SENRA Academic Publishers, British Columbia
Vol. 7, No. 3, pp. 2635-2638, October 2013
Online ISSN: 1920-3853; Print ISSN: 1715-9997

Canadian Journal of pure&applied sciences

Short Communication

FABRICATION OF DYE SENSITIZED SOLAR CELL (DSSC) USING ZnO NANOPARTICLES SYNTHESIZED FROM ZINC NITRATE HEXAHYDRATE

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ABSTRACT

DSSC was fabricated using glass as the substrate with copper metal attached to the surface, eosin blue as sensitizer, Lemon juice as electrolyte and ZnO nanoparticles as photoelectrode. The nanostructured ZnO was synthesized by precipitating Zn nitrate hexahydrate with NaOH which was characterized structurally using XRD and optically with a UV-VIS Spectrophotometer. The fabricated DSSC was evaluated and a fill factor of 0.85 obtained with an efficiency of 0.15%.

Keywords: UV-VIS, XRD, ZnO, nanoparticles, DSSC.

INTRODUCTION

The utilisation of renewable energy resources has increased largely in the last years owing to the ever increasing need for electrical energy. The finiteness of fossil fuel used for generation of conventional electrical power on one hand and climate change as a result of the co_2 emission by the use of burning those fuels on the other hand. This has led to an indispensable change from fossil fuels to renewable energy. Solar energy is one of the most promising renewable energy and in other to utilize this energy we make use of photovoltaic device. Among the diverse photovoltaic devices, the dye-sensitized solar cells (DSSCs) technology has made enormous progresses and is highly competitive for large scale commercial fabrication (Tao-Hue Lee *et al*., 2011). The DSSC can be classified as a Photoelectrochemical (PEC) solar cell due to its utilization of photons, charges and electrolyte for its basic operation (Yu and Chen, 2009). DSSC are unique compared with almost all other kinds of solar cells in that electron transport, light absorption and hole transport are each handled by different materials in the cell (Brian *et al*., 2012).Since the invention by O' Regan and Gratzel in 1991 it has attracted widespread academic and industrial interest because it offers some advantages over traditional photovoltaic cells (Abel *et al*., 2012). Based on the original design of Gratzel, the cell is basically composed of a working electrode made of nanocrystallineTiO_2 typically 5-10nm in diameter deposited on a transparent conducting (TCO), a dye sensitizer usually Ruthenium based on iodide/Triiodide redox couple electrolyte and a platinum or carbon coated counter electrode (Gratzel, 2003). For almost two decades, many investigators have tried various combinations of nanocrystalline TiO_2, dye sensitizers, electrolytes and assembly methods to optimize the solar cell performance (Aydil, 2007). Though Oxides such as titanium oxide, zinc oxide, tin oxide. Niobium oxide or chalcogenides such as cadmium selenide are the preferred photo electrode because photoelectrodes made of materials such as silicon and cadmium sulfide decompose under irradiance in solution owing to photocorrosion (Monishka, 2012). The most common aspect of the DSSC that has been extensively studied to improve its efficiency is the design and fabrication of the photoelectrode using TiO_2nanomaterials (Zhang *et al*., 2009) and it is reported that practical advantage can be gained by the replacement of the liquid electrolyte with a solid charge transport (Bach *et al*., 1998). The problem of availability of material faced in developing countries for example conductive glass has been scarce and cost expensive. In this paper non-conductive glass and metal electrodes are used in place of transparent conductive oxide glass and ZnO nanoparticles synthesized from zinc nitrate used as photoanode.

MATERIALS AND METHODS

Methodology

Synthesis of ZnO nanoparticles

According to the chemical reaction to be followed for this process.

$$Zn(NO_3)_2 + 2NaOH \rightarrow Zn(OH)_2 + 2NaNO_3 + 6H_2O$$

Zinc Nitrate hexahydrate,ethanol of 97% purity and Sodium hydroxide were purchased which are all analytical grade.

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Preparation procedure:

0.5M aqueous solution of zinc nitrate hexa-hydrate was prepared and was kept under constant stirring using magnetic stirrer to completely dissolve the zinc nitrate for one hour. 0.9M aqueous ethanol solution of Sodium hydroxide [NaOH] was also prepared in the same way with stirring for one hour. After complete dissolution of Zinc nitrate, 0.9MNaOH aqueous solution was added under high speed constant stirring, drop by drop [slowly for 50min]. After complete addition of Sodium hydroxide the solution was allowed to be under stirring for hours. The beaker was sealed at this condition. After the whole process, ZnOH Precipitate was assumed settled at the bottom and the excess mother liquor was removed. The precipitate was washed three times with deionized water and ethanol to remove the by-products which were bound with the nanoparticles and then dried in air atmosphere at about 400˚C. During drying $Zn(OH)_2$ is completely converted into ZnO.

Characterization of the ZnO nanoparticles

The prepared ZnO nanoparticles were characterized for their optical and Nano structural properties. X-ray diffraction pattern for the ZnO nanoparticles was recorded using an X-ray diffractometer (MD-10) using CuKa radiation of wavelength λ=1.5406 in the scan range 2θ=20˚-90˚. The optical transmission /absorption spectra of ZnOdispersed in water were recorded using UV-VIS Spectrophotometer (GENESYS 10s v1.200 2L7H311008).

DSSC Fabrication

After synthesizing the ZnO nanoparticles. Ordinary glass was used as substrate in growing the ZnO nanomaterial prepared in form of paste using nitric acid. To serve as photo electrode of the DSSC (Note: metal electrode of resistance less than 30Ω has been attached to the surface of the glass to serve as electrode). The nanostructured ZnO grown on the glass substrate was soaked in a dye solution of Eosin B, for a period of 48hrs to adsorb enough amount of dye as a sensitizer. The glass with the ZnO nanomaterial and the sensitizer was rinsed with ethanol to remove the excess dyes that were not completely adsorbed to the nanostructured ZnO. Once the whole dye coated ZnO has totally dried, small drops of lemon juice was applied. Finally the metal plate attached to the surface of the second ordinary glass was coated with graphite using pencil and p [laced on top of the working electrode. An offset of about 3.0mm on opposite was included to serve as electrical contacts. The fabricated DSSC was sealed on all its sides to prevent leakage of the electrolyte.

Performance evaluation of the DSSC

The DSSC was connected to a series of potentiometers with resistance ranging from 100Ω to 1000Ω resistance values. Connecting a very sensitive digital voltmeter to the setup the values of the voltage for each amount of load was obtained and the corresponding value for current was calculated using ohms law. The values for current and voltage was used in plotting a graph where the values for maximum current I_m, maximum voltage V_m, open circuit voltage V_{oc} , and the short circuit current I_{sc} was obtained to calculate the fill factor(FF) and the overall energy conversion efficiency. Using the equations presented below:

$$conversionefficiency = \frac{outputpower}{inputpower} \times 100\% = \frac{I_m \times V_m}{inputpower} \times 100\%$$

.

Fill factor= $\frac{I_m \times V_m}{I_{sc} \times V_{oc}}$

RESULTS AND DISCUSSION

Characterization of nanostructure ZnO

The functionalized particles were characterized by the following techniques.

X-ray diffraction (XRD)

Figure 1 reports the XRD spectra of pure ZnO powders in order to compare the sample preparation method, an XRD pattern of a commercial ZnO powder is also shown in the figure. These peaks at scattering angles (2θ) of 31.72˚, 34.39˚and 35.00˚ correspond to the reflection from: 101,002 and 001 crystal planes respectively. The XRD pattern is identical to the hexagonal phase with wurtzite structure with space group (P63 mc) and lattice constants a=b=3.24982 and c=5.20661.

The crystallite size of ZnO powders was deduced using Scherer formula

$$D_{hkl} = \frac{k\lambda}{\beta cos\theta}$$

Where k=Scherer’s constant=0.89
.λ= wavelength of X-rays
.θ= Bragg diffraction angle
.β=full width at half maximum FWHM of the diffraction peak corresponding to plane (001).
The average crystallite size of the sample was calculated to be 26.04nm using the Scherer’s formula.

UV-VIS absorption spectrum

The absorption spectrum of ZnOnanopowder is shown in figure 2.

From the spectrum an excitonic absorption peak was noted at wavelength of about 202nm in the UV-range which is much below the band gap wavelength of ZnO (358nm). More peaks were also noticed at wavelengths of 925 and 1093nm in the NIR region of the spectrum but at a very much lower absorption and this shows that σ-bond electrons are more pronounced in this sample.

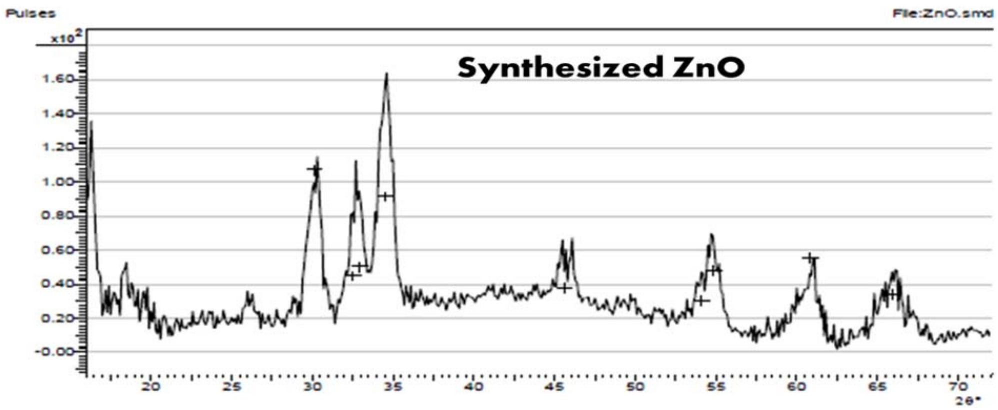

Fig. 1. XRD spectra of ZnOnanopowder.

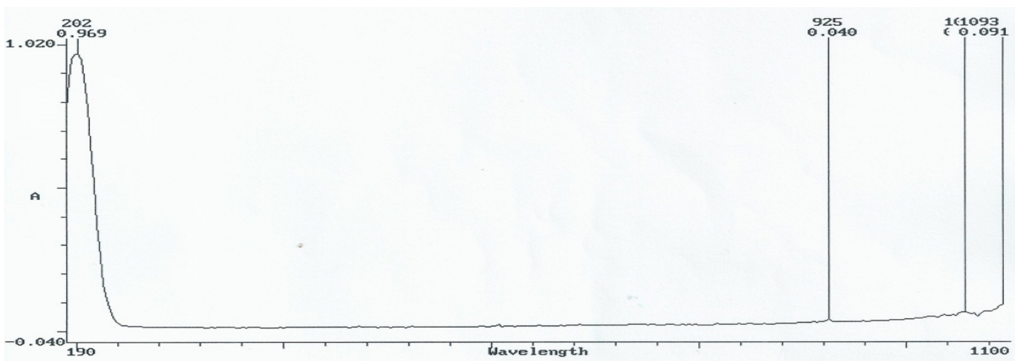

Fig. 2. UV-VIS- NIR spectra of Zn Onanopowder.

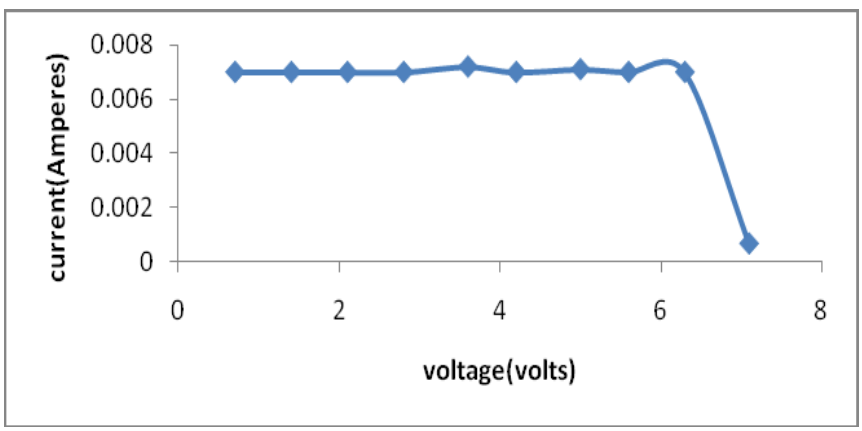

Fig. 3. I-V characterization curve obtained from the performance evaluation.

DSSC Characterization

The fabricated DSSC was characterized in the laboratory using a 220W halogen lamp that emits a mean intensity of 514 lux. The light intensity was converted to the amount of $^{W}/_{cm^2}$ to serve as the input power density on the DSSC which was calculated to be 285.5$^{W}/_{cm^2}$

I-V characterization curve obtained is shown in figure 3. From the graph the following data shown in the table 1 were obtained:

The solar cell efficiency obtained in this work is shown in the table above. This efficiency is still low compared to similar devices made of TiO_2through lower efficiency is reported in several published work which is based on ZnO solar cells which can be due to some properties directly related to ZnO nanomolecules are most likely the efficiency limiting factors. There could be highly-density defects in the surface of ZnO nanomolecules which trap charge and leed to step-wise electron-hole recombination through mid-based gap defect energy level. Additionally oxygen molecules absorbed at the surface of ZnO

Table 1. Evaluation parameters obtained from the DSSC.

$I_m(A)$	V_m(V)	I_{sc}(A)	V_{oc}(V)	FF	η
0.0070	7.1000	0.0712	7.3000	0.855	0.15%

nanomolecules can serve as efficient excitation quenching centre (Tao *et al*., 2011).

CONCLUSION

ZnO nanoparticles synthesized by precipitating Zinc nitrate hexahydrate has been used in the fabrication of DSSC using Eosin blue as the sensitizer with lemon juice as the electrolyte and for the first time using metal contact on a nonconductive glass as electrode from the performance evaluation the ZnO with crystal size of 26.04nm was used to obtain an efficiency of 0.15% which has made this new dimension successful and a new foundation for easy research in the world of photovoltaic in developing countries.

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Received: Feb 23, 2013; Accepted: June 5, 2013