Enhance the Photocurrent of Cu/n-Cu_2O Solid State Solar Cell Using Coconut Shell Activated Carbon (CAC) as Upper - Electrode

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Abstract: Coconut shells are used for production of activated carbon. In this research, alkaline-bio scoured coconut shell powder was subjected to one step pyrolysis activation by using Phosphoric acid. The acid treated coconut shell particles were fed into a tube furnace with a heating rate of 10 ^oC min^{-1} until the temperature reached at 360 ^oC and dwell time 15 min in N_2 atmosphere. Next, they were cooled into room temperature. A thin film of n-Cu_2O was fabricated by immersing a well cleaned copper sheet in a 10^{-3} M HCl solution for 60 h. CAC was placed on Cu/n-Cu_2O substrate and ITO conductive glass plate was placed to fabricate Cu/n-Cu_2O/CAC/ITO solid state photovoltaic cell. Here, CAC acts as an upper electrode, separate photo-generated charge carriers and enhance photocurrent. BET surface area analysis, diffuse reflectance spectra, photocurrent action spectra, time development of photocurrent and SEM morphology were used to analyse the prepared samples.

Keywords: Activated carbon, BET, Coconut shell, n-Cu_2O.

I. Introduction

In the 21st century, the oil prices have been increased due to the rapid depletion of resources. Therefore, there are no more reliance on coal, oil and natural gas. Today many researches are focused on the renewable energy sources and it provide promising alternatives. Wind turbines, wave and tidal power, solar cells, solar thermal, hydropower, biomass-fired electricity and biomass-derived liquid fuels are some of renewable source technologies. However, among of all these renewable energy, solar energy is the most promising energy source since it is readily available. The most popular and commercially available type of solar cell is silicon-based solar cell. But the manufacturing cost is very high. Therefore, this research study focuses on fabricating a solar cell by using low cost method.

Due to the special chemical and physical properties of metal and their oxides, recently numerous researches have been reported. Therefore, in this study Cu metal was used to fabricate the Cu_2O layer. Cuprous Oxide (Cu_2O) has many advantages such as direct bandgap structure, suitable bandgap (1.9-2.2 eV), non-toxic, inexpensive and abundant source material [1-2]. Also Cu_2O is used in many applications such as gas sensing, photovoltaic (PV), catalysis and dilute magnetic semiconductors [3]. As reported, many methods were used to synthesize p-type Cu_2O and only few methods for n-type Cu_2O [4-9]. Therefore, in the present work n-type nano crystalline Cu_2O layer was synthesized by a simple chemical method and here we demonstrate the photocurrent enhancement of Cu_2O thin film using coconut shell activated carbon.

Coconut shell activated carbon (CAC) is a highly available and eco-friendly material, which used for catalytic supports, capacitors, gas storages for biomedical engineering, battery electrodes and solar cells [10-11]. The proper characteristics of activated carbon are high surface area, porous structure, pore volume and surface functional groups [12-13]. In present study, activated carbon is used for solar application as an upper electrode [14-15].

Here, we demonstrate a remarkable photocurrent enhancement in Cu_2O thin film after fabricating CAC as an upper electrode. The proposed structure for Cu/n-Cu_2O/CAC photoelectrode will be discussed from diffused reflectance spectra, photocurrent action spectra, and SEM. Also, BET surface area analysis and ash content calculation were used to characterize the CAC.

II. Experimental

A. Preparation of CAC Powder

Phosphoric acid (H_3PO_4) chemical activation one step pyrolysis methods were used for production of activate carbon from coconut shells. Cleaned small coconut shell pieces were milled at 550 rpm for 12 min to obtain the micro range particles. After Scouring, shell particles were leached with phosphoric acid and sonicated. Sonicated particles were put into the muffle furnace at 110 °C for 5 h.

Coconut shell pieces were fed into the tube furnace with a constant Nitrogen flow rate of 10 until the temperature was reached a range between 400 °C to 450 °C. At a selected temperature between 360 °C to 370 °C, the samples were kept inside the tube furnace for 15 min and subjected to a nitrogen flow. After pyrolysis, carbon was removed from the furnace and allowed to cool down to the room temperature. Again that granular particles were milled at 550 rpm for 30 min to convert the powder form CAC.

B. Preparation of Cu/n-Cu_2O/CAC Photoelectrode

Well-cleaned copper sheet (1 x 3 cm^2) was immersed into a 10^{-3} M HCl solution at room temperature. The immersing time was controlled the amount of growth of n-Cu_2O (gcm^{-2}) on Cu substrate. After fabricating Cu/n-Cu_2O substrate, 3 mg of coconut shell activated carbon (CAC) were deposited on n-Cu_2O layer to form Cu/n-Cu_2O/CAC photoelectrode. After ITO conductive glass plate was placed on top of Cu/n-Cu_2O/CAC photoelectrode as shown in schematic diagram in Fig. 1.

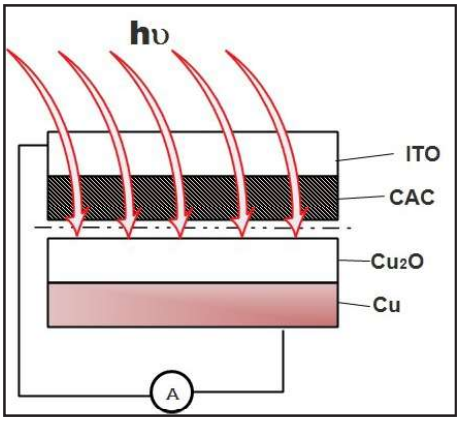

Fig. 1: Schematic Presentation of the Thin Film Photovoltaic Device Structure: Cu/n- Cu_2O/CAC/ITO

C. Experimental Techniques

Coconut shell small pieces were grounded by using Fritsch supreme line Pulverisette 7 ball mill. Rocker Soner 203 H Ultra-sonic heat bath was used for cavitation. Proximate analysis was measured by according to ASTM-D stranded. Defuse reflectance spectra were measured by using Shimdzu 1800 UV Spectrophotometer. The surface morphology of the samples were observed using Scanning Electron Microscope (SEM) Zeiss Evo LS15.

III. Results and Discussion

A. CAC Characterization

Fig. 2 shows the nitrogen adsorbent and de adsorbent curve. Nitrogen adsorption isotherms were measured at -196 °C on an ASAP 2010 volumetric analyzer. Prior to adsorption measurements, all samples were out gassed under vacuum at 200 °C for 2 h. The shape of curve shows that chemically treated activated carbon has meso pores size range. It reveals that more adsorbent side available in surface of activated carbon. The BET surface area Value and ash content of produced activated carbon show in Table I. BET surface area of CAC is 825 (m^2/g). This adsorption values are directly related with porosity of carbon and same as commercially developed one. The ash content of CAC is 2 %.

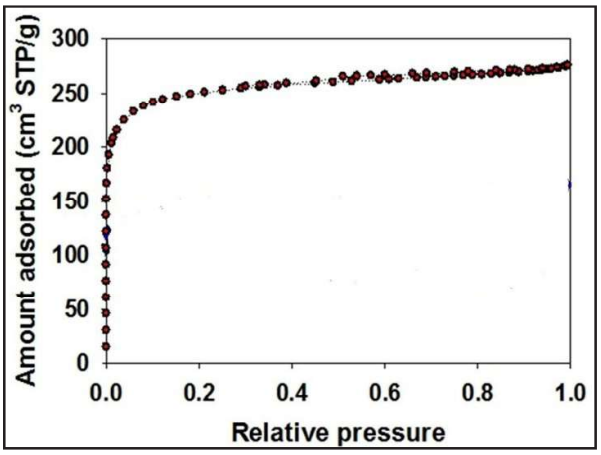

Fig. 2: Nitrogen Absorption Isotherm of Coconut Shell Activated Carbon

Table I: BET Surface Area Values Obtained For The Coconut Shell sample Studied

Content	S_{BET} (m^2/g)	*Ash Content*
Coconut Shell	825	2 %

B. The Growth Mechanism of n-Cu_2O Nano Surface Layer on Copper Substrate

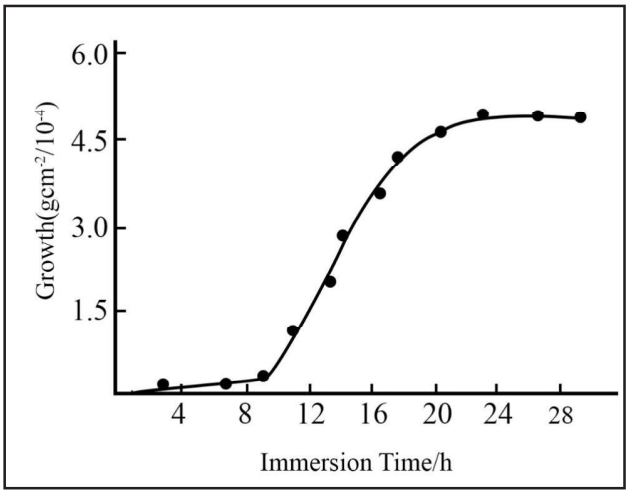

Fig. 3: Growth Rate of Cu_2O Layer on Cu Plate

Fig. 3 shows the variation of growth of n-Cu_2O layer on copper plate with the immersion time for this preparation method.

Initial growth stage of Cu_2O layer is not fast with immersing time. After 9 h, growing amount is gradually increased and reached to a saturation level at 24 h. These phenomena can be explained as follows. Initially, in HCl solution the concentration of Cu^{2+} is very low until HCl gradually dissolves sufficient copper from the copper substrate. The growth of Cu_2O layer increases rapidly and saturates after dissolving considerable amount of copper into the solution forming Cu^{2+} ions.

C. *Diffuse Reflectance Spectra and the Photocurrent Action Spectra*

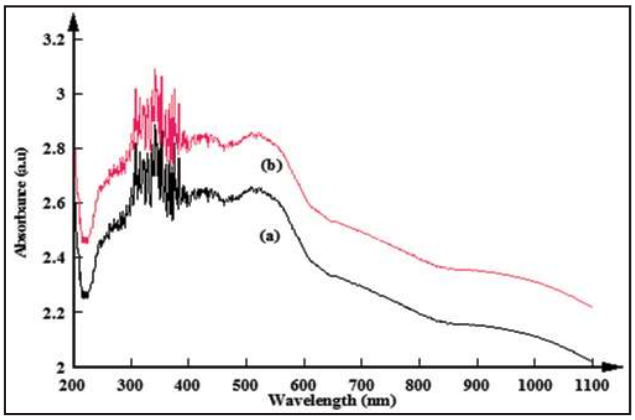

Fig. 4: Diffuse Reflectance Spectra for (a) Cu/n-Cu_2O (b) Cu/n-Cu_2O/CAC

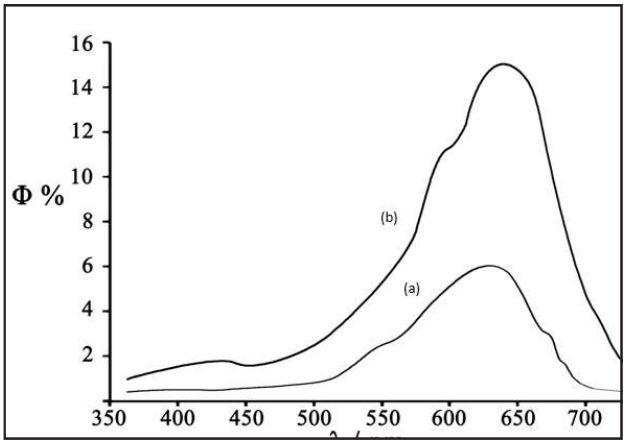

Fig. 5: Photocurrent Action Spectra for (a) Cu/Cu_2O and (b) Cu/Cu_2O/CAC

Fig. 4 shows the diffuse reflectance spectra of Cu/n-Cu_2O and Cu/n-Cu_2O/CAC. The shape of the graph (a) and graph (b) were resembled with each other because when introducing CAC on Cu/n-Cu_2O layer, there is no transformation made. It proves that CAC served as an upper electrode to collect the photo charge carriers. The estimated bandgap from the absorption edge corresponding to the light absorption of n-Cu_2O is ≈ 1.98 eV (λ ≈ 625 nm). Photocurrent action spectra for Cu/n-Cu_2O and Cu/n-Cu_2O/CAC are shown in Fig. 5. According to the figure, the maximum photocurrent can be observed corresponding to the absorption edge of diffuse reflectance spectra (λ ≈ 625 nm) and it further confirms that the photocurrent generation is due to the light absorption of n-Cu_2O semiconductor. Therefore, the highest photocurrent enhancement is observed due to introducing the CAC layer on Cu/n-Cu_2O substrate.

D. *The Time Development of Photocurrent of Cu/n-Cu_2O/CAC/ITO*

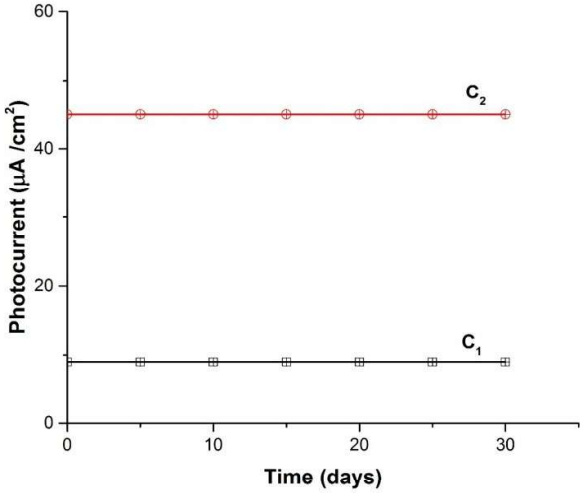

Fig. 6: Time Development Curves for (a) Cu/Cu_2O and (b) Cu/Cu_2O/CAC

Time development of photocurrent under visible range light for Cu/n-Cu_2O (C1) and Cu/n-Cu_2O/CAC (C2) are shown in Fig. 6. Maximum stability can be seen in both curves and steady state photocurrent increases after introducing CAC. Meso size pore structure of CAC supports to move the excited electrons from Cu_2O to CAC layer and separate photo-generated electrons and subsequently absorb the visible light. Then the recombination of photo-generated charge carries is suppressed. Miso pore size carbon particles in the Cu_2O upper layer can act as collection spot to transfer the photo-generated carries to the ITO glass plate to flow the photocurrent. This shows that the CAC is act as an upper electrode for solar cells.

E. *SEM Micrographs*

Scanning electron micrograph shown in Fig. 7 can confirm the surface morphology of Cu_2O is nano size. Micrograph of the thin film is uniform and consists crystals in Nano range. This morphology can be explained that uniform nano surface produced on top of the Cuplate.

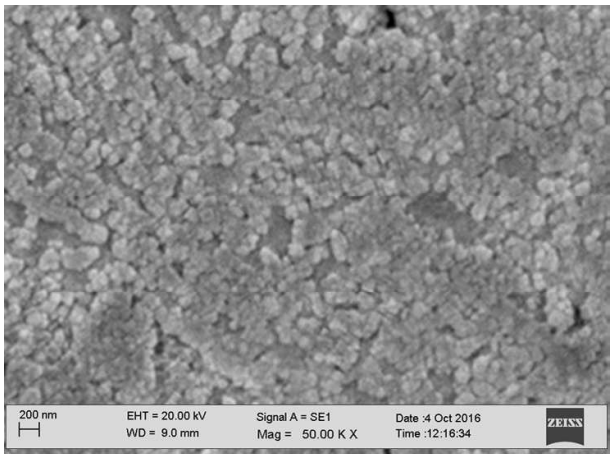

Fig. 7: SEM Image of the Top View for Cu/n-Cu_2O Substrate

IV. Conclusion

The photocurrent enhancement was observed in Cu/n-Cu_2O/CAC photoelectrode compared with Cu/n-Cu_2O. The photocurrent enhancement can be seen after including CAC due to increment of contact between Cu/n-$Cu_2O$and ITO and it serves as upper electrode. Significant stability was observed in Cu/n-Cu_2O/CAC solid state photovoltaic cell.

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