ISSN: 2349 - 4891

International
Journal of Recent Research and Applied Studies
(Multidisciplinary Open Access Refereed e-Journal)

Enhancement the Performance ofSpin Coated Metal Oxide Heterojunction Solar Cell Using Modified Aluminothermic Processed Si-NPs

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Received 02[nd]January 2021, Accepted 27[th] February 2021

Abstract

The efficacy of modified Aluminothermic processed Si-NPs to improve the photovoltaic performance of spin coated copper oxide/zinc oxide (CuO/ZnO) heterojunction solar cell deposited on FTO using simple spin coating technique has been investigated in this contribution. At first, copper oxide was directly synthesized from its acetate through solution process and silicon Nano-particles (Si-NPs) were prepared by ultra-sonication of extracted silicon from Padma river sand through Magnesio-Aluminothermic (modified alumino-thermic) reaction. After that, thin films of CuO and Si-NPs doped CuO are deposited through simple and inexpensive spin coating technique. X-ray diffraction (XRD), Energy Dispersive X-ray Spectroscopy (EDX), ultraviolet-visible spectroscopy (UV-Vis) and thickness profilometer were used to characterize the deposited films. Photovoltaic performance of Si-NPs doped CuO as an absorber of metal oxide ZnO/CuO based inorganic heterojunction solar cells also studied. Experimental results show that, Si-NPs have improved the optical and electrical properties of CuO noticeably. Optical absorbance of NPs-CuO thin film is increased ~21%. The photo conversion efficiency of FTO/ZnO/Si-NPs-CuO/Al heterostructure solar cell is enhanced from η= 0.96 % to η= 1.37 % for the using of Si-NPs with absorber CuO. With no anti-reflection coating, hole transport layer and electron transport layer, this value of inorganic heterojunction solar cell efficiency is one of the highest reported value for a ZnO/CuO interface formed in air using spin coating technique.

Keywords: Modified Alumino-thermic, Si-NPs, Spin coating, X-ray diffraction, Heterojunction.

Introduction

Recently, copper oxide has gained much attention due to their particular physical and chemical properties [1-2]. In the past decade, a large amount of research was carried out on synthesis of inorganic materials like ZnO, CuO, and Cu_2O for their outstanding properties as well as potential for various device applications [3-4]. Copper oxide is very much promising material which has unique features such as a p-type semiconductor with monoclinic structure and has a narrow band gap in the range of 1.2 - 2.1 eV [5-6]. Non-toxicity in nature, low cost, the abundant availability, high optical and electrical properties, relatively simple formation of the oxide layer and the theoretical solar cell efficiency is 18% with ZnO are the great features of copper oxide [2, 4]. Copper oxide has various applications such as semiconductors [7], gas sensors [8], photo catalysis [9], batteries [10], magnetic storage [11], biosensors [12], solar cells [13] and capacitors [14], CuO thin films have received much attention already. Since the chemical and physical attribute of copper oxide just depends on its size, numerous researchers have centered their endeavor on the found of nano construction of copper oxide in order to stratify them in nano electronics, optoelectronics, biosensors [15-21]. Copper oxide nano-materials have the great advantage of a low surface potential partition than that of metals, which influence on electron field release possession. Copper oxide considered as a potential field emitter and very strong catalytic factor as well as a valid gas sensing substance. It likewise shows a significant assignment in

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optoelectronics and solar cell. A number of techniques like chemical bath deposition, radio frequency magnetron sputtering, chemical vapor deposition, spray pyrolysis, electro-deposition, hydrothermal, pulsed laser deposition, and sol gel spin coating are used to prepare and grow micro/nano-scale thin films [22-28]. Sol-gel spin coating process is very efficient among all these techniques. Sol-gel spin coating process has the ability to produce a uniform thin film with a low cost production and fast porting time. But one of the main disadvantages of this process is the efficiency of material used. The effectiveness of this process can be enhanced by control its conditions and parameters [17]. In this work, structural and optical characteristics of copper oxide and silicon nano-particles doped copper oxide thin films deposited onto glass substrate by sol-gel spin coating technique were investigated. And, the role of modified Aluminothermic processed Si-NPs to enhance the photovoltaic performance of spin coated copper oxide/zinc oxide (CuO/ZnO) heterojunction solar cell deposited onto FTO using sol-gel spin coating technique are investigated.

Experimental

Synthesis of Si-NPs from extracted silicon from Padma river sand

The silicon powders were mechanically grinded using mortar and pestle after heated at 150 ^{0}C in carbolite CWF oven for 20 minutes after extracting silicon from sand of Padma river. Then, obtained Si-powder was dispersed in 2-isopropanol and sonicated for 150 minutes using ultrasonic vibrator. To reduce the particle size and passivate the particle surface, Si-powder was etched with of 4% HF solution. Later of etching, the particles again dispersed in alcohol and filtered using nanoparticles filter paper. Finally, silicon nano-particles were collected in 2-iso-propanol after filtration.

Preparation of Si-NPs-CuO

Reagents copper (II) acetate monohydrate [Cu $(OAc)_2 \cdot H_2O$], sodium hydroxide (NaOH), 2-iso-propanol were purchased from commercial suppliers (Loba chemic. Ltd and Sigma Aldrich) and used without further purification. High purity copper acetate dehydrates salt is easily dissolved in alcohol solvent to make homogeneous CuO solution. Synthesized Si-NPs with 2-iso-propanol was used as solvent to synthesis copper oxide from its acetate. For making 0.3 M CuO, the sol-gel synthesis is started with dissolving [Cu $(OAc)_2$] in 50 mL 2-iso-propanol which contains the Si-NPs and 0.3 M NaOH in 10 mL of distilled water. Then, the sodium hydroxide solution was added drop wise under stirring of at 70 °C for 1hr. The solution was then cooled to room temperature to prepare for spin coating. Using this procedure, black CuO solution was prepared. After that, final solution was spin coated onto the substrate to investigate its optical and structural properties.

Fabrication of FTO/ZnO/Si-NPs-CuO/Al heterojunction solar cell

Synthesized ZnO solution from zinc acetate was deposited first onto the pre-cleaned (with methanol and distilled water) fluorine doped tin oxide (FTO) coated glass substrate which was purchased from Sigma-Aldrich. ZnO solution was spin coated at 500 rpm for 10s (warm up speed and time) then 2000 rpm for 30s. Then, films were dried in the oven at 70 ºC for 10 min and the process was repeated for deposition of required number of layers (thickness). Then copper oxide which contains the Si-NPs was deposited on ZnO with 700 rpm for 10s (warm up speed and time) and 1000 rpm for 30s. After deposition ZnO and CuO, the film was annealed at 350 ºC. Finally, Al was deposited on CuO absorber layer using thermal deposition process using Edward E-306. The microstructure of the films was studied using X-ray diffraction (XRD). Photovoltaic performance of FTO/ZnO/Si-NPs-CuO/Al structure solar cell was measured using solar simulator (AM1.5 illumination) with Keithley-2400 Source Meter.

Results and discussion

X-ray diffraction study

The crystal structure of copper oxide thin films was identified by X-ray diffraction (XRD). X-rays diffraction patterns of NPs-CuO thin films annealed at 350 ºC are shown in Figure I. It has endorsed the growth orientations and crystal structure of copper oxide thin films by revealing emission peaks 29.5, 36.4, 42.3, 61.3,73.5° corresponding to the (110), (111), (200), (220), (311) orientations, respectively. XRD reveals monoclinic structure of copper oxide. However no diffraction peaks of other impurities were detected, which testify that the substance deposited on the substrate only belongs to copper oxide.

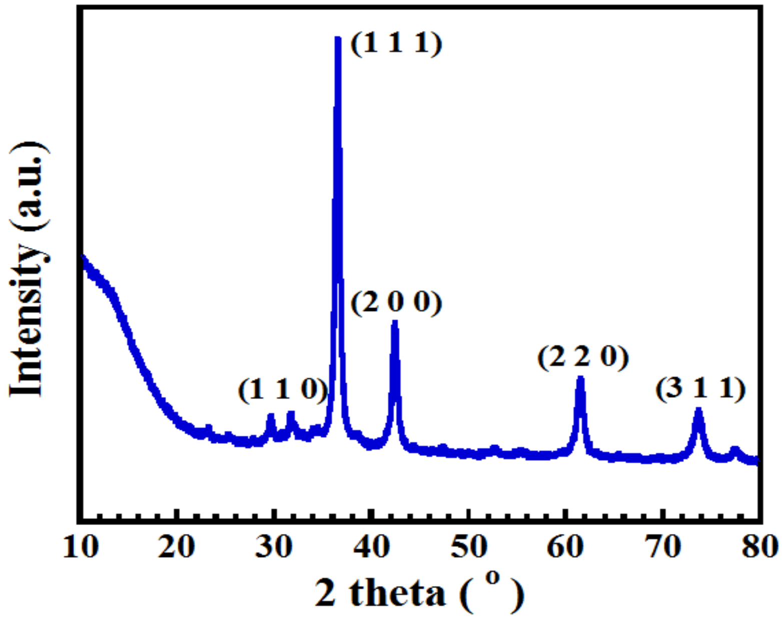


*Figure I.*XRD of spin coated NPs-CuO at 350ºC

Scanning Electron Microscopy and Energy Dispersive X-ray Spectroscopy

The cross-sectional scanning electron microscopy of spin coated FTO/Si-NPs-CuO/ZnO/Al heterojunction solar cell is depicted in Figure IIa The results show that the surface of fabricated cell is uniform, dense and homogeneous with less cracks or pinholes. The EDX technique was used to the study the compositions of FTO/Si-NPs-CuO/ZnO/Al heterojunction solar cell and NPs-CuO thin films. The obtained results indicate that the prepared cell is composed of Copper (Cu), Zn, Si and Oxygen (O) as shown in Figure IIb And, presence of (Cu), Si and Oxygen (O) in Si-NPs-CuO spin coated thin film on glass substrate is confirmed by EDX that is depicted in Figure IIc.

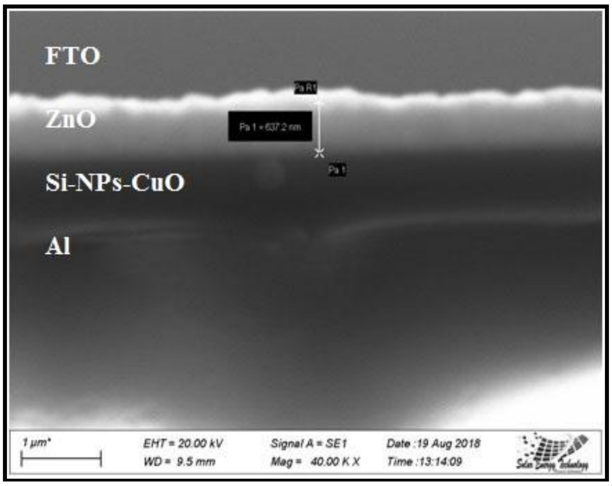


Figure II. (a) Cross-sectional SEM of FTO/Si-NPs-CuO/ZnO/Al heterojunction solar cell

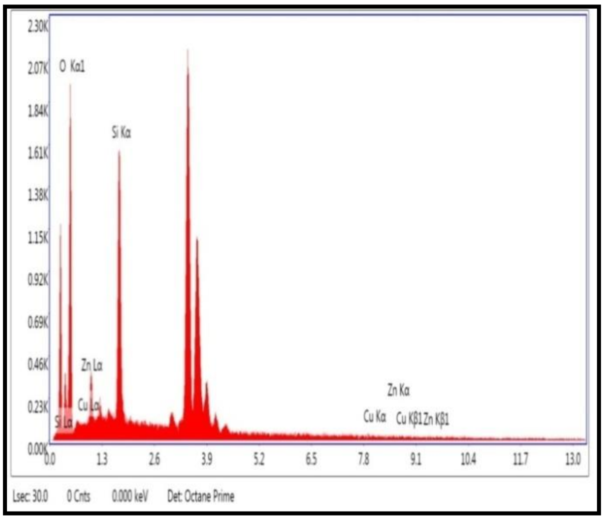


Figure II. (b) EDX of Si-NPS doped Si-NPs-CuO/ZnO heterojunction solar cell

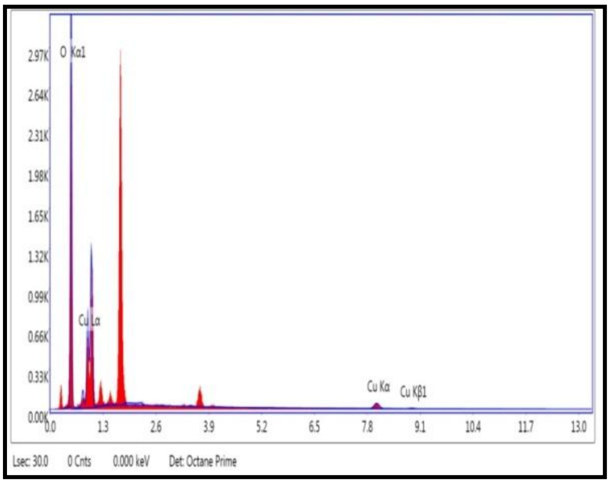


Figure II. (c) EDX of Si-NPS doped copper oxide.

ISSN: 2349 – 4891

Fourier Transform Infrared Spectroscopy

In order to be sure of the chemical and structural nature of the material, FT-IR spectroscopy analysis has been done. Copper oxide nano-particles prepared by sol-gel methods have been scanned from 225 cm^{-1} to 4000 cm^{-1} as shown in Figure III. Absorption bands in the range (1300 and 2000 cm^{-1}) are mainly attributed to the chemisorbed and/or physisorbed H_2O and CO_2 molecules that may be attached on the surface of nano-structured CuO/Cu_2O crystals. Above 3000 cm^{-1}, peaks refer usually OH bond. Furthermore, absorption peak at 618 cm^{-1} confirms that the synthesized product is copper oxide [29-32].

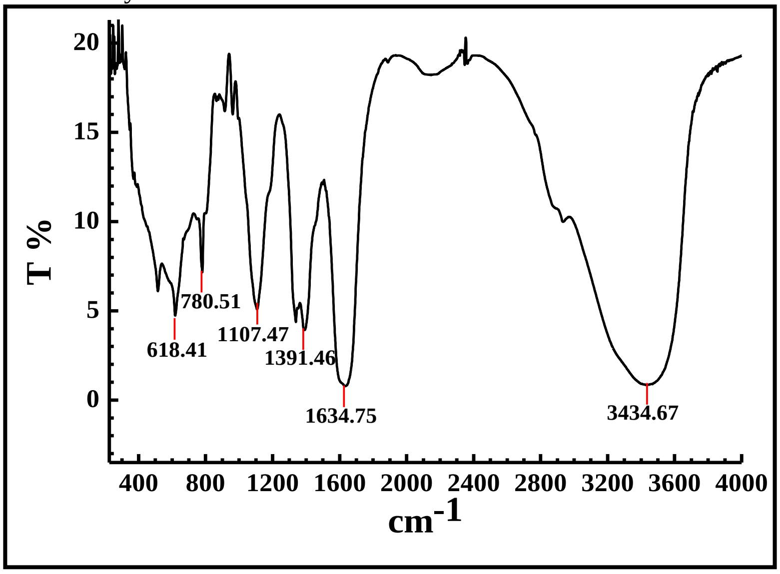
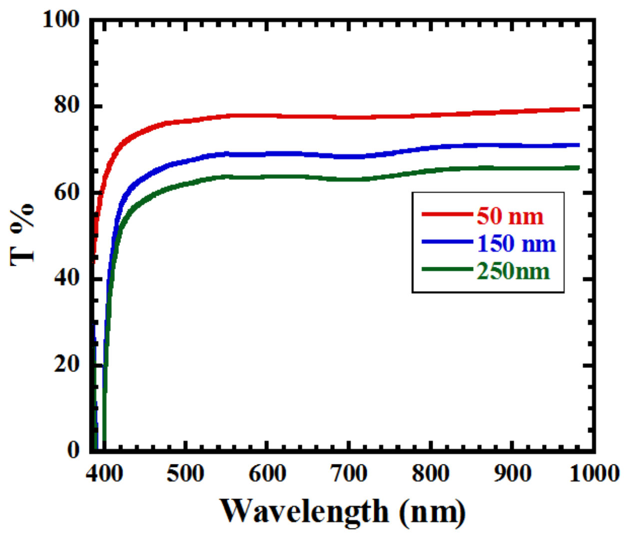


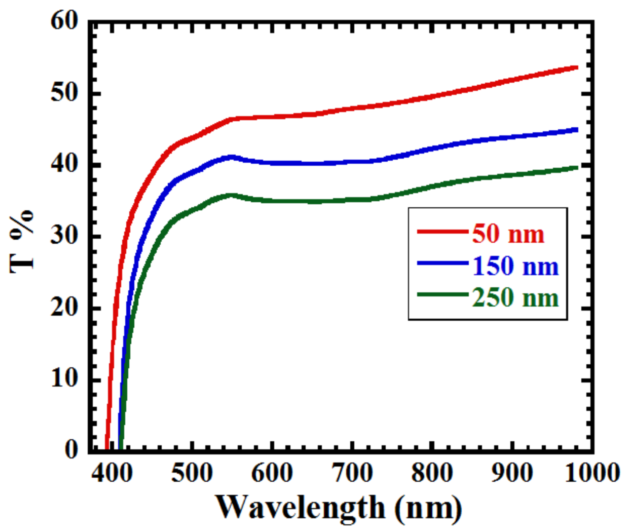
Figure III. FTIR spectrum of copper oxide

Optical study

Figure IVa shows variation of Optical Transmittance of copper oxide thin films before adding Si-NPS for different layers. The optical transmission of CuO thin film deposited on glass substrates by sol-gel spin coating technique are measured by a UV-visible spectrophotometer with wavelength range 380-1000 nm. The Figure IVb represents the variation of transmittance with the different number of layer of copper oxide with Si-NPs. These spectra show low transmittance in the wavelength range from 600 -1000 nm. Below 500 nm there is a sharp fall of transmittance of the films. Figure IV refers with increasing number of layer transmittance decreases.



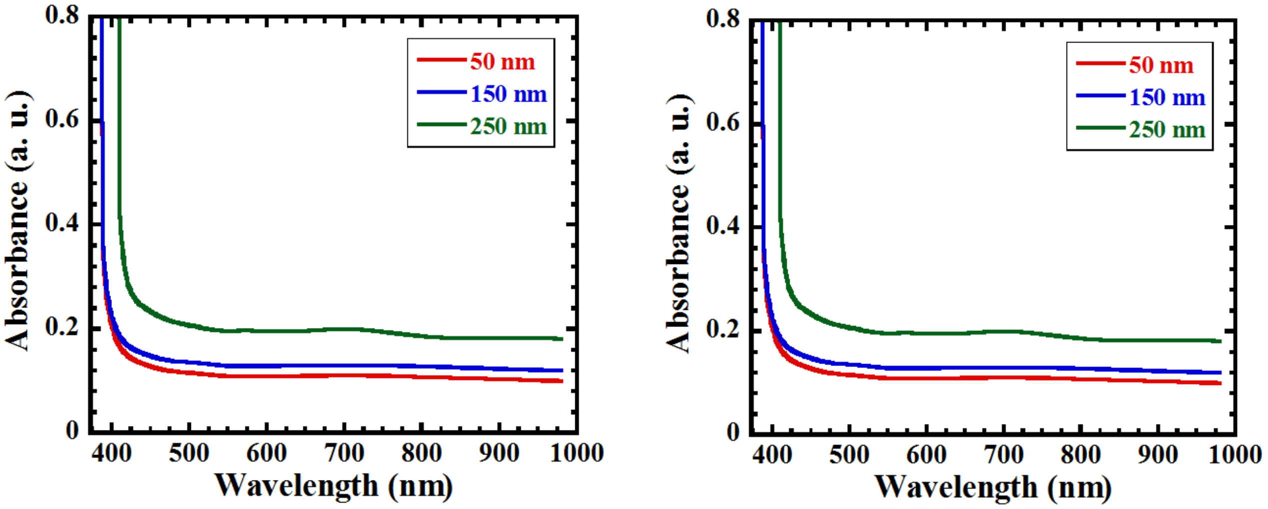
(a)



(b)

Figure IV. Transmittance of CuO thin films (a) without Si-NPs (b) with Si-NPs

The optical absorbance of copper oxide thin films deposited on glass substrates by sol-gel spin coating technique are measured by a UV-visible spectrophotometer with same wavelength range 380 nm - 1000 nm as transmittance measurement and the result is shown in Figure V.



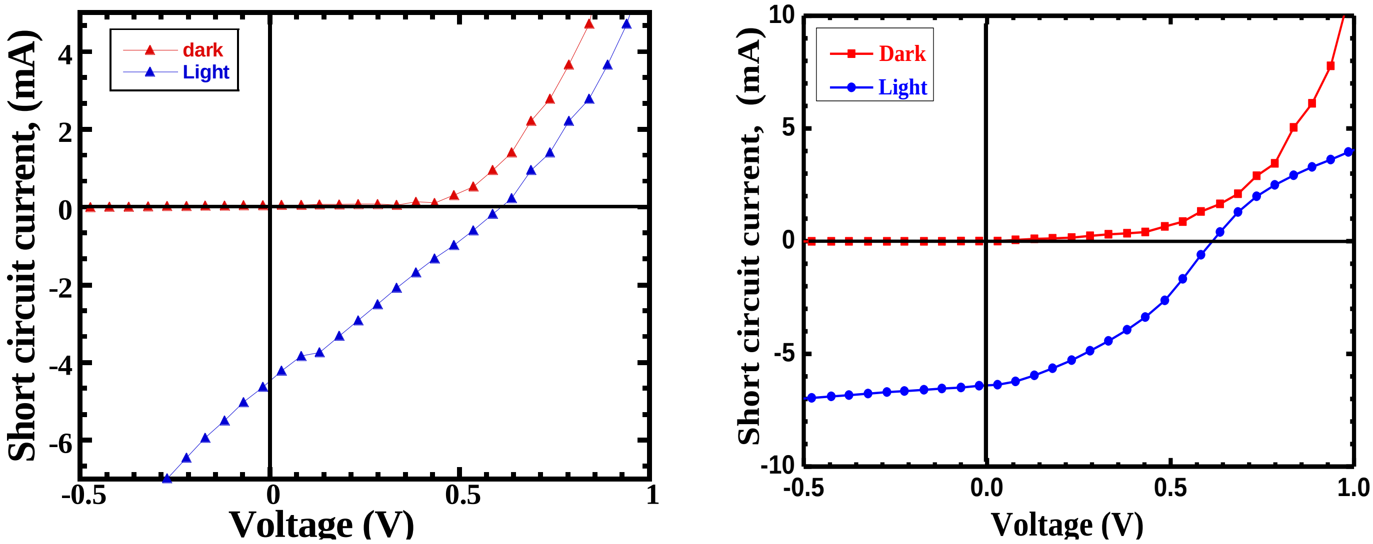
(a) (b)

Figure V. Absorbance of CuO thin films (a) without Si-NPs (b) with Si-NPs

Figure Va refers optical absorbance without Si-NPs for different layers and Figure Vb for represents absorbance with Si-NPs (absorbance of copper oxide increases (~ 20%) surprisingly due to Si-NPs with copper oxide).

Photovoltaic performance

Figure VI shows the current-voltage characteristics of tandem hetero-junction solar cell (THJSC) fabricated using sol-gel Spin Coating technique. Figure VIa shows J-V characteristics of THJSC with structure Glass/FTO/ZnO/CuO/Al (without Si-NPs with absorber CuO). It is seen that, photo conversion efficiency (PCE) of fabricated solar cell is η= 0.96 % (with Voc= 0.607 V, Jsc=3.33 mA/cm^2 and FF= 46%).Figure VIb shows the current-voltage (J-V) characteristics of tandem hetero-junction solar cells (THJSC) with synthesized Si-NPs from sand of Padma River through modified alumino-thermic process fabricated using spin coating technique. The cell with Si-NPs doped CuO offers better performance, η= 1.37% (Voc= 0.620 V, Jsc=4.43 mA/cm^2 and FF= 56%) than CuO absorber without Si-NPs.



(a) **(b)**

Figure VI. J-V characteristics of FTO/ZnO/CuO/Al HSC (a) without and (b) with Si-NPs doped CuO

Conclusion

XRD of NPs-CuO thin films has been endorsed the monoclinic crystal structure by revealing emission peaks at 2 theta equal to 31.8º, 36.6º, 42.5º and 61.5º corresponding to (002), (111), (200) and (-113). EDX report confirms the elemental presence of Cu, Zn, O and Si-NPs in synthesized sample by giving their own strongest peaks. Optical study of Si-NPs-CuO film refers higher (~ 21%) absorbance at wide ranges than absorbance of CuO without Si-NPs therefore photovoltaic performance of FTO/ZnO/Si-NPs-CuO/Al heterostructure SC awards ~30% enhanced efficiency. Without anti-reflection coating, hole transport layer and

ISSN: 2349 – 4891

electron transport layer, this value of inorganic heterojunction solar cell efficiency is one of the maximum reported value for solution processed spin coated ZnO/CuO heterojunction solar cell fabricated in open air condition.

Acknowledgement
Authors thank to Md. Shahriar Bashar, BCSIR, Dhaka, Bangladesh for providing instrumental support to study XRD, EDX and Md. Humayun Kabir, RUET, Rajshahi, Bangladesh to study SEM.

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