PROPERTIES ENHANCEMENT OF ELECTRODEPOSITED-Cu_2O-BASED HOMOJUNCTION THIN FILM SOLAR CELL USING ETCHING TREATMENT

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To my beloved mother, thank you.

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ABSTRACT

The need for sustainable power generation has encouraged research into a variety of photovoltaic (PV) systems, which can cope with the global energy crisis in the future. Cuprous oxide (Cu_2O) is a naturally p-type semiconductor with E_g of 1.6 to 2.1 eV and gains a wide spotlight as a layer in the photovoltaic device. Electrodeposition of Cu_2O thin film is a well-known technique due to the low fabrication cost, controllable properties and low temperature needed. However, the reported efficiency value is still unsatisfactory to compete in the market. The low energy conversion efficiency is caused by lattice and thermal mismatch between heterojunction thin films. Therefore, Cu_2O based homojunction thin film solar cell was developed. However, to fabricate homojunction Cu_2O thin film is intricate due to highly resistive of n-Cu_2O thin film. Thus, etching treatment via hydrothermal method was implemented on n-Cu_2O thin film by potassium impurity that presents during the fabrication process. This will decrease the resistivity and ease the electrodeposited of p-Cu_2O thin film. Moreover, transportation of minority carrier from the p- to n-Cu_2O were improved. Diluted ethanol was used as a medium for etching treatment. The ethanol concentration and etching time were optimized. The properties and conversion efficiency were analyzed using XRD, FE-SEM, UV-vis, AFM, Four Point Probe and Solar Simulator, respectively. From EDX measurement, the composition of potassium decreased from 14.62% (as-deposited) to 2.52% of (etched n-Cu_2O). The etched-n-Cu_2O thin film was more crystalline and showed significantly improved properties. Thus, the improvement in the quality and purity of the Cu_2O layer is crucial to increase the efficiency value. Through modifying the n-Cu_2O thin film with etching treatment, a relatively high-power conversion efficiency (PCE) of 1.4833% was obtained from 0.018% as-deposited. Although a lot of improvement is still needed to meet up with the current trends of solar technology, it does prove that the properties and efficiency of homojunction-based Cu_2O thin film solar cell incorporating with etching treatment at bottom layer of n-Cu_2O is improved.

ABSTRAK

Permintaan tinggi terhadap penggunaan tenaga telah menarik minat penyelidik untuk melakukan kajian terhadap sistem fotovoltaik, disebabkan kemampuannya menangani krisis tenaga pada masa hadapan. Umumnya, tembaga oksida (Cu_2O) adalah separa pengalir jenis-p dengan sela jalur tenaga 1.6 - 2.1 eV dan mendapat perhatian sebagai lapisan dalam alat fotovoltaik. Penghasillan Cu_2O daripada elektroenapan telah diketahui umum, disebabkan oleh kelebihanya yang kos efektif, keupayaan mengubah sifat dan memerlukan suhu yang rendah. Mengikut laporan, kecekapan mengubah tenaga solar masih rendah dan tidak mampu untuk bersaing di pasaran. Ini disebabkan oleh ketidakpadanan kekisi dan haba di antara filem nipis simpanghetero. Oleh itu filem nipis simpanghomo Cu_2O telah difabrikasi. Walau bagaimanapun, untuk mengfabrikasi simpanghomo Cu_2O adalah mencabar kerana rintangan yang tinggi di lapisan Cu_2O jenis-n. Oleh itu, rawatan punaran dengan menggunakan teknik hidroterma dilaksanakan bagi menghakis bahan potassium yang wujud ketika proses fabrikasi. Hal ini akan mengurangkan rintangan dan memudahkan proses elektroenapan lapisan Cu_2O jenis-p. Tambahan pula, pergerakaan pembawa minoriti dari lapisan jenis-p ke -n dapat dipertingkatkan. Cairan etanol digunakan sebagai larutan bagi rawatan punaran. Kepekatan cair etanol dan tempoh rawatan punaran telah dioptimumkan. Sifat-sifat filem nipis dan keupayaan tenaga telah dianalisa dengan menggunakan XRD, FE-SEM, UV-vis, probe empat titik dan simulator suria. Daripada ukuran EDX, didapati kandungan potassium didalam jenis-n menurun daripada 14.62% kepada 2.52%. Filem nipis punaran n-Cu_2O lebih kristal dan sifat film nipisnya telah bertambah baik. Ini membuktikan, peningkatan kualiti dan ketulenan Cu_2O sangat penting bagi meningkatkan keupayaan tenaga. Keupayaan tenaga bagi filem nipis terpunar adalah 1.4833% dan filem nipis tanpa rawatan adalah 0.018%. Banyak pembaikpulih sifat perlu dilakukan untuk memenuhi tuntutan pasaran semasa, ia tetap membuktikan teknik rawatan punaran telah meningkatkan sifat dan keupayaan filem nipis persimpanganhomo Cu_2O.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	-	Percentage
°	-	Degree
°C	-	Degree Celsius
α	-	Absorption Coefficient
λ	-	Wavelength
µm	-	Micrometer
A	-	Absorbance
a.u	-	Arbitrary unit
AFM	-	Atomic Force Microscopy
Au	-	Gold
Ag/AgCl	-	Silver/Silver Chloride
Al	-	Aluminium
bcc	-	Body centered cubic
CE	-	Counter electrode
cm	-	Centimeter
CO_2	-	Carbon dioxide
Cu	-	Copper
Cu_2O	-	Cuprous Oxide
$CuSO_4$	-	Copper sulphate
CuPc	-	Copper (II) Pthalocyanine
CV	-	Cyclic voltammetry
CVD	-	Chemical Vapour Deposition
DSSC	-	Dye Synthesis Solar Cell
e	-	Electron
ECL	-	Electrochemiluminescene
EDX	-	Elemental disperse X-ray
E_g	-	Energy bandgap

EIS	-	Electrochemical Impedance Specroscopy
fcc	-	Face centered cubic
FE-SEM	-	Field Emission Scanning Electron Microscope
ff	-	Fill factor
FTO	-	Fluorine doped tin oxide
FWHM	-	Full Width Half Maximum
h	-	Plank constant
H_2O	-	Water
ITO	-	Indium doped tin oxide
JCPDS	-	Joint Committee on Powder Diffraction Standards
I_{sc}	-	Short circuit current
J_{sc}	-	Short circuit current density
KOH	-	Pottasium hydroxide
M	-	Mol
mA	-	milli Ampere
Mg	-	Magnesium
NaCl	-	Sodium chloride
NaOH	-	Sodium hydroxide
nm	-	nanometer
O	-	Oxygen
OCP	-	Open circuit voltage
PEC	-	Photoelectrochemical Cell
Pt	-	Platinum
PV	-	Photovoltaic
PVD	-	Physical Vapour Deposition
RE	-	Reference electrode
rF	-	Radio Frequency
Se	-	Selenium
Sns	-	Tin (II) Sulphide
TiO_2	-	Titanium dioxide
TCO	-	Transparent coating oxide
TFSC	-	Thin Film Solar Cell
UV	-	Ultraviolet
UV-Vis	-	Ultraviolet and Visible absorption spectroscopy

v	-	Speed of light
V	-	Volt
V_{oc}	-	Open circuit voltage
vs	-	Versus
WE	-	Working electrode
XPS	-	X-ray Photoelectron Spectroscopy
XRD	-	X-ray Diffractometer
Zn	-	Zinc
ZnO	-	Zinc oxide

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CHAPTER 1

INTRODUCTION

1.1 Project Background

As the world's population grows rapidly, the demand for energy is getting high and almost reaching a critical limit. Nearly every place in the world has become industrial. To meet their requirement of energy usage, renewable energy needs to be taken seriously to replace the use of non-renewable energy such as fossil fuel, coal, gas, and oil. Updated data from Electrical Power Annual on January 2020, about 60% of this electricity generation was from fossil fuels, 20% from nuclear energy and only 20% was from renewable energy sources [1]. From this percentage, water and air pollution, greenhouse effect and ozone layer depletion are the consequences that need to be handled if not considering renewable energy as the primary sources for electricity generation. The renewable energy that is mainly used in certain places are wind, hydrothermal, geothermal and solar energy.

Solar cells are devices used to convert sunlight into electricity by the photovoltaic effect. Photovoltaic effect is defined as the creation of voltage or electric current in a material upon exposure of light. This happens because when the light is incident upon a material surface, the electrons in the valence band absorbs energy and become excited, making them jump to the conduction band and become free electrons [2]. There are three fundamental attributes required in the operation of the photovoltaic cell as listed below:

i. The light absorption which generates either electron-hole pairs or excitons,
ii. The charge carriers of the opposite type being separated,
iii. The separated carriers being extracted to an external circuit.

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[142] N. Ahmad *et al.*, "International Journal of Advanced Trends in Computer Science and Engineering Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse8491.12020.pdf Effect of TBOT Concentration n-nanorod Tio 2 and p-Cu 2 O for Heterojunction Thin Film Sola," vol. 9, no. 1, 2020.

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APPENDIX C

LIST OF PUBLICATIONS

1. **Anis Zafirah Mohd Ismail**, Fariza Mohamad, Bong Liang Thung, Nurliyana Mohd Arifin, Norazlina Ahmad, Nik Hisyamudin Mohd Nor & Masanobu Izaki. (2020). Properties enhancement of electrodeposit-n-Cu_2O thin film by annealing treatment. *International Journal of Advanced Trends in Computer Science and Engineering*, *9*(2), 1537–1542. https://doi.org/10.30534/ijatcse/2020/96922020 (Scopus-indexed, Q2)

2. **Anis Zafirah Mohd Ismail**, Fariza Mohamad, Nurliyana Mohd Arifin, Norazlina Ahmad, Nik Hisyamudin Mohd Nor & Masanobu Izaki. (2020). The effect of annealing treatment on n-Cu_2O thin film for homostructure application. *International Journal of Advanced Trends in Computer Science and Engineering*, *9*(1.1 Special Issue), 510–515. https://doi.org/10.30534/ijatcse/2020/8391.12020 (Scopus-indexed, Q2)

3. **Anis Zafirah Mohd Ismail**, Fariza Mohamad, Nik Hisyamudin Mohd Nor & Masanobu Izaki. (2020). The Effect of annealing treatment on n-Cu_2O thin film fabrication. *International Journal of Integrated Engineering*, *12*(1), 102–107. https://doi.org/10.30880/ijie.00.00.0000.00.0000 (Scopus-indexed, Q2)

4. **Anis Zafirah Mohd Ismail**, Fariza Mohamad, Faresha Husna Zaidi, Nurliyana Mohamad Arifin, Shazleen Ahmad Ramli, Nurul Amiera Shahida Maarof, A.M.S Nurhaziqah, Nik Hisyamudin Mohd Nor, Masanobu Izaki. (2022). The Effect of Etching Treatment on Electrodeposited n-Cu_2O Thin Film for Homostructure Application. Optik-International Journal for Light and Electron Optics (Under Reviewed ISI-Indexed, Q2)

5. Fariza Mohamad, Nurliyana Mohd Arifin, **Anis Zafirah Mohd Ismail**, Norazlina Ahmad, Nik Hisyamudin Muhd Nor, and Masanobu Izaki. (2019). Cu2O-Based Homostructure Fabricated by Electrodeposition Method. Acta Physica Polonica A, 135(5), 911-914. (ISI-Indexed, Q2)

6. Nurliyana Mohd Arifin, Fariza Mohamad, Rosniza Hussin, **Anis Zafirah Mohd Ismail**, Shazleen Ahmad Ramli, Norazlina Ahmad, Nik Hisyamudin Mohd Nor, Mohd Zainizan Sahdan, Mohd Zamzuri Mohammad Zain, & Masanobu Izaki. (2021). Development of homogenous n-TiO_2/ZnO bilayer/p-Cu_2O heterostructure thin film. *Journal of Sol-Gel Science and Technology, 100*(2), 224–231. https://doi.org/10.1007/s10971-021-05650-7 (ISI-indexed, Q2)

7. Norazlina Ahmad, Fariza Mohamad, Fadilah Norazni Fahrizal, **Anis Zafirah Mohd Ismail**, Nurliyana Mohd Arifin, Nik Hisyamudin Mohd Nor & Masanobu Izaki. (2020). *International Journal of Advanced Trends in Computer Science and Engineering Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse8491.12020.pdf Effect of TBOT Concentration n-nanorod* Tio_2 *and p-*Cu_2O *for Heterojunction Thin Film Solar Cell*. *9*(1). (Scopus-indexed, Q2)

8. Norazlina Ahmad, Fariza Mohamad Arifin, Nurliyana Mohd Arifin, **Anis Zafirah Mohd Ismail**, Nik Hisyamudin Mohd Nor & Masanobu Izaki. (2020). *International Journal of Advanced Trends in Computer Science and Engineering Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse5391.12020.pdf Construction of Nanorod-*TiO_2 */ p-*Cu_2O *Heterostructure Thin Films for Solar Cell Applicat*ion. *1*, 304–310. (Scopus-indexed, Q2)

9. Fariza Mohamad, Ahmad Norazlina, Fahrizal Fadilah Norazni, **Anis Zafirah Mohd Ismail**, Ahmad Mohd Khairul, Talib Azman, Ahmad Nabihah, Nik Hisyamudin Muhd Nor, and Masanobu Izaki. (2019). Fabrication of Nanorods-TiO_2 for Heterojunction Thin Film Application with Electrodeposit-p-Cu_2O Absorbing Layer. *Materials Today: Proceedings*, *18*, 468-472. (ISI-indexed)

APPENDIX D

VITA

The author was born in July 11th, 1995, in Senai, Johor, Malaysia. She went to Maktab Rendah Sains Mara Kuala Terengganu, Terengganu, Malaysia for her secondary school and Selangor Matriculation College before continued her studies in degree. She pursued her degree at Universiti Teknologi Mara (UiTM) Jengka, Pahang, Malaysia, and graduated with Bachelor Degree (Hons) in Applied Science Physics in 2017. Upon graduation, she worked as research assistant at Microelectronic and Nanotechnology Shamsuddin Research Centre (MiNT-SRC) at Faculty of Electrical and Electronic Engineering Universiti Tun Hussein Onn Malaysia. In September 2017, she enrolled as graduated research assistant at UTHM and honoured with Master of Electrical Engineering within a year.