fashion, we prepared composite of SnS/SiO_2.

Characterization

The physic-chemical analysis of prepared sample was done through various analytical tools. The structural study of sample was completed using X-ray diffraction (XRD) analysis on XRD (Philips PW 1830). Morphologis of the sample was directly characterized by a JEOL JSM 7050F scanning electron microscope(SEM) equipped with an energy dispersion X-ray spectrometer to analyze the element content and distribution. For optical study of sample, doctor blade method was used to prepare photovoltaic cell. In this fabrication process, ITO plate was used as transparent electrode whereas aluminum foil was used as metallic electrode. As-prepared sample was sandwiched between ITO and aluminum. The diode parameters of photovoltaic cell were checked in dark conditions. The data of diode parameters such as short circuit current (I_{SC}), open circuit voltage (V_{OC}), fill factor (FF), and power conversion efficiency (η) were tested under incandescent light bulb.

Results and Discussion

XRD analysis

Figure 1 dipict the XRD patterns of SnS (10 wt.%) loaded SiO_2 rich composite. The structural purity and phase analysis of as-prepared composite was confirmed by comparing X-ray diffraction data with JCPDS cards. The presence of prominent diffraction peaks at 31.38, 43, 51 so it reflects that it is crystalline nature [14]. The broad hump with some shoulder peak appears in the range 25-35° indicates the presence of Si in composite it reflect amorphous phase. This simultaneous amorphous and crystalline nature in same material confirms the semicrystallization of prepared samples [15,16].

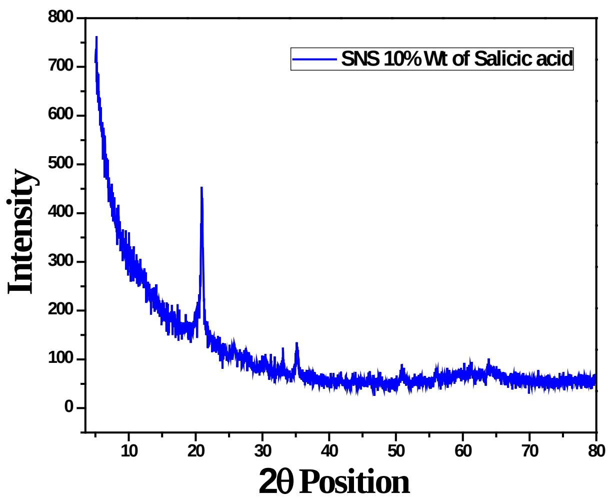

Figure 1 XRD pattern of 10 wt.% SnS

FESEM Analysis

Figure 2 shows the SEM image SnS/SiO2 composite, it shows the surface morphology of the SnS/SiO2 composite. From SEM images, SnS/SiO_2 composites have elongated granules of mesh like structure. The aggregation present in the prepared sample was because of the SiO_2 cluster deposition on the boundary surface. Further minute observation of the SEM image shows that the particle size was irregular and aggregate form. Composite particles cemented together with the intercalation of SiO_2 [17].

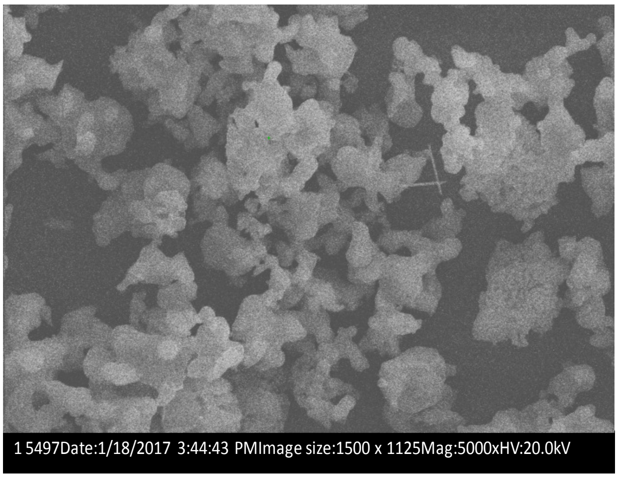

Figure 2. FESEM SnS/SiO2 of 10 wt. %

I-V Characteristics

Figure 3 shows the Current-Voltage (I–V) characteristics of SnS (10wt %) loaded SiO_2 composite measured at 303 K (room temperature). The incandescent light source (0.0104 W/m^2) was used for photovoltaic The parameters of PV cell were listed in Table 1.

response of as fabricated PV cell of SnS/SiO_2 composite. The PV response was recorded with separation between light and PV cell of 20 cm. The different diode parameters such as open circuit voltage (V_{OC}), short circuit current (I_{SC}), fill factor (FF), and power conversion efficiency (η) of PV cell with architecture ITO/SnS-SiO_2/Al were find out. The fill factor of PV cell was calculated using Eq. (1) Power conversion efficiency (η) of PV cell determined using Eq. (2) [18].

$$FF = \frac{I_{MAX} \times V_{MAX}}{I_{SC} \times V_{OC}} \qquad (1)$$

The power conversion efficiency (η) of PV cell determined using Eq (2) [19],

$$\%\eta = \left(\frac{I_{SC} \times V_{OC} \times FF}{P_{in}} \right) \times 100 \qquad (2)$$

Sample	I_{sc} (mA)	V_{oc} (V)	I_{max} (mA)	V_{max} (V)	FF	%η
10 wt.%	35	0.45	27.7	0.25	0.4396	2.5

Table 1. Diode parameters of photovoltaic cell I_{sc}, V_{oc}, I_{max}, V_{max}, %FF and %η with architecture ITO/SnS-SiO_2/Aluminum.

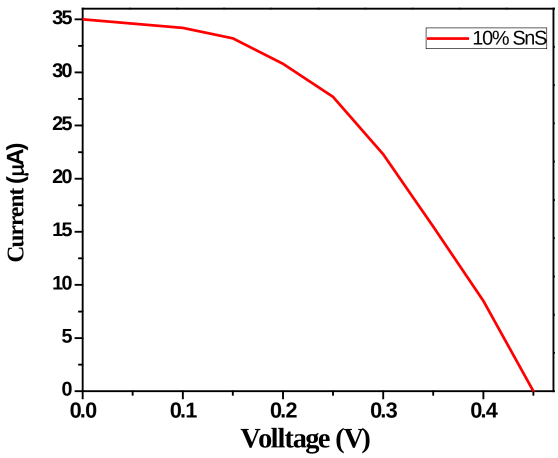

Figure 3. IV characteristic of SnS/SiO2 Composite

From Table 1, it is observed that power conversion efficiency associated with 10 wt.% SnS loaded SiO_2 composite. The SnS loaded SiO_2 composite shows the PV performance through variation of Isc, Voc and FF. The optimize sample of SnS loaded SiO_2 exhibits the maximum value of Isc = mA, Voc = V and FF = corresponding the η = %. Variation of PV parameters for SnS loaded SiO_2 may be due the variation particle size and surface morphology.

Conclusions

In this work successfully synthesize SnS/ SiO2 composite by chemical route approach was adopted for the synthesis of SnS nanoparticles and fabricated the PV cell in ITO/SnS-SiO2/Al structure. The composite between SnS and SiO_2 was successfully prepared by using solid state diffusion route. As prepare the sample of SnS/SiO2 goes under the semi crystalline structure and rougher morphology. The power conversion efficiency was obtained for 10 wt.% SnS loaded SiO_2 rich composite is % for incandescent light source of radiating power 0.0104 $Watt/m^2$.

Reference .

[1] Ding, D., Rath Thomas, Luis Lanzetta, Jose Manuel Marin-Beloqui, Saif A. Haque, Efficient Hybrid Solar Cells Based on Solution Processed Mesoporous TiO2/Tin(II) Sulfide Heterojunctions, *ACS Appl. Energy Mater*. 1, 7, 3042-3047.

[2] Chapin, DM, Fuller, CS, Pearson, GL. A new silicon p-n junction photocell for converting solar radiation into electrical power. 1954, *J Appl Phys*,25,676-7.

[3] Fan-Yong Ran, Zewen Xiao, Yoshitake Toda, Hidenori Hiramatsu, Hideo Hosono, and Toshio Kamiya, n-type conversion of SnS by isovalent ion substitution: Geometrical doping as a new doping route, 2015, *Sci Rep.*, 5, 10428.

[4] Gisa Grace Ninan, C. Sudha Kartha, K. P. Vijayakumar, Spray pyrolysed SnS thin films in n and p type: Optimization of deposition process and characterization of samples, 2016, *Journal of Analytical and Applied Pyrolysis*, 120, 121-125.

[5] Shaojie Chen, Dongjiu Xie, Gaozhan Liu, Jean Pierre Mwizerwa, Xiayin Yao, Sulfide solid electrolytes for all-solid-state lithium batteries: Structure, conductivity, stability and application, 2018, *Energy Storage Materials*, 14, 58-74.

[6] Tian-Ran Wei, Chao-Feng Wu, Fu Li, Jing-Feng Li, Low-cost and environmentally benign selenides as promising thermoelectric materials, *Journal of Materiomics*, https://doi.org/10.1016/j.jmat.2018.07.001.

[7] Kusum Rawat, P. K. Shishodia, Thermal annealing induced modification on structural and optical properties of Cu2ZnSnS4 thin films for solar cell application, 2018, *Superlattices and Microstructures*, 122, 444-452.

[8] M. Suresh Kumar, Sreejith P. Madhusudanan, Sudip K. Batabyal, Substitution of Zn in Earth-Abundant Cu2ZnSn(S,Se)4 based thin film solar cells – A status review, 2018, *Solar Energy Materials and Solar Cells*,185, 287-299.

[9] Zhen-Hua Ge, Li-Dong Zhao, Di Wu, Xiaoye Liu, Jiaqing He, Low-cost, abundant binary sulfides as promising thermoelectric materials, 2016, *Materials Today*,19, 227-239.

[10] Guifang Han, Sam Zhang, Pablo P. Boix, Lydia Helena Wong, Shui-Yang Lien, Towards high efficiency thin film solar cells, 2017 *Progress in Materials Science*,87,246-291.

[12] Zinab H. Bakr, Qamar Wali, Azhar Fakharuddin, Lukas Schmidt-Mende, Rajan Jose, Advances in hole transport materials engineering for stable and efficient perovskite solar cells, 2017, *Nano Energy*, 34, 271-305.

[13] Tanka Raj Rana, SeongYeon Kim, JunHo Kim, Existence of multiple phases and defect states of SnS absorber and its detrimental effect on efficiency of SnS solar cell, 2018 *Current Applied Physics*,18, 663-666.

[14] Vinaya Kumar Arepalli, Yeonbae Shin, Jeha Kim, Influence of working pressure on the structural, optical, and electrical properties of RF-sputtered SnS thin films, 2018, *Superlattices and Microstructures*,122,253-261.

[15] Takpire, S,R.,Nemade K,R., Waghuley,S,A. Further exploration of photovoltaic performance of polythiophene-co-polyaniline–Ti copolymer composites PV system, 2016, *Materials and Design* 101, 294–300

[16] Takpire,S,R.,Waghuley,S,A.,Investigating the optical and structural properties of PANi/Ti polymer composites for photovoltaic application, 2017,*Journal of the Energy Institute* 90, 44-50.

[17] Kute , A.M. Waghuley,S.A., Photovoltaic application of ZnS loaded silicon dioxide rich composites, 2017, Materials and Design,116,1-7

[18] Kute, A.M., Waghuley,S.A., Photovoltaic properties of nanostructured copper sulfide incorporated silicon rich composites,2018, *Journal of Materials Science: Materials in Electronics*, 29, 16199-16206

[19] Takpire, S,R., Waghuley,S,A., Optical and thermal properties of PTh -co- PANI-Ti random copolymer composite for photovoltaic application, 2015, *St. Petersburg Polytechnical University Journal: Physics and Mathematics* 1, 417–423.