IJIREEICE

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 4, Issue 3, March 2016

Fabrication of Dye Sensitized Solar Cells Using ZnO Nanocomposites

Safia A Kazmi[1], Salman Hameed[2]

Assistant Professor, Electrical Engineering , ZHCET, AMU, Aligarh, India [1]

Associate Professor, Electrical Engineering , ZHCET, AMU, Aligarh, India [2]

Abstract: In the present work, the effect of zinc oxide (ZnO) and its nanocomposite on the performance of dye sensitize solar cells (DSSCs) was studied. ZnO is a wide band gap semiconductor that is of interest for applications in a wide variety of optoelectronic devices, including dye-sensitized organic solar cells (DSSCs). Initially ZnO and CuO nanoparticles were synthesized using sol gel method then ZnO-CuO nanocomposite were synthesized and the structural, optical, characterization were done using various techniques such as XRD, FT-IR,UV-Vis, SEM. The band gap of ZnO was calculated using Debye Scherer's equation. The prepared nanoparticles and nanocomposites were pasted on FTO glass using doctor blading technique and used as working electrodes in dye sensitized solar cells (DSSCs).These working electrodes were sensitized with N719 dye and coupled with platinum coated cathode. The J-V characteristics of the DSSCs were studied under standard conditions and their photovoltaic performance was compared. Improved performance of ZnO-CuO nanocomposite DSSCs were observed as compared to ZnO DSSC due to reduced band gap, increased crystallite size and reduced charge recombination.

Keywords*:* DSSC, ZnO, Photovoltaic, CuO.

I. INTRODUCTION

Dye sensitized solar cells (DSSCs) also known as Gratzel's cell was invented by Gratzel and O'Regan they first reported the DSSC in 1991[1]. DSSCs are the devices which convert visible light into electricity based on sensitization of wide band gap semiconductor [2]. It consist of nanoporous wide band gap semiconducting oxide layer, dye sensitizer which plays important role in harvesting sunlight and transforming solar energy into electric energy, an electrolyte and a counter electrode which may be graphite coated or platinum coated [3]. DSSCs are attractive, inexpensive, non-polluted, easy production solar cells [4].

ZnO is a promising material for solar cell applications. ZnO is a wide band gap semiconductor with a band gap of 3.30 eV at room temperature. Low dimensional ZnO nanostructures have been extensively investigated due to its unique structural, electrical, and optical properties [5] [6].ZnO is a multifunctional semiconductor with various properties which are suitable in many applications like in nanoscale lasers piezo- electric devices, chemical sensors and solar cells [7,8].

ZnO has been considered as a promising candidate for DSSCs due to its carrier mobility and direct band gap, and position of conduction band but inspite of these advantages, the efficiencies of zinc oxide based DSSCs are usually low.

To overcome this limitation, structural changes in ZnO were done and nanocomposites of zinc oxide were used to enhance the efficiency [9-13]. In this work, ZnO-CuO nanocomposite is used for increasing the photovoltaic performance of Dye sensitized solar cell. Initially these materials were synthesized and then characterized using XRD patterns, FTIR and UV-Vis spectroscopy, and SEM images.

II. EXPERIMENTAL

A. *Materials*

The entire chemical used were of analytical grade and used without further purification. Fluorine-doped tin oxide (FTO), conducting glass plates and used as substrates and cleaned by standard procedures prior to use and Iodide electrolyte were purchased from ICE USA. The Zinc acetate dehydrate (Zn(CH3COO)2.2H2O), Cu(CH3COO)2.2H2O, tri-ethanolamine (TEA) were purchased from sigma Aldrich , the other chemical used are ethyl cellulose, NH4OH, iso-prppanol (iPrOH) and TritonX-100.

B. *Synthesis*

For synthesis of ZnO NPs, 2ml ethanol was added to a mixture of 20ml water and 30 ml tri-ethanolamine (TEA) and kept on magnetic stirrer until solution become homogeneous. 0.5M Zinc acetate dihydrate ($Zn(CH_3COO)_2.2H_2O$) and 50 ml DI water was added in another beaker stirred until solution became homogeneous. Both solutions were mixed and 50 ml NH_4OH was added on magnetic stirrer keeping the temperature at 120°C for 30 minutes. After 30 minutes the mixture was washed with distilled water and then put in oven at 95°C for 8 hours and finally grinded in mortar. The synthesis of ZnO-CuO nanocomposite was done by adding 4.5g of Zn $(CH_3COO)_2.2H_2O$ and 2g of $Cu(CH_3COO)_2.2H_2O$ to 60ml of isoprppanol (iPrOH) stirred at 75°C for 2 hours. Aging this solution for 1 day and evaporated at 82°C forms the gel and then gel were annealed by taking it up to 550°C for 2 hrs.

C. *DSSC Fabrication:*

To fabricate the DSSC, the conducting side of fluorine doped tin oxide glass (FTO) was checked by multimeter by placing the glass FTO face up. The synthesized 0.5g

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 4, Issue 3, March 2016

nanoparticles in 10 ml ethanol were mixed and grinded in mortar for about 30 min adding 1ml glycol and kept in sonicator for 20 minutes, again grinded in the mortar after adding TritonX-100 till the paste becomes smooth , the paste was applied on pre cleaned FTO glass using doctor blade technique for 1cm^2 area. The electrodes are sintered at 450^{o}C for half hour and cooled at room temperature. The electrodes are then immersed in N719 ruthenium dye solution for 24 hours. After sensitisation colour of wide band gap semiconductor coated electrode was changed. It absorbed dye. The DSSC cathode was made by using platisol solution and annealing at 450°C.Both the electrodes were tied together with the help of clips and a drop of iodide electrolyte was poured in between. The open circuit voltage, short circuit current finally I –V characteristics were drawn under standard conditions.

III. RESULTS AND DISCUSSION

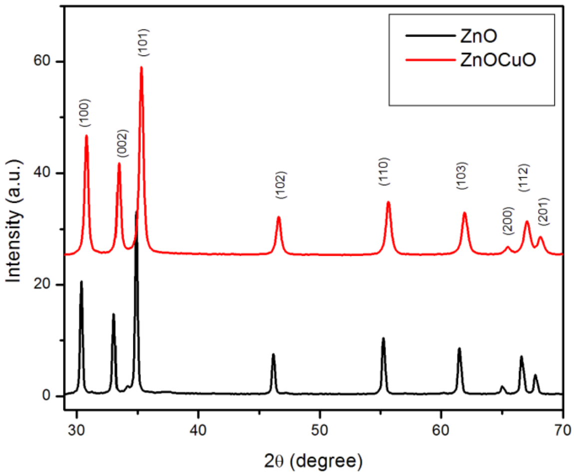

Fig.1 XRD patterns of ZnONPs, and ZnO-CuO nanocomposites.

Fig.1 shows the XRD patterns of ZnONPs, and ZnO-CuO nanocomposite. XRD measurements were performed to confirm the crystalline phase and the phase composition of the ZnO and ZnO-CuO nanocomposite. In figure the diffraction peaks at 30.34, 33.07^o, 34.8^o, 46.20^o, 55.25^o, 61.5^o, 65.0^o , 66.6^o and 67.7^o are correspondingly assigned to ZnO (100), (002), (101), (102), (110), (103), (200), (112) and (201). The XRD pattern of ZnO-CuO shows same pattern but peak broadening and reduction in FWHM shows increase in crystallite size.

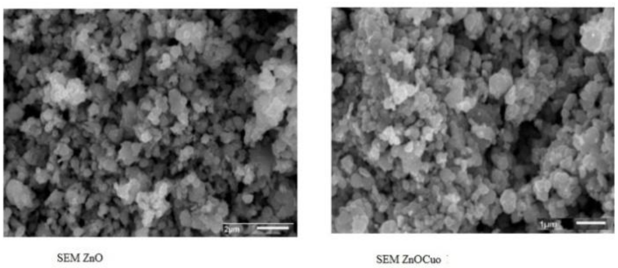

Fig.2: SEM images of (a) ZnO NPs, (b) ZnO-CuO

Fig.2 shows the SEM images of ZnO NPs, and ZnO-CuO nanocomposites which show the CuO particles within the aggregates of the ZnONPs, and there is good contact between the CuO and ZnONPs. Further observation also confirms the porous structure of the ZnONPs, ZnO-CuO, nanocomposite films, which is favourable for the harvesting of photo energy and transporting of electrolyte molecules.

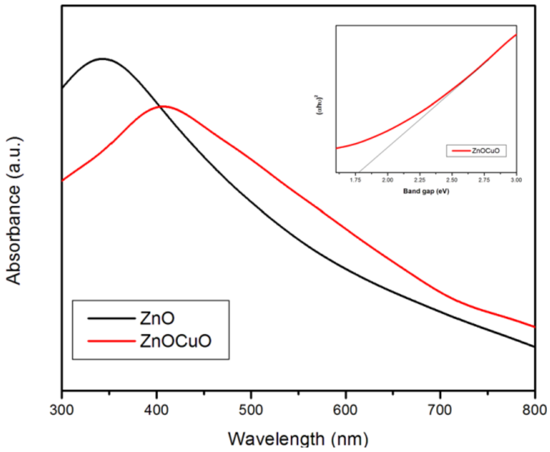

Fig. 3 Absorbance and energy band gap of ZnONPs and ZnO-CuO

Fig.3 shows the absorbance of ZnO and ZnO-CuO and red shift was observed with the addition of CuO. The inset shows that the band gap of ZnO-CuO nanocomposite reduces to 1.69eV.

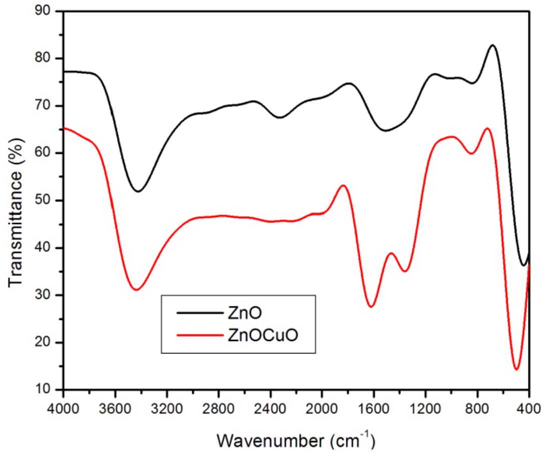

Fig. 4: FT-IR of ZnONPs, and ZnO-CuO, nanocomposites

Fig.4. shows the FT-IR patterns, the peak at 445cm^{-1}shows the Zn-O stretching band. The peaks near 1540 cm^{-1}is due to OH bending of water. The peaks at 3430 correspond to fingerprint stretching vibration modes of surface O-H.

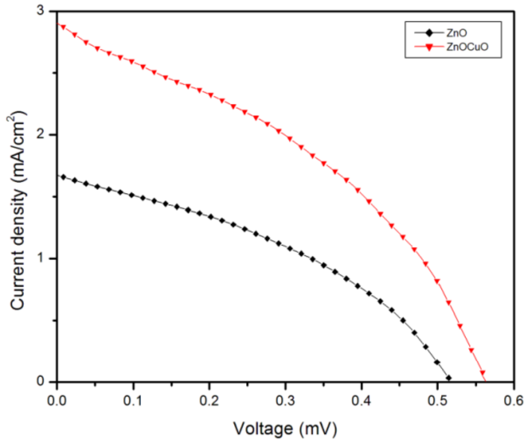

Fig.5. J-V Characteristics of ZnO and ZnO-CuO nanocomposite

DOI 10.17148/IJIREEICE.2016.4312

Fig.5shows the comparison of J-V characteristics of ZnO nanomaterials film and ZnO-CuO nanocomposite film DSSCs compared in Table-I. It was observed that the efficiency of DSSCs using ZnO NPs, and ZnO-CuO, was 3.4%, and 6.2% respectively but no change in fill factor. From these results, it was conclude that the nanocomposite such as ZnO-CuO has better photovoltaic performances.

Table I

Anode Material	Voc (A)	Jsc (mA/cm^2)	Vm (A)	Jm (mA/cm^2)	Efficien-cy (%)	Fill factor
ZnO	0.515	1.67	0.368	0.92	3.4	0.39
ZnO-CuO	0.562	2.91	0.378	1.66	6.2	0.38

IV. CONCLUSION

Nanocrystalline DSSC is considered to be of low cost, environment friendly and flexible solar cell. The only problem associated with it is its efficiency. However if suitable material and fabrication techniques are applied, its efficiency can be increased. The nanostructured DSSC is going to provide economically credible alternative to present day p-n junction photovoltaic. In this work, ZnO NPs and its nanocomposites were used for thin film coating on DSSC anode with N719 dye and platisol (platinum) coated cathode. It was concluded that the efficiency of DSSC using ZnONPs only film is 3.4 % whereas for nanocomposite the efficiency increases to 6.2% however there is no change in fill factor.

ACKNOWLEDGMENT

Authors are thankful to the Centre of Excellence in material science (nanomaterials) department of Applied physics, AMU, Aligarh for the experimental and characterisation facilities.

REFERENCES

[1]. B. O'Regan, M. Gratzel. Nature 353. PP 737-740. 1991.
[2]. Wei Hao Lai et al. "Commercial and natural dyes as photo sensitizers for a water based dye-sensitized solar cell loaded with gold nanoparticles". Journal of Photochemistry and Photobiology A: Chemistry 195. (2008) PP 307-313.
[3]. Vinoth Shanmugam a, Subbaiah Manoharan b, Sambandam Anandan , Ramaswamy Murugan "Performance of dye-sensitized solar cells fabricated with extracts from fruits of ivy gourd and flowers of red frangipani as sensitizers" Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 104 (2013) 35–40.
[4]. Xiaohuan Miao et al. "Highly crysatalline graphene/carbon black composite counter electrodes with controllable content: Synthesis, characterization and application in dye-sensitized solar cells". Electrochimica Acta 96. PP 155-163. 2013
[5]. T. S. Senthil, N. Muthukumarasamy, and Misook Kang, "ZnO Nanorods Based Dye Sensitized Solar Cells Sensitized using Natural Dyes Extracted from Beetroot, Rose and Strawberry" Bull. Korean Chem. Soc. 2014, Vol. 35, No. 4 T.
[6]. Amal Al-Kahlout, "Thermal treatment optimization of ZnO nanoparticles-photoelectrodes for high photovoltaic performance of dye-sensitized solar cells" Journal of the Association of Arab Universities for Basic and Applied Sciences (2015) 17, 66–72
[7]. Tang Z et al. "Room temperature Ultraviolet laser emission from self-assembled ZnO microcrystalline thin films". Appl PhysLett 72: 3270. 1998.
[8]. Zhong MinYi et al. "ZnO microsheet modified TiO_2nanoparticle composites films for dye sensitized solar cells". Chinese Science Bulletin. Vol 55 No. 18. PP 1945 1948. June 2010
[9]. Mohammad Hossein Habibi et al. "Fabrication, Characterization of two composite CuO-ZnO working electrodes for dye sensitized solar cells". Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 116. PP 374-380. 2013.
[10]. S. S. Kanmani, K. Ramachandran, and S. Umapathy, "Eosin Yellowish Dye-Sensitized ZnO Nanostructure-Based Solar Cells Employing Solid PEO Redox Couple Electrolyte" International Journal of Photoenergy, Hindawi Publishing Corporation,Volume 2012, Article ID 267824, 8 pages.
[11]. Seok-Soon Kim, Jun-Ho Yum, Yung-Eun Sung , 'Improved performance of a dye-sensitized solar cell using a TiO2/ZnO / Eosin Y electrode" Solar Energy Materials & Solar Cells 79 (2003) 495–505
[12]. Kyung Ho Kim , Kazuomi Utashiro, Yoshio Abe and Midori Kawamura "Structural Properties of Zinc Oxide Nanorods Grown on Al-Doped Zinc Oxide Seed Layer and Their Applications in Dye-Sensitized Solar Cells" Materials 2014, 7, 2522-2533; doi:10.3390/ma7042522
[13]. Ming-kwei lee, han yen, and nai-roug cheng, "Efficiency enhancement of dssc with aqueous solution deposited zno nanotip array" IEEE photonics technology letters, vol. 26, no. 5, march 1, 2014