Enhance Photocurrent of Cu/n-Cu_2O/p-CuI Solid State Solar Cell using Bamboo Activated Carbon (BAC) as Upper-electrode

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Abstract: Bamboo is a natural vegetable fibre originated from the tropical and sub-tropical countries. In this research, alkaline-bio scoured raw bamboo fibre powder was subjected to alkaline one step pyrolysis activation by using KOH. The bamboo carbon powder was fed into a tube furnace with a ramping rate of 10°C min^{-1} until the temperature reached at 360°C and dwell time 15 min for N_2 atmosphere. Subsequently they were cooled to room temperature. A thin film of n-Cu_2O was fabricated by boiling a well cleaned Copper sheet in a $5x10^{-3}$M $CuSO_4$ solution inside an ultrasonic bath at 60°C for 50 min. There after thin layer of colloidal CuI was deposited on the n-Cu_2O layer. BAC was placed on n-Cu_2O/p-CuI and ITO conductive glass plate was placed to fabricate Cu/ Cu_2O/BAC/ITO solid state photovoltaic cell. BAC acts as an upper electrode; separate photo generated charge carriers and enhanced photocurrent. Mean Particle size distribution curves, Absorption spectra, Photocurrent action spectra and time development of photocurrent were used from this study.

Keywords: Bamboo activated carbon (BAC), n-Cu_2O, p-CuI, Thin film solid state solar cell.

I. Introduction

Bamboo fibre is a naturally occurring vegetable fibre which widely grown throughout the tropical and sub-tropical countries. Physical properties of bamboo vary with the age of the bamboo and the height of the culm [1]. The bamboo culm contains about 50% parenchyma cells [2]. Chemical composition of bamboo culms are cellulose, hemi-cellulose and lignin [3]. Bamboo fibre morphology has an important influence on the activated carbon production. Bamboo charcoal contains many pores and gaps in the structure, making it excellent for adsorption [4-5]. Carbon materials have been widely used as electrode substrates to make various electrodes [6-7]. Cu_2O is an ideal raw material for making n-type semi-conductor devices [8]. Cu_2O layer can be easily produced on the Cu substrate by boiling purified Cu plate in $CuSO_4$ (aq) solution [9-10]. Recently CuI was used as a hole-collecting agent in solar cells and band gap close to 3 eV [11].

This paper reports the enhancement of photocurrent of a solid state thin film solar cell when including Bamboo activated carbon which derived from lingo-cellulosic fibres (Bamboo) and act as an upper electrode of the Cu/n-Cu_2O/p-CuI layers. In this work, Potassium Hydroxide (KOH) chemical activation one step pyrolysis methods were used to activate the raw Bamboo fibre. The particle size distribution and SEM micrograph were used to characterize the BAC and diffuse reflectance spectra, photocurrent action spectraand time development of photocurrent measurements were used to compare the solid state thin film solar cells.

II. Experimental

Two year age green bamboos were used for this experiment. The sample were cut into 2cm x 2cm x 0.5 cm pieces and, then soaked in tank for 2 weeks. After retting, the samples were crushed to fibre stage and combed. Before the heat treatment raw bamboo fiber were scoured (alkaline-bio) thoroughly and wash ultrasonically with distilled water to remove excess chemicals and dried at 80°C in electrical muffle oven for 5 hours. Scoured bamboo fibers were grinded by using ball mill machine with 290-300 rpm for 10 min to produce bamboo micro level particles. Bamboo particles were leached with 0.5 M KOH for 1hour and bamboo pulp was separated by filtering. Activated carbon was prepared by one step pyrolysis by chemical treatment with 0.1 M of Potassium Hydroxide (KOH). Scoured bamboo fiber particles pulp was fed in to tube furnace in 350°C for fifty minutes in a nitrogen atmosphere.

To fabricate n-Cu_2O on a copper, a well cleaned copper sheet (1 x 4 cm^2) in 350°C was immersed into a $5x10^{-3}$M $CuSO_4$ solution placed inside an ultrasonic bath at 60°C for 15 min.

A solution of CuI was prepared by dissolving 5mg of CuI in 10ml of moisture free acetonitrile. CuI colloidal solution was lightly spread on the Cu/n-Cu_2O surface to fabricate the Cu/n-Cu_2O/p-CuI Photoelectrode as shown in Fig. 3 (a). After fabricating Cu/n-Cu_2O/p-CuI photo electrode, a thin layer of Bamboo activated carbon (BAC) were spread on p-CuI layer to form Cu/n-Cu_2O/p-CuI/BAC and ITO conductive glass plate was placed as upper contact as shown in Fig. 3 (b).

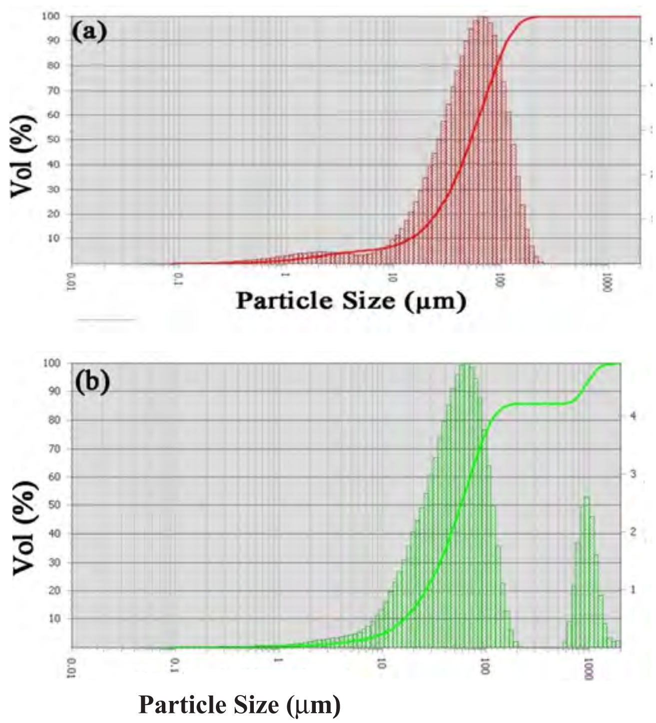

Fig. 1. Particle size distribution curve of for (a) scoured bamboo (b) bamboo carbon (BAC)

Table I: Average Particle Size of Before Activation and After Activation of Bamboo Powder

Particle Category	*D10*	*D50*	*D90*	*Diameter (µm)*
Bamboo (before activation)	14.4 µm	57.6 µm	115.8 µm	59.9 µm
Bamboo (after activation)	16.2 µm	57.6 µm	849 µm	186.3 µm

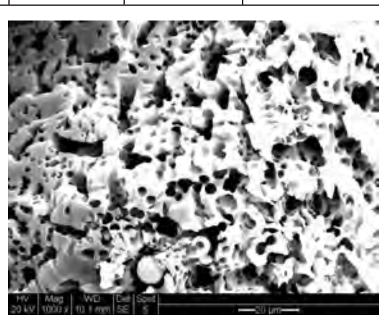

Fig. 2. SEM micrograph of bamboo activated carbon

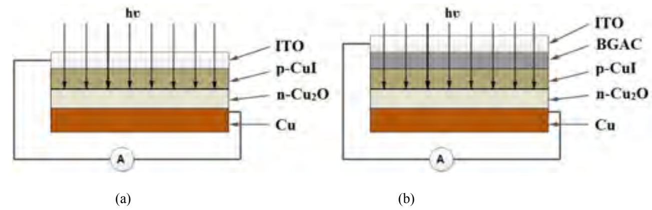

Fig. 3. Schematic presentation of the thin film photovoltaic device structure: CU/ n-CU_2O/BAC/ITO

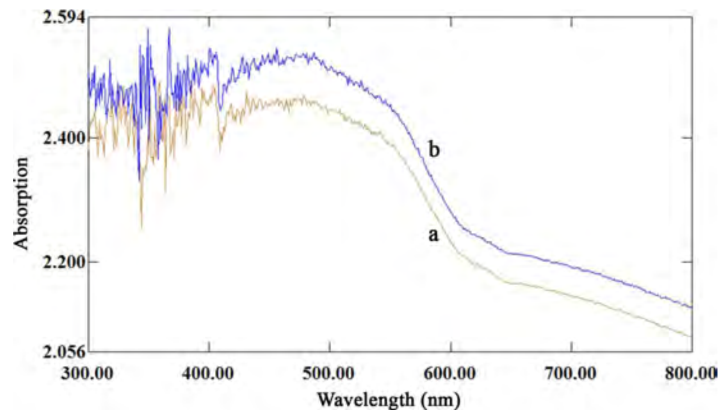

Fig. 4. Diffuse reflectance spectra of (a) Cu/Cu_2O/CuI and (b) Cu/Cu_2O/CuI/BAC

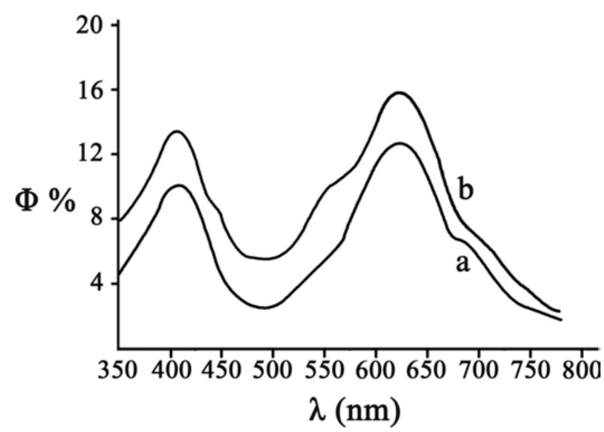

Fig. 5. Photocurrent action spectra for (a) Cu/Cu_2O/CuI and (b) Cu/Cu_2O/CuI/BAC

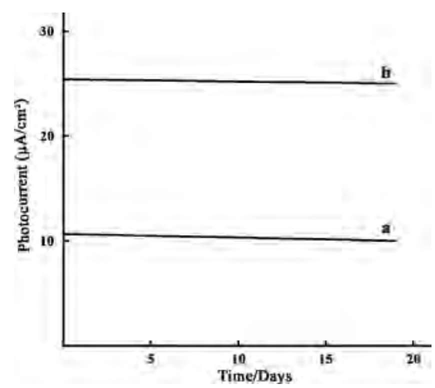

Fig. 6. Photocurrent action spectra for (a) Cu/Cu_2O/CuI and (b) Cu/Cu_2O/CuI/BAC

Raw bambooscouredfiber were grounded by using ball mill machine (Model: Fritsch supreme line Pulverisette 7). Particle sizes were determined by using Fritsch Analysette 22 Nano Tec plus particle size analyser. Ultra-sonic (Model: Rocker Soner 203H) heat bath was used for scoured bamboo fibre and Cu_2O deposition process. Absorption properties were determined by Shimdzu 1800 UV Spectrophotometer. A 100W tungsten filament lamp and Hokuto Denko HA301 Potentiostat were used to time development of photocurrent measurement and water circulated Perspex cell was used to cut off the IR radiation of the tungsten lamp.

III. Results And Discussion

A. BAC Characterization

Fig. 2 shows a SEM micrograph of after activation of the bamboo carbon. Micrograph of the film is uniform and consists of pores in micro range. This shape of activated carbon layer is coated on the CuI layer. CuI particles are in nanometre range and top layer of CuI go through the Carbon pores and made well contacts.

B. Mean Particle Size Distribution of Before and After Activation of Raw Bamboo Fibers

In the Fig. 1 graph (a), raw bamboo scoured fibre was ground for ten min in the Ball Mill that is shown in Fig. 1 (a) as a red graph in the all area of the distribution. In the second example, raw bamboo scoured fibre were after activation that is shown in Fig. 1 (b) as a green graph in the all area of the distribution. Average particle size of the raw bamboo type show that d10 and d50 value are almost similar with that of bamboo (BAC) (Table 1). Conversely d90 values are higher for raw bamboo than bamboo activated carbon (BAC). The particle size distribution of raw bamboo and BAC in this examples span from approximately 1.91 μm – 14.47 μm in this range between some additional peaks occurs, which is caused by the abrasion of the GAC used during the comminution. In case of higher amount Absorption of charge carries by n-Cu_2O surface was controlled by specific area and average particle size, smaller size of activated carbon particle, Diameter of before activation bamboo particle is lower than Diameter of BAC particle.

C. Diffuse Reflectance Spectra

Fig. 3 shows diffuse reflectance spectra of (a) Cu/Cu_2O/CuI and (b) Cu/Cu_2O/CuI/BAC. The shapes of the curves were resembled with each other. It should be mentioned that no transformation has been made by introducing BAC on CuI layers. The estimated band gaps from the absorption edges corresponding to the light absorption of n-Cu_2O was ≈1.9eV (λ≈640nm) and p-CuI was ≈3.0eV (λ≈420nm). It proves that the BAC serves as an upper electrode to collect photo charge carriers and most light was absorbed by the n-Cu_2O film at the solid state device.

D. Photocurrent Action Spectra

Fig. 5 shows the photo current action spectra of (a) Cu/Cu_2O/CuI and (b) Cu/Cu_2O/CuI/BAC. A high photocurrent peak near to the absorption edge was observed in the photocurrent action spectra around 640nm due to band to band transitions after the light absorption of n-Cu_2O and peak around 420nm due to band transitions after the light absorption of p-CuI. Photocurrent quantum efficiency enhancement can be observed for the Cu/Cu_2O/CuI/BAC cell due to porosity of the BAC.

E. The Time Development of Photocurrent of Cu/n-Cu_2O/BAC/ITO

Time development of photocurrent under visible light for (a) Cu/Cu_2O/CuI and (b) Cu/Cu_2O/CuI/BAC are shown in Fig. 6. Optimum stability can be seen in both curves steady state photocurrent increases when after including BACs. Carbon pore structure helps to move the excited electrons from p-CuI to BAC layer to separate photo-generated after absorbing the visible light. So that the recombination of photo-generated charge carries is suppressed. Carbon particles highly penetrated in the p-CuI top layer can act as collection centres to transfer the photo-generated carries to the ITO to flow the photocurrent. This proves that the BAC is serving as a upper electrode for photovoltaic cells.

IV. Conclusion

A solid state thin film photovoltaic cell produced by BAC and Cu/n-Cu_2O/p-CuI for the first time. The photocurrent enhancement was observed in Cu/n-Cu_2O/p-CuI/BAC compared with Cu/n-Cu_2O/p-CuI photo electrodes. The photocurrent enhancement can be seen after including BAC due to increment of contact between Cu/n-Cu_2O/p-CuI and ITO and it serves as upper electrode. Remarkable stability was observed in Cu/n-Cu_2O/BAC solid state photovoltaic cell.

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