COMPARATIVE STUDY ON PHOTOVOLTAIC BEHAVIOR IN ORGANIC- INORGANIC HYBRID PHOTOVOLTAIC CELLS OF SI AND FTO SUBSTRATES

May Thu Aung[1], Myo Min Thein [2], Cho Cho Khing[3], Ei Ei Phyu Htwe[4]

Abstract

Organic Inorganic hybrid Photovoltaic cells were fabricated by using Polyaniline (PANI) nanofibers and semiconducting oxide (BSO). PANI-BSO hybrid polymeric blend were coated on two different substrates Si and FTO by using spin coating method. The structure and surface morphology of PANI-BSO/Si film and PANI-BSO/FTO film were characterized by using XRD, SEM, and AFM respectively. UV-vis spectroscopy was carried out to study light absorption behavior of fabricated films. Especially, comparison between photovoltaic properties of fabricated hybrid photovoltaic cells was studied.

Keywords: Hybrid Photovoltaic cell, Spin coating, XRD, SEM

Introduction

Organic-inorganic photovoltaic (PV) solar energy conversion is an attractive method for clean and green energy generation. Organic –inorganic hybrid have attracted considerable attention as possible next-generation thin-film solar cells because of advantages such as low-cost, environmentally safe, flexible, light weight and inexpensive[D.G. Michael et al 2009].A typical OPV device consists of one or several photoactive materials sandwiched between two electrodes. An organic photovoltaic cell (OPV) composed of a film of organic photovoltaic active layer (electron transport layer, hole transport layer) is sandwiched between transport electrode (anode and cathode). There are two fundamental functions: photogeneration of charge carriers (electron and hole) in a light absorbing material and separation of the charge carriers to a conductive interaction to transmit electricity. The active region of an organic device consists of two materials, one which acts as, an electron donor and the other as an electron acceptor[H. Jin, H. Sang & K.Nazeeruddin 2013]. Organic photovoltaics were extensively investigated because of their potentially low-cost nature and simplicity in fabrication. The interest in organic/inorganic heterojunctions (HJs) has grown simultaneously with most studies on BSO based photovoltaics. The active participation of polymer in photocurrent generation was also confirmed [D.J. Hermant et al 2011].

In recent decades, several studies have been carried out to enhance polyaniline-metal oxide hybrid nanocomposites materials. The electrical property of polyaniline is an important factor which could be modified by the addition of inorganic fillers such as metal oxide nanostructures with dimensions in the nanoscale. In this study, hybrid photovoltaic devices use a blend of aniline polymers and n-type semiconductive oxide, BSO to convert sunlight into charges. There are several types of interlayer materials including the conductive polymeric materials, self- assembled molecules and metal oxides. One of the key components in the inverted OPV is the electron transport layer (ETL) materials on conducting oxide electrodes such as titanium oxide (TiO_2), zinc oxide (ZnO), Lead Sulphide (PbS), Barium Stannate ($BaSnO_3$) and

[1] Dr, Demonstrator, Department of Physics, Maubin University.
[2] Assistant lecturer, Department of Physics, Maubin University.
[3] Professor and head, Department of Physics, Maubin University.
[4] Lecturer, Department of Physics, West Yangon University.

Cadmium Suiphide (CdS), cesium carbonate (Cs_2CO_3). Perovskite structure$BaSnO_3$has gained increasing attention recently as a candidate material for next generation oxide electronic devices. This material has shown notably high electron mobility at room temperature, reported to be up to 320 $cm^2V^{-1}s^{-1}$in bulk single crystal ,with good optical transparency in the visible region. These properties are desirable in transparent conducting materials for solar cells, displays, high-mobility channels for transistors, and other applications[J. Cerda, et al 2002].Hole transport layer (HTL), polyaniline which is more effective charge transport properties in hybrid photovoltaic cell. Herein, we demonstrate that we have successfully synthesized highly crystalline and discrete $BaSnO_3$ nanoparticles, which enable the fabrication of mesoporous films with improved photovoltaic properties. We demonstrate the photovoltaic performance of hybrid photovoltaic cells based on two different electrodes. [N. Go spodinova, & Terlemezyan1998].

In this research, PANI-BSO/Si and PANI-BSO/FTO nanocomposite film were fabricated and comparative Study on Photovoltaic Behavior of fabricated hybrid photovoltaic cells was carried out.

Experimental

Synthesis of polyaniline (PANI) polymer

Polyaniline has been synthesized by chemically in emeralidine salt from using redox polymerization of aniline in presence of ammonium peroxyd isulfate (APS) as an oxidant and HCl as a dopant. Aniline 43 ml in 10ml of 1M HCl solution at room temperature was stirrered for 1hr,then 20g of APS solution was added at a rate of 5 drop/min. After adding complete solution of APS the mixture was stirring for 2hr. The precipitate was washed with ethanol, acetone and DI water and then filter with filter paper. To get fine and dry PANI polymer, the specimen was annealed at 100ºC for 5hr.The structure and particle size of the PANI nanoparticles were characterized by XRD.

$BaSnO_3$ (BSO) Nanoparticle fabrication

Perovskite $BaSnO_3$ was successfully synthesized by solid state reaction method. $BaCO_3$ and SnO_2 were used as precursors. (1:1) weight ratio of $BaCO_3$ and SnO_2 were grinded by mortar and pestle. 2methoxythanol was used as solvent. To obtain homogeneous mixture, the mixture was grinded for 3hr. Then, the specimen was preheated at 900°C for 4hr.This ceramic is high melting point. So the sample was calcined at 1100°C for 4hr in order to disappear coformation of Ba_2SnO_4 phases along with $BaSnO_3$. To obtain fine powder of BSO nanoparticles the specimen were crushed with mortar and pestle and then sieved with mesh for three times.

Preparation of Nanocomposite Films

Nanocomposite films of inorganic materials (BSO) and PANI were prepared by mixing (1:2) weight ratio of PANI and inorganic nanoparticles. 2-methoxythanol was used as solvent. At first, the desired composition of inorganic materials, organic material and solvent were mixed and the mixture was stirred with magnetic stirrer for 1hr. To get homogeneous mixture, this solution was refluxed with water bath at 100ºC for 1hr. For the substrate, FTO coated glass was used. Before the deposition of thin film, the substrate was also cleaned with ethanol, acetone and deionized water respectively. After that nanocomposite mixture was deposited on FTO substrate using spin coating machine. The deposition parameters were 3000 rpm deposition speed and 1 min deposition time at room temperature. After heated at 400 ºC for 1hr and dried at room

temperature, a good nanocomposite films were obtained. To determine their microstructure, optical absorption and photovoltaic cell properties, SEM, AFM, UV-visible spectroscopy and current density-voltage characteristics measurement analyses were carried out.

Results and Discussion

Structural Characterization of PANI and BSO

XRD technique was used to examine toward studying phase analysis, powder structure, crystallographic investigation and lattice parameters for fabricated samples. The structural properties were determined by using a Diffractometer (Rigaku RINT 2000). XRD was performed using monochromatic CuK_{α} radiation (λ= 1.54056Å) operate at 40 kV(tube voltage) and 40 mA (tube current). Sample was scanned from 10° to 70° in diffraction angle.

The XRD spectrum of BSO and PANI samples were indicated as shown in Figure 1(a&b). Upper side of XRD profile was represented the observed profile while the lower side indicated the standard/ reference profile was JCPDS (Joint Committee on Powder Diffraction Standards) library file.

The XRD spectrum of polyaniline (PANI) samples was indicated as shown in Figure 1(a). In these spectrums, six diffraction patterns were observed and all of these patterns were consistent with standard polyaniline. Study of standard data JCPDS 00-0531890 confirmed that the synthesized materials were orthorhombic structure. In these spectrum, (110) diffraction plane was the most intense. The two extra peaks of (100) and (110) was observed and it was due to formation of poly(aminobenzene).

In XRD spectrums of BSO sample was shown in Figure1(b). these spectrums, five diffraction patterns were observed and all of these patterns were consistent with standard BSO. Study of standard data JCPDS 15-0780 confirmed that the synthesized materials were cubic BSO phase (perovskite structure). In these spectrum, (110) diffraction plane was the most intense. The calculation of lattice constant and crystallite size for PANI and BSO samples were listed in Table1 and 2.

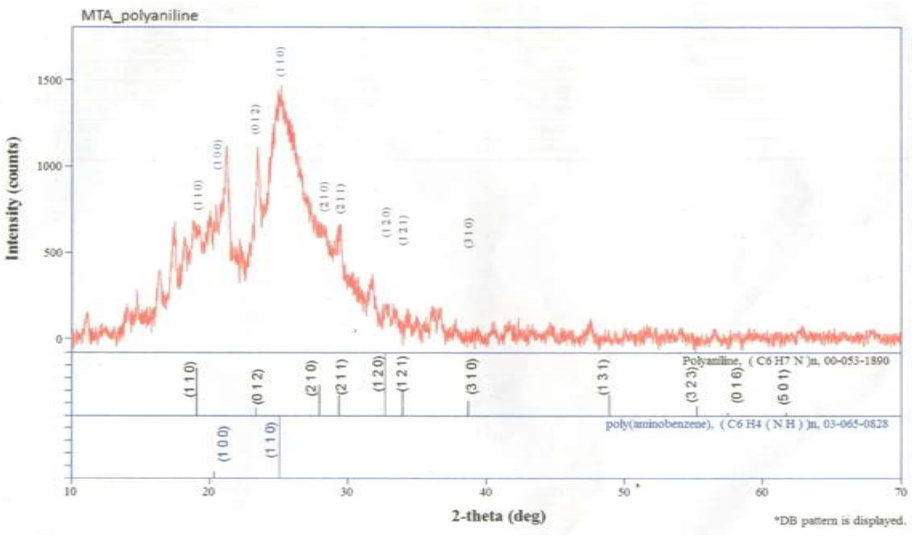

Figure 1 (a) XRD Profile of PANI

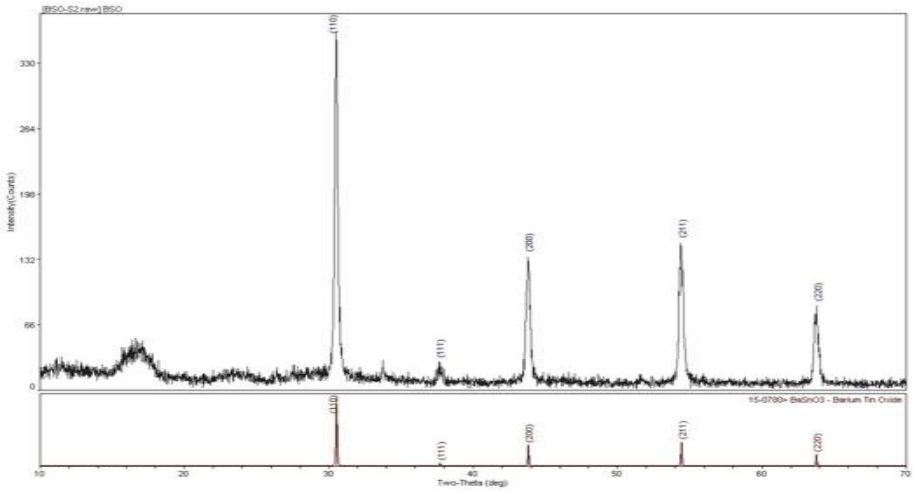

Figure 1 (b) XRD Profile of BSO

Table 1 The value of lattice constant and crystal structure of fabricated PANI, PbS and BSO samples.

Sample	Lattice constant a (Å)	Lattice constant c (Å)	Lattice Strain c/a	Phase
PANI	7.7148	5.7956	0.7512	Orthorhombic
BSO	4.1301	4.1301	1	Cubic

Table 2 The variation of crystallite size of fabricated PANIandBSOsamples

Sample	G(nm)
PANI	34.52
BSO	30.72

Microstructural Properties of Polyaniline and BSO Samples

The microstructural properties of fabricated samples were studied by Scanning Electron Microscopy (SEM). Figure 2(a) showed the SEM images of polyaniline. In this figures, polyaniline nanofibers was clearly observed. The connectivity between grain were observed and they were agglomerated to each other. Figure 2(b) showed the SEM images of BSO. In this figures microstructural particles were observed. The surface morphology was rough and dense. All grains have circular feature. The connectivity between grains were pronounced. It was consistent with XRD results. The average grain size of these samples were found to vary from 0.2 to 0.3 μm. It was consistent with XRD results.

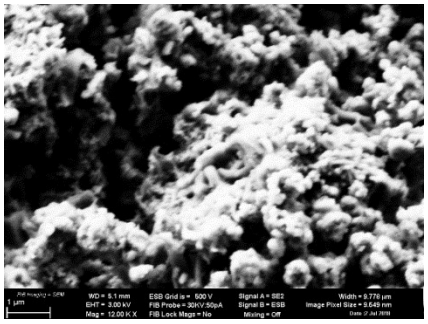

Figure 2 (a) Scanning Electron Image of PANI

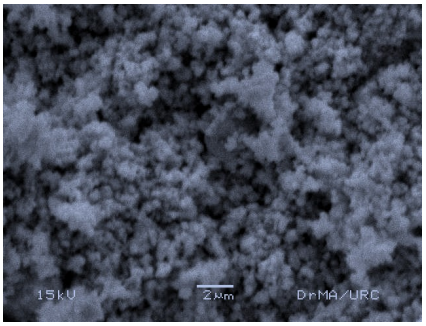

Figure 2(b) Scanning Electron Image of BSO

AFM studied of PANI-BSO/Si and PANI-BSO/FTO Nano Hybrid

The properties of a broad range of materials and performance of different devices depend strongly on their surface characteristics. The morphological and surface roughness of the functionalized nanocomposite films were characterized by atomic force microscopy(AFM).In order to understand the morphological and roughness changes with different high work function electrode layer, Si and FTO. The AFM image of PANI-BSO/Si and PANI-BSO/FTO films were shown in Figure 3(a&b). In these figures, the films were accompanied by picometric roughness. Compact distributions of micro size well defined particles were observed in AFM image. The picorange (10^{-12}) of root mean square roughness of the active layer showed that the improvement of exciton dissociation and has a significant effect on the performance of OPV. It was found that the smoother the interlayer of the active layer (with a larger donor /acceptor interfacial area in the active layer that facilitates exciton dissociation. The bright area in figure is interpreted as BSO rigid nanomaterials and the darker areas as polymer of soft material. The surface roughness for PANI-BSO/Si film was 190.5 pm^2 and the surface roughness for PANI-BSO/FTO film was 297 pm^2. They are suitable for hybrid solar cell because it is a simple way to fabricate the low cost and high efficiency hybrid solar cells at one time**.**

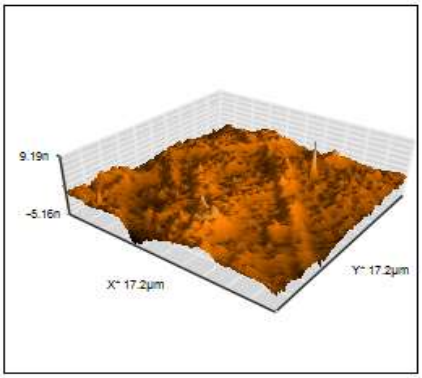

Figure 3 (a) AFM Image of PANI-BSO/Si Film

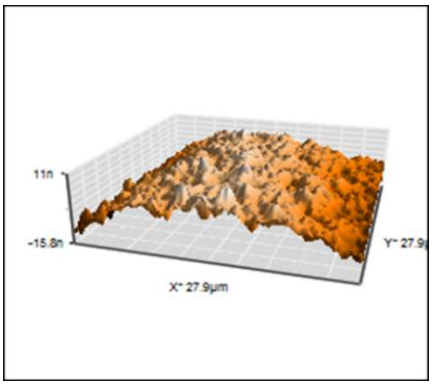

Figure 3 (b) AFM Image of PANI-BSO/FTO Film

UV-vis Absorption Spectrum of PANI-BSO Nanocomposite

The optical properties and energy band gap value of the functionalized nanocomposite films were characterized by UV-vis microscopy. The absorption spectrum of PANI-BSO was shown in Figure4. From the spectrum an excitonic absorption peak was noted at wavelength of about454nm and 302nm. So, it indicate that the absorbing nature of material were high and the

band gap of PANI-BSO has 3.24eV. It is clearly observed that the optical band gap of this material was situated between (1~4)eV and it is good for construction of hybrid photovoltaic cells.

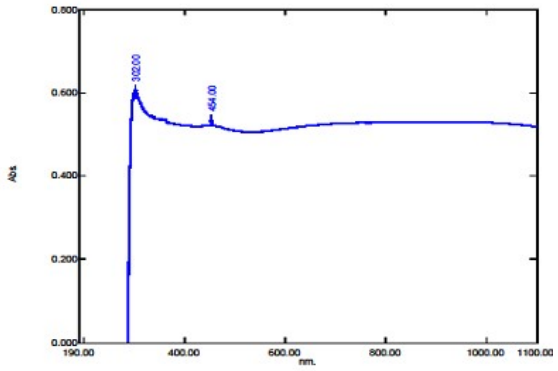

Figure 4 UV-Vis Absortion Spectrum of PANI-BSO Nanocomposite

Photovoltaic Cell Performance of PANI-BSO/Si and PANI-BSO/FTO

Current-voltage measurements were performed, under illumination in order to determine the performance and electrical characteristics of the photovoltaic devices. A typical current voltage characteristic of PANI-BSO/Si and PANI-BSO/FTOPV cells under illumination were shown in Figure 5(a & b). The current density under illumination at zero applied voltage V_{oc} is called the short-circuit current density J_{sc}. The conditions include the light intensity (10000 lux). In these figures, the current density–voltage characteristic showed photovoltaic cell nature. The increased voltages and the current density were probably caused by the effect of the different high work function electrodes such as Si and FTO layers. The PCE of PANI-BSO/Si was higher than that of PANI-BSO/FTO with the influence of increased Jsc and this increase was probably a consequence of a better junction at the high work function electrodes caused by the PANI-BSO layer. The calculated solar cell parameters such as open circuit voltage(V_{oc}), short circuit current density(J_{sc}), maximum current density (J_m), maximum voltage(V_m), fill factor(FF) and energy conversion efficiency(η) were listed in Table 4.

Table 4 Photovoltaic cell parameters of PANI-BSO/Siand PANI-BSO/FTOCells

Parameter	PANI-BSO/Si	PANI-BSO/FTO
V_m(mV)	189	275
J_m(μAcm^{-2})	101	60
V_{oc}(mV)	320	350
J_{sc}(μAcm^{-2})	140	120
FF(%)	43	39
η (%)	1.31	1.12

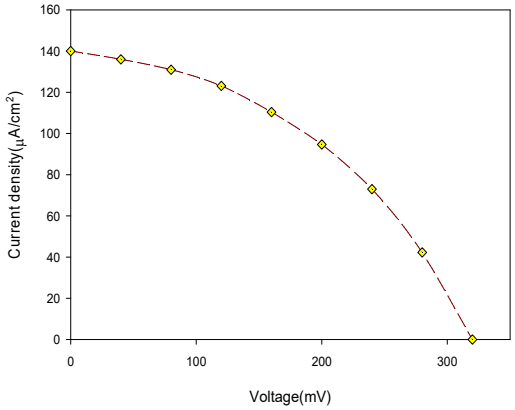

Figure 5(a) J-V characteristic curve of PANI-BSO/Si

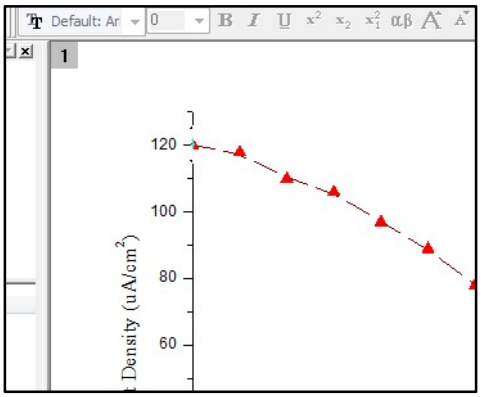

Figure 5(b) J-V characteristic curve of PANI-BSO/FTO

Conclusion

PANI-BSO/Si and PANI-BSO/FTO nano hybrids films have been fabricated by spin coating method. Compact distribution of micro size well defined particles were observed in AFM image. The surface roughness for PANI-BSO/Si film was 190.5 pm^2 and The surface roughness for PANI-BSO/FTO film was 297 pm^2. The pico range (10^{-12}) of root mean square roughness of the active layer show that the improvement of exciton dissociation and has a significant effect on the performance of OPV. According to AFM and SEM results, it was clear that of the nanocomposite materials has good crystallinity. The calculated band gap energy values for PANI-BSO film was 3.24eV and it can be shown as good light absorption nature. The energy efficiency of fabricated PANI-BSO/Si and PANI-BSO/FTO were 1.31%.and 1.12% respectively. The different cell efficiency occurred is due to the nature of different substrates. In summary, it was observed that the nanostructure PANI-BSO/Si and PANI-BSO/FTO hybrid photovoltaic cells were fabricated by simple method and these materials were quite promising specimens for photovoltaic cells application.

Acknowledgements

This result was totally implemented at Department of Physics, University of Yangon, Myanmar(2018-2019). We would like to thank Professor Dr Khin Khin Win, Head of Department of Physics, University of Yangon for her kind permission to carry out this work. We are delighted to thank, Dr Cho Cho Khine, Professor and Head of Department of Physics, Maubin University for her kind permission and help. We would like to express our gratitude to several of my supervisor for making useful suggestion.

References

A.J. Heeger, (2014). "Bulk Heterojunction Solar Cells: Understanding the Mechanism of Operation", Advanced Materials Journal, 26, 10–28.

D.J. Hermant, E.G. Joshua, C. Stephen, & T.M. Daniel, (2011). "Orienting Periodic Organic – Inorganic Nanoscale Domains Through One-Step Electro deposition", American Chemical Society Nano Journal, 5(1), 565-573.

D.G. Michael, (2009). "Nanostructured Organic–Inorganic Hybrid Solar Cells", Material Research Society Bulletin journal, 34, 96-100.

G. Serap, &Gunes, (2007). "Conjugated Polymer-Based Organic Solar Cells", Chem. Review, 107, 1324-1338.

H. Jin, H. Sang, & K.Nazeeruddin, (2013). "Efficient inorganic–organic hybrid heterojunction solar cells containing perovskite compound and polymeric hole conductors", Nature Photonics Journal, 7, 486-49.

J. Cerda, J. Arbiol, R. Diaz, G. Deanneau, & J.R. Morante, (2002). "Synthesis of Perovskite-type $BaSnO_3$ Particles Obtained by a New Simple Wet Chemical Route Based on a Sol-gel process", Material letters, 56, 131-136.

N. Gospodinova, &Terlemezyan, (1998). "Conducting polymers prepared by Oxidative polymerization: polyaniline", Science Journal, 23, 1443–1484.