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Fabrication of dye sensitized solar cell using chemically tuned CuO nano-particles prepared by sol-gel method

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ABSTRACT

Purpose: This work details about the isolation of CuO nanoflakes by a simple precipitation technique. Further it is coated over ITO substrate using spin coating technique. DSS cell capabilities were checked by placing a drop of plant dye derived from pomegranate.

Design/methodology/approach: CuO nano flakes, a novel Nano sized metal oxide have been synthesized by sol-gel method. The synthesised flakes were characterized by using XRD (X-ray diffraction), FESEM, UV-VIS and PL measurements techniques. XRD studies show that, the copper oxide formed has monoclinic structure.

Findings: The grain size of the synthesized copper oxide nanoflakes were measured from FESEM and found that the size was around 200 nm. The UV-VIS measurement show that the band gap of CuO nanoflakes were found to be 3.03 eV, which is in the range of a good semiconductor. Finally, the dye sensitized solar cell was fabricated and its power conversion efficiency η (PCE) was determined.

Practical implications: The search for green sources or generators of energy is considered as one of the priorities in today's society and occupies many policy maker's agenda. It is believed that nanocrystalline photovoltaic devices are becoming viable contender for large scale future solar energy converters.

Keywords: Nanaoflakes; Copper oxide; Dye sensitized solar cell; Semiconductor; Photoluminescence

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PROPERTIES

1. Introduction

In response to the changing global landscape, energy has become a primary focus of the major world powers and scientific community [1-6]. There has been great interest in developing and refining more efficient energy storage devices. To solve this issue, research in alternative renewable energy sources is being one of the thrust area

[7, 8]. Nanotechnology is the art of manipulating matter at the nano scale which is nowadays playing a vital role in solar technology [9,10]. In fact, the conversion of solar energy into electrical energy, normally mediated by employing various categories of semiconducting materials selection is one of the important criteria in fabricating an efficient solar cell [11,12]. CuO being first transition elements of the d-block requires only a very small amount of energy for the excitation of electron from one energy level to the other could be a promising material for solar cell application.

The CuO nanoflakes are the novel materials for photo electronic devices and the properties are expected to change. The study made on solid-state synthesis and effect of temperature on optical properties of CuO nanoparticles [13, 14] showed that CuO is attractive as a selective solar absorber since it has high solar absorbance and a low thermal emittance. Moreover, the problem in the existing solar cell is that the absorption of the light is very less (<60%). Hence the utilization of the light must be done effectively [15]. Presently dye sensitized molecules incorporated in wide band gap semiconductor electrodes plays a vital role in photo electrochemical solar cells. The application of sensitizers with a large absorption band anchored with the oxide films permits to collect huge amount of sunlight [16-20]. This work details about the isolation of CuO nanoflakes by a simple precipitation technique. Further it is coated over ITO substrate using spin coating technique. DSS cell capabilities were checked by placing a drop of plant dye derived from pomegranate.

2. Materials and methods

The sol gel method involves the formulation of colloidal suspension (sol) and gelatin of the sol to form a network in continuous liquid phase (gel). The $Cu(OH)_2$ is prepared by reacting aqueous solution of 0.01 M copper nitrate, and 0.02 M sodium hydroxide solution. The sodium hydroxide solution was prepared by dissolving NaOH pellets in 20 ml of distilled water. The NaOH solution was added in drops to the aqueous solution with constant stirring by magnetic stirrer. This process was continued until the desired pH value of 14 was reached. The chemical reaction between copper nitrate and sodium hydroxide solution is shown below.

$$Cu(NO_3)_2 + 2NaOH \ \text{->}\ Cu(OH_2) + 2NaNO_3 \qquad (1)$$

The resulting blue-green gel was washed several times until the nitrate ions were removed out. The resulting precipitate was collected in a watch glass and kept in hot air oven at 150 degree Celsius for 2 hours. The copper hydroxide decomposes into copper oxide as follows,

$$Cu(OH_2) \ \text{------>}\ CuO + H_2O \qquad (2)$$

3. Fabrication of dye sensitized solar cell

Photo anode for solar cell was prepared by using CuO nano flakes is as follows 0.5 g of CuO nanoflakes were dissolved in 0.5 ml of ethanol and is mixed well for about 30 minutes. This CuO nano flakes were coated on ITO coated conductive glass plate such that the overall cell area is restricted to 1.0 cm^2. Glass surface containing CuO flakes were annealed for about 10 minutes in a hot plate at 150ºC. Then the electrode was soaked in dye solution for about 10 minutess (pomegranate extract). This electrode acts as the photo anode for the DSSC. The counter electrode was coated with graphite and both the electrodes were sandwiched. The electrolyte composed of lithium chloride and iodine were put in between the holes of the electrodes. The fabricated solar cell was tested for its efficiency.

4. Units

4.1. XRD analysis

Room temperature X-ray diffraction patterns of all the prepared samples were obtained using a XPERT- PRO X-ray diffractometer uses Cu K_α radiation(wavelength of λ=1.5418A°). Intensity of the diffracted beam is recorded as a function of the 2theta at a step of 0.05 degree of a scan rate of 3 degree per minute. The X-ray diffraction pattern of the prepared copper oxide nano flakes is shown in Figure 1.

It was found out that $Cu(OH)_2$ decomposes into CuO on heating above 200 degree Celsius. The XRD pattern of copper oxide nanoflakes corresponds to the monoclinic structure. The XRD graph obtained for the sample resembles with the JCPDS no 89-2529 and it was confirmed that copper oxide (tenorite) was formed with monoclinic geometry.

The peak crystallinity was obtained at 2θ= 38.7205, the peak crystallinity of the copper oxide nanoflakes was obtained at 0.572363 (FWHM). The crystalline size of the copper oxide nanoflakes was found using Scherrer formula and it was estimated to be about 15 nm.

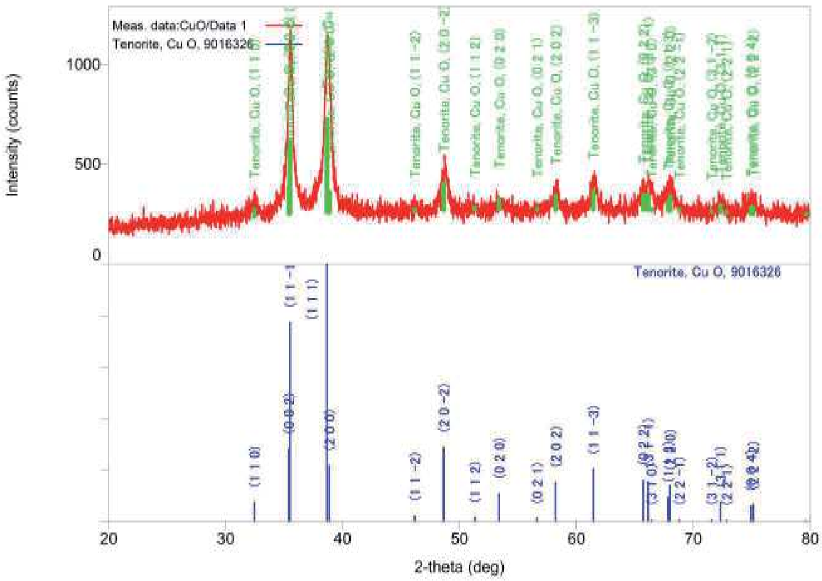

Fig. 1. XRD diffraction pattern

4.2. FESEM analysis

FESEM is used to determine the morphology of the deposited films. The FESEM is capable of producing high-resolution images of a sample surface in the secondary electron mode. From the Fig. 2 which was taken at 1,000,000x magnification, at an operating voltage of 10 KV. FESEM image revealed about flakes like arrangement.

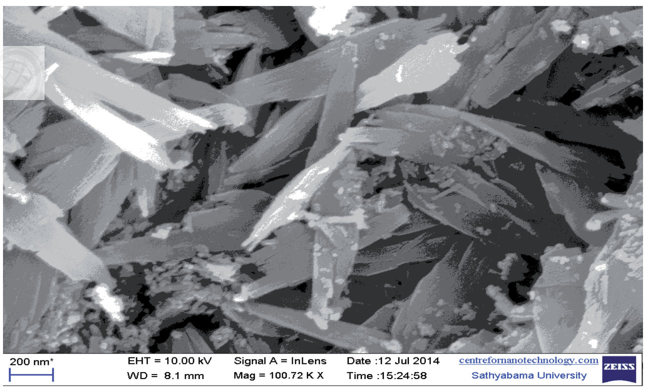

Fig. 2. Surface morphology of copper oxide nanoflakes

A major key factor in enhancing solar cell efficiency depends on the size and shape of the used nanoparticle. The morphology of copper oxide is uniform and it looks like nano flakes like structure which is suitable for photovoltaic applications [21].

Moreover the particle size was estimated to be around 200 nm. The FESEM image (Fig. 2) clearly shows the grain boundary of nano flakes with some small size particles found in between them. The nano flakes like structures are capable of accumulating more charge carriers because of the porous nature of the structure as shown in Fig. 3. Hence this structure is well suitable for solar cell applications.

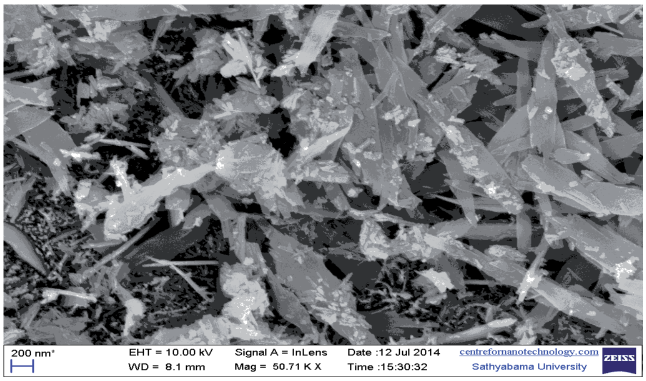

Fig. 3. Porous nature of CuO nanoflakes

4.3. UV-VIS spectroscopy

UV-Visible absorption spectroscopy has been used to investigate the optical properties of CuO nanoflakes. CuO nano flakes were dispersed in distilled water and taken in a cuvette. UV-VIS absorption spectra recorded in 300-700 nm was shown in Figure 4.

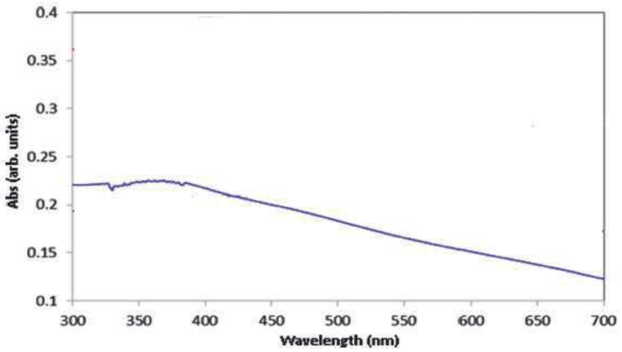

Fig. 4. UV-VIS Spectrum of CuO suspension

It has been observed that CuO nanoflakes exhibit a peak absorption edge at around 403 nm and also exhibit additional peaks around 650 nm. Band gaps of CuO nanoflakes were determined by Planck-Einstein relation. The Planck-Einstein relation for a photon can be expressed as:

$E_g = hc/\lambda$ (3)

From the Planck–Einstein relation, the band gap of CuO nano flakes was found to be 3.07 eV. This value is very high compared with the band gap of bulk copper oxide which is about 1.07 eV.

4.4. PL study

The room temperature photoluminescence emission spectrum of prepared CuO nano particles is shown in Fig. 5. It is recorded by exciting the sample as 350 nm CuO nano flakes shown a band edge emission peak at 417 nm. Using this absorption edge, the band gap value of CuO has been calculated and found to be 3.1 eV higher than the reported value.

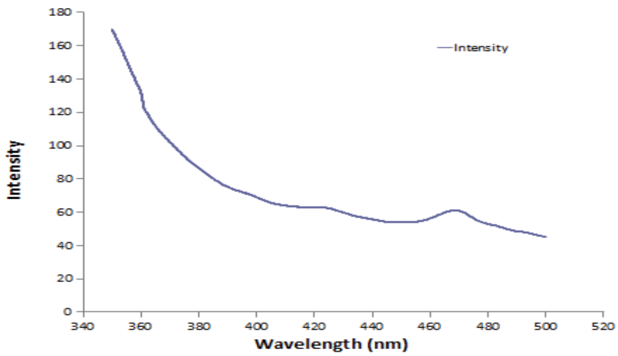

Fig. 5. PL Characteristics of copper oxide nanoparticles

4.5. I-V Characteristics

A digital millimetre was utilized to measure the open-circuit photo voltage and short-circuit photocurrent of the DSSC. A solar stimulator with a 500 W halogen lamp and a light intensity of 100 mW/cm^2 at 1.5 AM were employed to illuminate the dye solar cells. In addition, the power conversion efficiency of the solar cell was determined. Using the explanation,

η =(Isc × Voc ×ff × 100)/light intensity (4)

where Voc, Jsc, represent the open-circuit photo voltage, the short-circuit photocurrent respectively. Furthermore, the fill factor is given by

ff = Pm/(Jsc × Voc) (5)

where Vmax and Imax represents the voltage and the current at the maximum output power point respectively.

The conversion efficiencies of the fabricated DSSCs was evaluated. The open-circuit voltage (Voc), short-circuit current density (Jsc), fill factor (FF) and conversion efficiency (η) of the DSSC was, Voc=0.72 V, Jsc=1.03 mA/cm^2, FF=0.707 and (η) is 0.5 % respectively.

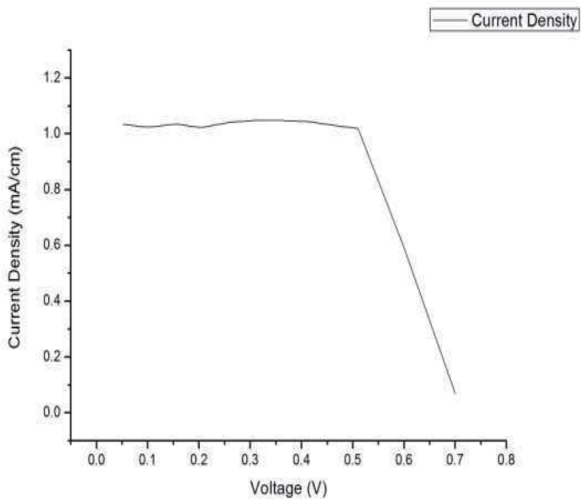

Fig. 6. I-V characteristics of fabricated DSSC

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