



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 11, November 2023

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

Photovoltaic Properties of PbS Doped Si Composite for Solar Cell Application

A.M.Kute, S.R.Takpire

Department of Physics, Ghulam Nabi Azad Art's, Commerce and Science College, Barshitakli. Akola India

Department of Physics, Mahatma Jyotiba Fule Commerce, Science and Vitthalrao Raut Art's College

Bhatukali, Dist- Amaravati. India

ABSTRACT: Nanosized PbS particles synthesized by using precursor solutions of lead nitrite $[(\text{PbNO}_3)_2]$ and sodium sulfide (Na_2S). The fabrication and detail properties of PbS doped SiO_2 composite were reported. Present paper discusses the performance of ITO/PbS/Si/Al solar cell performance. In present work, silicic acid oxidizes to silicon dioxide and formation of PbS/Si composites takes place simultaneously by solid state diffusion method. X-ray diffraction (XRD), I-V measurement is used to determine crystallographic structure, optical and photovoltaic properties. Open circuit voltage (V_{oc}), Fill factor (FF), Short circuit current (I_{sc}) and efficiency of solar cells are determined using I-V curve. The photovoltaic performances of PbS/Si composite were found. The obtained results were discussed reconfirmation of PbS as an absorber for the fabrication of low-cost solar cells.

KEYWORDS : PbS/ SiO_2 photovoltaic application.

I. INTRODUCTION

Solar energy is extensively used as the most important renewable energy sources in recent years. The available solar energy can be converted directly into electrical energy by the phenomenon of the photovoltaic effect. Among the various solar cells, multi-crystalline Silicon (Si) solar cell is still dominating and ruling in the market because of its efficiency, earth abundance of Si, non toxicity and its established methods of fabrication [1]. In spite of the market dominance, silicon solar cells have small absorption of light as Si is an indirect bandgap material [2,3]. Thus, a thick layer of silicon is needed to increase the light absorption, which in turn increases the cost of device fabrication. Due to this limitation, the other solar technologies also evolved intending to deliver photovoltaic energy at a reduced cost [4]. The inorganic sensitizers usually consist of narrow bandgap metal chalcogenide compounds, such as transition metal sulfides (S), selenides (Se), and tellurides (Te), CdS, CdSe, CdTe, PbS, PbSe. So far, the highest QDSSC efficiency was achieved by a PbS sensitizer [5,6].

Lead Sulfide (PbS) colloidal quantum dot solar cells are one of the most efficient and shows potential candidates among various quantum dot solar cells [7][8][9]. Lead sulfide (PbS) QDs are considered as the inspiring material in QDSCs due to their adjustable optical band gap from 0.4 to 1.5eV improves infrared absorption [10], which would significantly enhance the power conversion efficiency (PCE) of solar cells. Ag:PbS semiconductor materials have good potential not only due to their tunable optical and electrical characteristics but due to their potential for use as solar cells, IR detector, photoconductor photovoltaic cells, and electrochemical storage devices [11][12]. The higher dielectric permittivity of PbS reflects more efficient charge separation at interface and hence enhancing the short circuit current density (J_{sc}) and fill factor (FF) of the device. PbS nanoparticles have variety of applications in the areas of high efficiency solar cell [13], photodetectors operating from infrared to ultraviolet wavelength range [14], optical switches [15], solar control coatings [16] etc. There are numerous methods for synthesis of PbS nanoparticles such as hydrothermal route [17], colloidal synthesis in aqueous media [18], electrochemical preparation [19], electron beam irradiation [20], hot injection method [21] etc. Transparent and conductive electrodes are one of the necessary layers for realizing monolithic perovskite silicon tandem solar cells. Transparent conductive oxides (TCOs) offer good electro-optical properties with simplistic processing and are used widely among other transparent and conductive electrodes [22]. One of the most used TCOs is indium tin oxide (ITO) due to its superior electro-optical properties and stability. Since the ITO film is in direct contact with the organic thin film in the devices, the surface properties of ITO anodic electrode directly affect the hole injection/extraction process at ITO/organic interface and electrical properties of the devices

As-prepared sample was characterized using X-ray diffractions (XRD), and photovoltaic response measurements.

II. EXPERIMENTAL

In this process, chemicals were used of high purity grade. In the present work, PbS doped Silicon composite is formed by solid state diffusion method. Chemical route approach adopted for the synthesis of PbS nanoparticles. The synthesis method involves the preparation of PbS nanoparticles by using $(\text{PbNO}_3)_2$ as a lead source and Na_2S as a sulfur source. Both chemicals were mixed in distilled water in 1:2 ratio, respectively by maintain pH=3. As-obtained PbS nanoparticles were used to prepare composite with SiO_2 . The heating of silicic acid above 800 °C oxidizes silicic acid. By considering this principle, for fixed value of silicic acid, prepared 10 wt % PbS added in silicic acid. The acetone is added to the mixture between silicic acid and PbS nanoparticles and homogenized by rigorous magnetic stirring. Prepared mixture was kept for 24 h to evaporation of acetone. The obtained fine powder further 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 sample of PbS loaded SiO_2 rich composites.

The physic-chemical analysis of prepared samples was done through various analytical tools. The structural study of samples was completed using X-ray diffraction (XRD) analysis on XRD (Philips PW 1830). The photovoltaic cell for the study was prepared by simple doctor blade method. In this fabrication process, ITO plates were used as transparent electrode whereas aluminium 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.

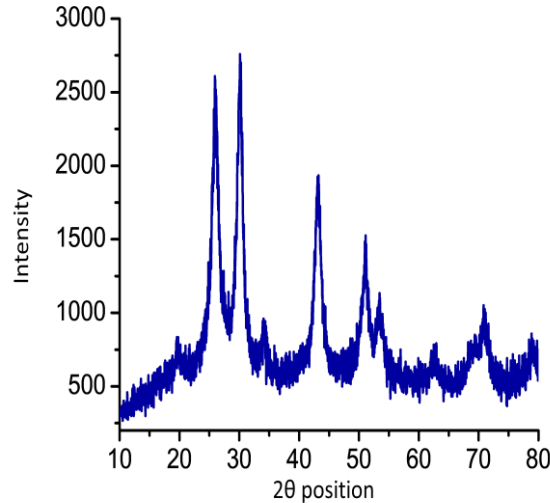
III. CHARACTERIZATION TECHNIQUE

Formation of PbS nanoparticle was confirmed using X ray diffraction technique. Figure 4.1 depict the XRD patterns of PbS (10 wt.%) loaded SiO_2 rich composites. The structural properties and phase analysis of as prepared PbS-Si composite is confirm by X-ray diffraction (XRD) with JCPDS data card. in the XRD patterned shows that all the crystal planes are mostly matching with reference data with crystal orientations (111), (200), (220) and (311) respectively, this peak clearly shows the PbS-Si has cubic structure because $\beta\text{-ZnS}$ phase present in composite .

The wide diffraction peak at 21.3° also present in this peak indicates that presence of SiO_2 cluster in composites. As the PbS-Si are crystalline phase, its average crystalline grain size was computed using the Debye-Scherrer equation (eq. (4.1)), [10]

$$D = \frac{K\lambda}{\beta \cos \theta} \quad (4.1)$$

Where, D is average crystallite grain size, K is shape factor and its standard value for unknown shape is $K=0.89$, λ is the wavelength of X-Rays used for analysis ($\lambda=1.54 \text{ \AA}$), β is full width at half maxima (FWHM) and θ is diffraction peak position. The value of average size of particle is in between 17-20 nm, which are most desirable for generation of charge carrier.

Figure 4.1. XRD patterns of PbS loaded 10 wt.% SiO₂ rich composites.

IV. I-V CHARACTERISTICS

The PV parameters of the Solar cells are determined by observing I-V characteristics under light irradiation. From the observation of I-V characteristics, typical diode behavior was obtained for as-fabricated solar cells. I-V curve has several characteristic points. When electrodes were connected externally, the short circuit current (I_{sc}) was obtained and voltage starts to approach towards zero. The open circuit voltage (V_{oc}) was obtained, when the current was zero. At both points, the cell does not produce power, since $VI = 0$. The maximum power (P_{max}) was obtained when the product VI was maximum also known as “maximum power point”. I-V characteristic curve for the prepared PV cell was shown in figure 4.9. The values of I_{max} and V_{max} are directly measured from I-V plot of PV cell and provided in table 4.2. Another indicator for the performance was the fill factor (FF) and power conversion efficiency (η). The relations for the determination of FF and η , is given by eq (4.2) [17] and eq. (4.3)[18],

$$FF = \frac{V_{max} \times I_{max}}{V_{oc} \times I_{sc}} \quad (4.2)$$

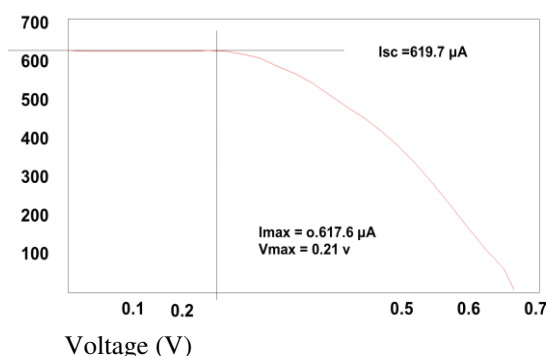
$$\eta = \frac{(V_{oc} \times I_{sc}) \times FF}{P_{in}} \quad (4.3)$$

where, P_{in} is input power of light irradiation

The obtained value of PV parameter was listed in Table 4.2. From table 1, it is observed that power conversion efficiency is not linearly varied with ZnS concentration in composites. The highest power conversion efficiency is associated with 25 wt.% ZnS loaded SiO₂ composite.

Table 4.2. Diode parameters of photovoltaic cell I_{sc} , V_{oc} , I_{max} , V_{max} , % FF and % η with architecture ITO/ZnS-SiO₂/Aluminum.

Sample	I_{sc} (μA)	V_{oc} (V)	I_{max} (μA)	V_{max} (V)	FF	% η
10 wt. %	619.7	0.63	617.6	0.21	0.332	1.29

Figure 4.2. I-V characteristics of PbS loaded 10 wt.% SiO₂ rich composites.

V. RESULTS AND DISCUSSION

Figure 1 shows the XRD patterns of PbS (10 wt.%) loaded SiO₂ rich composites. The structural purity and phase analysis of as-prepared composites was confirmed by comparing X-ray diffraction data with JCPDS cards. The broadening of peaks in XRD pattern indicates the nanocrystalline nature of the sample. In this work, we ably demonstrated salicylic acid as a source of silicon in the process of solid state diffusion. The power conversion efficiency from 10 % of PbS loaded SiO₂ found to be 1.29 % and Fill factor was 0.332 for weak light source of radiating power 0.0104 W/m².

REFERENCES

- 1] V. Kanneboina, Detailed review on c-Si/a-Si:H heterojunction solar cells in perspective of experimental and simulation, *Microelectronic Engineering*, 265(2022).
- 2] Qi Geng, Zhe Wang, Zhen Liu, Yuzhou Liu, Zhongliang Gao, Yingfeng Li, Xin Sun, Lei Chen, Xiaojun Lv, Meicheng Li, Construction of V₂O₅/Si heterojunction and carrier-assisted collection for high-efficiency silicon solar cells, *Materials Today Energy*, 34(2023).
- 3] Vikas Kashyap, Chandra Kumar, Vivek Kumar, Neeru Chaudhary, Kapil Saxena, The effect of dopant on light trapping characteristics in random silicon nanowires for solar cell applications, *Physica B: Condensed Matter*, 638(2022).
- 4] Priyanka Dubey, Sadanand, B.K. Pandey, D.K. Dwivedi, Contribution towards the selection of electron and hole transport layers for the development of highly efficient PbS colloidal quantum dot solar cell, *Optik*, 266(2022).
- 5] Bui Van Thang, Ha Thanh Tung, Dang Huu Phuc, Tan Phat Nguyen, Tran Van Man, Lam Quang Vinh, High-efficiency quantum dot sensitized solar cells based on flexible rGO-Cu₂S electrodes compared with PbS, CuS, Cu₂S CEs, *Solar Energy Materials and Solar Cells*, 250(2022).
- 6] Dong Huang, Zhuoyin Peng, Chengtang Long, Wen Luo, Yue Wang, Yilong Fu, Inorganic iodide surface passivation on PbS quantum dots by one-step process for quantum dots sensitized solar cells, *Chemical Physics Letters*, 791(2022).
- 7] Siyu Zheng, Jingxuan Chen, Erik M.J. Johansson, Xiaoliang Zhang, PbS Colloidal Quantum Dot Inks for Infrared Solar Cells, *iScience*, 23(2020).
- 8] Jinhuan Li, Yinglin Wang, Shuaipu Zang, Daoheng Pan, Xintong Zhang, Yichun Liu, CuS_x hole transport layer for PbS quantum dot solar cell, *Solar Energy*, 209(2020).
- 9] Meibo Xing, Yaohong Zhang, Qing Shen, Ruixiang Wang, Temperature dependent photovoltaic performance of TiO₂/PbS heterojunction quantum dot solar cells, *Solar Energy*, 195(2020).
- 10] Rijun Gui, Hui Jin, Zonghua Wang, Lianjiang Tan, Recent advances in synthetic methods and applications of colloidal silver chalcogenide quantum dots, *Coordination Chemistry Reviews*, 296(2015).
- 11] Chao Xie, Yi Wang, Zhi-Xiang Zhang, Di Wang, Lin-Bao Luo, Graphene/Semiconductor Hybrid Heterostructures for Optoelectronic Device Applications, *Nano Today*, 19(2018).
- 12] Yuncheng Mu, Ziyu He, Kun Wang, Xiaodong Pi, Shu Zhou, Recent progress and future prospects on halide perovskite nanocrystals for optoelectronics and beyond, *iScience*, 25(2022).
- 13] Jyothilakshmi V.P., Bhabhina N.M., Dharsana M.V., Sindhu Swaminathan, Wet chemical synthesis of lead sulfide nanoparticles and its application as light harvester in photovoltaic cell, *Materials Today: Proceedings*, 33(2020).

- 14] Venkatarao Selamneni, Parikshit Sahatiya, Mixed dimensional Transition Metal Dichalcogenides (TMDs) vdW Heterostructure based Photodetectors: A review, *Microelectronic Engineering*, 269(2023).
- 15] B.K. Murgunde, M.K. Rabinal, M.N. Kalasad, Biologically active nanocomposite of DNA-PbS nanoparticles: A new material for non-volatile memory devices, *Applied Surface Science*, 427(2018).
- 16] Bo Liu, Chunyu Wang, Shahab Bazri, Irfan Anjum Badruddin, Yasin Orooji, Samrand Saeidi, Somchai Wongwises, Omid Mahian, Optical properties and thermal stability evaluation of solar absorbers enhanced by nanostructured selective coating films, *Powder Technology*, 377(2021).
- 17] S. Jana , S. Goswami , S. Nandy , K.K. Chattopadhyay, Synthesis of tetrapod like PbS microcrystals by hydrothermal route and its optical characterization, *Journal of Alloys and Compounds*, 481(2009).
- 18] Minji Kim, Kyounghee Jeon, Won Hee Kim, Jeong Wook Lee, Yoon-Ho Hwang, Hyomin Lee, Biocompatible amphiphilic Janus nanoparticles with enhanced interfacial properties for colloidal surfactants, *Journal of Colloid and Interface Science*, 616(2022).
- 19] Eftade Pınar Gür, Mesut Eryiğit, Ümit Demir, High-performance PbS/CdS quantum dot Co- sensitized hierarchical ZnO nanowall photoanodes decorated on electrochemically reduced grapheme, *Electrochimica Acta*, 438(2022).
- 20] P. Jeya, SP. Keerthana, L. Kungumadevi, R. Yuvakkumar, G. Ravi, Asokan Kandasami, T.S. Senthil, Gamma irradiation effect on photocatalytic properties of Cu and Sr ions codoped PbS, *Environmental Research*, 226(2023).
- 21] Michael B. Mensah, Johannes A.M. Awudza, Neerish Revaprasadu, Paul O'Brien, Synthesis of CdS and PbS nanoparticles by the thermal decomposition of ethyl xanthate complexes in castor oil using the heat-up technique, *Materials Science in Semiconductor Processing*, 122(2021).
- 22] Amitkumar R. Patil, Tukaram D. Dongale, Rajanish K. Kamat , Keshav Y. Rajpure, Binary metal oxide-based resistive switching memory devices: A status review, *Materialstoday*, 34(2023)



Impact Factor: 8.423



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details