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Characteristic On Electromagnetic Energy Harvesting Using Graphene/Silver Filled Epoxy For PVT Thermal Hybrid Solar Collector

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CHARACTERISTIC ON ELECTROMAGNETIC ENERGY HARVESTING USING GRAPHENE/SILVER FILLED EPOXY FOR PVT THERMAL HYBRID SOLAR COLLECTOR

AZMI BIN NAROH

A dissertation submitted
in fulfillment of the requirements for the degree of Master of Engineering
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DECLARATION

I declare that this thesis entitled "Characteristic On Electromagnetic Energy Harvesting Using Graphene/Silver Filled Epoxy For PVT Thermal Hybrid Solar Collector" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
Name	:	AZMI BIN NAROH
Date	:	21/03/2019

APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment of Master of Mechanical Engineering (Energy Engineering).

Signature :..................................

Supervisor Name : Ts. DR. MOHD AZLI BIN SALIM

Date : 22/03/2019

DEDICATION

This dissertation/report is dedicated to:

The sake of Allah, my Creator and my Master,

My great teacher and messenger, Mohammed (May Allah bless and grant him), who taught us the purpose of life,

My great parents, who never stop giving of themselves in countless ways,

My beloved mother,Hajah Asiah, who inspire a lot,

My beloved father and mother in law, Haji Salleh and Hajah Sareah,

My dearest wife, Siti Norazah, who leads me through the valley of darkness with light of hope and support,

My beloved brothers and sisters,

My beloved kids: Haziq Aiman, Adib Adam, and babies that will born,whom I can't force myself to stop loving,

To all my family, the symbol of love and giving,

My friends who encourage and support me,

All the people in my life who touch my heart,

I dedicate this report.

ABSTRACTS

Emerging wireless and flexible electronic systems such as wearable or portable devices and sensor networks call for a power source that is sustainable, reliable, have high power density, and can be integrated into a flexible package at low cost. These demands can be met using photovoltaic thermal (PVT) systems, consisting of solar modules for energy harvesting, battery storage to overcome variations in solar module output or load, and often power electronics to regulate voltages and power flows. A great deal of research in recent years has focused on the development of high-performing materials and architectures for individual components such as solar cells panel circuit and batteries. The use of graphene and silver conductive ink as a flexible, low-cost, solution-processed transparent electrode for photovoltaics is investigated. To fabricate these systems, conductive ink printing techniques are of great interest as they can be performed at low temperatures and high speeds and facilitate customization of the components. The parameters that were evaluated consist of resistivity, surface roughness, and morphological analysis. In order to accomplish the analysis, the four-point probe is used to measure the resistance value of the sample in ohms-per-square. Conductive ink loading has detected the presence of resistivity with a certain percentage. The highest average resistivity is detected in 1 layer coil conductive ink while the low resistivity in 3 layers coils conductive ink. In terms of surface roughness, Nanoindentation machine was used which resulted that the samples with a consistent average value of uniform and smooth surface. Conductive ink samples with 80% weight percentage of filler had consistent surface regularities that contributed to smooth surface. In morphological analysis, nanoindentation is used to visualize the microscopic image of graphene and silver nanoparticles ink categorized by the electrical properties of the ink.

ABSTRAK

Sistem elektronik tanpa wayar dan fleksibel yang sedang pesat membangun seperti peranti boleh pakai atau mudah-alih dan rangkaian sensor memanggil sumber kuasa yang berterusan, boleh dipercayai, mempunyai ketumpatan kuasa tinggi, dan boleh diintegrasikan ke dalam satu pakej yang fleksibel pada kos yang rendah. Keperluan ini boleh dipenuhi menggunakan sistem fotovoltaik termal (PVT), terdiri daripada modul solar penjana tenaga, menyimpan bateri untuk mengatasi perubahan dalam pengeluaran modul solar atau beban dan sering elektronik kuasa untuk mengawal voltan dan aliran kuasa. Banyak penyelidikan dalam beberapa tahun kebelakangan telah memberi tumpuan kepada pembangunan bahan-bahan yang berprestasi tinggi dan untuk komponen individu seperti sel solar panel litar dan bateri. Penggunaan dakwat pengalir graphene dan Perak sebagai elektrod telus yang fleksibel, kos rendah, penyelesaian-diproses bagi fotovoltaik diselidik. Untuk mencipta sistem ini, teknik-teknik cetakan dakwat pengalir yang memberi manfaat digunakan kerana ia boleh dilakukan pada suhu rendah dan kelajuan tinggi dan mudah untuk disesuaikan bersama komponen. Parameter yang dinilai terdiri daripada ketahanan rintangan, permukaan kasar dan analisis abdi sendiri. Untuk mencapai analisis, four-probe digunakan untuk mengukur nilai sampel rintangan dengan unit ohms per square. Dakwat pengalir yang dibancuh telah bertindak dengan kewujudan resistivity dengan peratusan tertentu. Purata ketahanan rintangan yang tertinggi dikesan di lapisan 1 gegelung pengalir dakwat semasa rintangan rendah dalam 3 lapisan gegelung pengalir dakwat. Dari segi struktur permukaan , mesin Nanoindentation telah digunakan untuk menilai bahawa sampel dengan nilai purata konsisten secara seragam dan permukaan licin. Contoh pengalir dakwat dengan berat 80% peratus pengisi secara konsisten keatas permukaan yang menyumbang kepada permukaan licin. Dalam analisis abdi sendiri, nanoindentation telah digunakan untuk menggambarkan imej mikroskopik graphene dan perak dakwat konduktif yang dikategorikan oleh sifat-sifat elektrik dakwat.

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Alhamdulillah, praise to Allah, with his inayah', Finally, I have successfully completed my master project report entitled "Characteristic On Electromagnetic Energy Harvesting Using Grphene/Silver Filled Epoxy For PVT Thermal Hybrid Solar Collector" successfully.

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ρ	-	Resistivity
A	-	Cross-sectional area of the ink
L	-	Length of sample trace from end to end
R	-	Resistance
l	-	Length of line in mm
W	-	Width in mm
R_{SH}	-	Resistivity of the sheet in Ohm/sq, Ω/sq
V	-	Voltage across the inner pins
I	-	Current between the outer pins
T_m	-	Melting point
E	-	Estimation of error
Ra	-	Average of roughness

CHAPTER 1

INTRODUCTION

1.1 Background

Development of large-scale, reliable and cost-effective thermal and solar energy power systems is critical for achieving a sustainable energy future, as the sun is the largest source of clean energy available to the planet. Photovoltaic and thermal (PVT) panel are also an ideal power source for remote locations without electric grid access, and are of interest for numerous smaller scale applications including consumer electronics and wearable devices, as well as electromagnetic energy harvesting from indoor light sources for low-power applications such as sensor nodes. For indoor and outdoor applications alike, combining the solar module with energy storage and power management electronics can create a complete power system that can reliably meet the current and voltage demands of electronic loads.

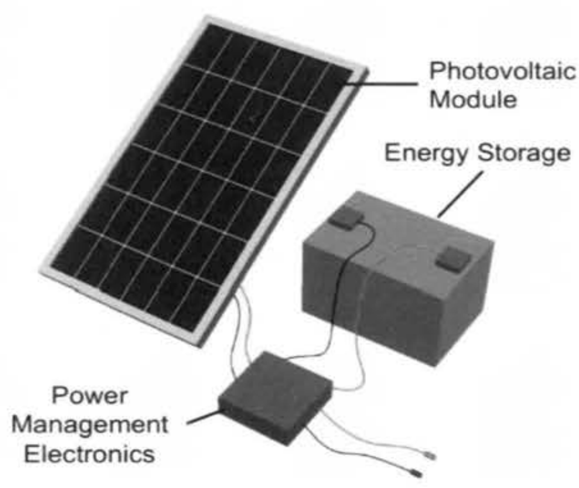

Figure 1.1 Illustration of Typical Photovoltaic System Including Energy Storage and Power Electronics.(Erin Ostfeld 2016)

In this paper, electromagnetic energy harvester (EEH) will be review from previous study. Conductive ink formulation are used to demonstrate conductive-structure fabrication on micro electromagnetic generators, and screen printing are used. Various sources vibration energy harvester are used such as electromagnetic, piezoelectric or electrostatic conversion mechanisms. Continuous improvement to overcome the limitation of energy harvester had been done such as the size and weight, and effectiveness in harvesting power output. A few layer of continuous volumes of metallic or insulating material were stacked on a cantilever microstructure which can increasing the output voltage and power, where enabled the all-additive fabrication of layers of coils without using vacuum deposition or any high-temperature process. By excite the generator that consist of magnet and coil turning the vibration energy into electrical energy. In the system flux that formed by magnetic core was cut through by the coil that causes induction of electromotive force as per state from Faraday's Law. The output power would increase as the numbers of coil turns increase. A schematic of the micro-generator with two coils layer is shown in Figure 1.1.

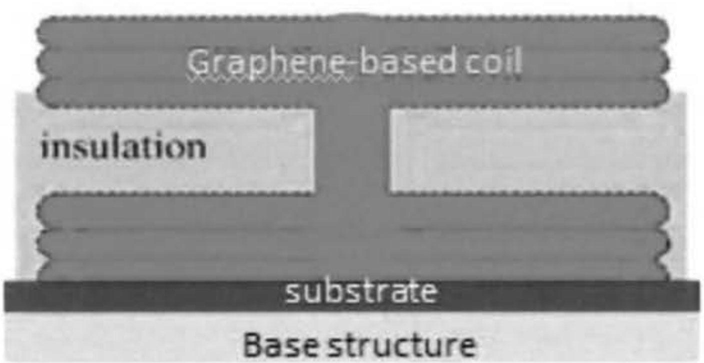

Figure 1.2 Layers Structure of the Printed Coil (Norhisyam 2018)

The generator coil was fabricated with two type of conductive ink nanoparticles which is graphene and silver conductive ink which is a single thin layer of pure carbon that the carbon atoms was firmly packed layer and hexagonal honeycomb lattice bonded. Material selection is one of crucial or important fundamental to take into consideration in formulating the conductive ink. Basically conductive ink consists of two main components; metal nanoparticles (usually silver or graphene), and liquid to carry the nanoparticles.

As for the liquid to carry the nanoparticles, there are two types of liquid with different viscosity, functioned as the binder and the hardener. Epoxy used as binder in this study is compatible to the viscosity behaviours of inks. It shows the anticorrosion properties when acting as coating ingredients. While for the hardener, it is an additional substance to the ink mixture to produce the ink finish strong or more durable, as well as the curing agent for epoxy. The final result of mixture from these three components is a conductive ink that maintains in liquid form until printed on certain surface at its drying point and succeed to conduct electricity.

Thus, troubleshooting problems with the characterization of conductive ink are elucidated to fabricate conductive ink which has high conductivity tracks or patterns. The characterization of conductive may consist of the parameters involved, the formulation of ink loading, the printing procedure, ink-substrate interaction, the temperature to cure and post-treatment of inks. For the formulation of ink loading, the interaction between filler, binder and hardener is important as it is the preliminary step to find out which ink loading can be resulted to have high conductivity. The ink loading is printed on the glass substrate, and then they will go through preheating method where the ink loading is cured in the oven for specialized time and temperature. The characterization of conductive ink is investigated so that a proper understanding may be gained through various methods (analysis); four point probe for sheet resistivity, surface roughness for surface texture and nanoidentation for morphological analysis.

All these described steps are repeated for the ink loading in accordance to the composition of element to produce conductive ink. This study highlights two research questions about the formulation of silver nanoparticles-filled epoxy to produce conductive ink and the relationship between all of the parameters investigated for silver nanoparticles-filled epoxy.

1.2 Problem Statement

The typical conductive inks available in the market place for printed electronics applications are formulated using expensive metallic particles. Although there are some other less expensive conductive materials available such as carbon and graphite, these materials are not as efficient conductors as silver, graphene and copper. Thus, in some applications where a high performance conductive ink is not required, a carbon or a mixture of carbon and silver could be sufficient for use. The conductive ink depends on the formation ways of metal nanoparticles, thus the issues that need attention are the materials composition and its behaviour to have high conductivity ink as the drawback to conductive ink circuits is their resistance.

Most researchers recently studied the effect of conductive ink for silver nanoparticles-filled epoxy by implementing measurement techniques to adjust the accuracy and parameter for quality and reliability of conductive ink through three techniques (Samano, 2017). In this report, the measurements involved are resistivity, surface roughness and morphological behavior; Samano described that using four point probe measurement sample produced for test lead resistance. In addition, for the surface roughness, it is one of the main critical issue that can affect the electrical resistivity of printings on the substrate (Maattanen, *et al.*, 2010) and from imaging methods from nanoidentation can contribute image with define details that included elemental details of printed sample (Ikeda, Watanabe, & Itoh, 2007).

The influence of various formulation parameters on the printability and conductive characteristic of the inks was studied and analysed on the formulated blended inks in comparison to silver performance.

1.3 Research Hypothesis

This research is experimental model strategy that can be utilized for finding estimated answer to obtained and improving the conductive ink by formulating the ink loading between filler and binder. Another working hypothesis brought up in this research is that the usage of graphene or silver conductive ink as coil is more efficient compares other materials used for the coil generator. The result should be found in the best conductivity of the ink in various patterns at constant temperature to cure.

1.4 Objectives

The objectives of this project as below:

i. To investigate the resistivity for silver nanoparticles filled epoxy for electromagnetic energy harvesting.

ii. To evaluate the surface texture and microstructure of silver nanoparticle filled epoxy conductive ink

1.5 Scopes and Limitation

In this study, the scopes will focus on electromagnetic energy harvester with graphene and silver conductive ink coil. This study aim is to investigate resistivity of silver and evaluate the relationship between surface roughness and microstructure using experimental approach. Below is the following scope and limitation in this study:

i. Using direct-write process for printing method
ii. Evaluating the effect of silver nanoparticles conductive ink in constant temperature by using 4-point probe
iii. The surface of the conductive ink surface is investigated using Nanoidentation

1.7 Thesis Outline

The structure of this report consists of five chapters. In Chapter 1, briefly described EEH and conductive ink coil structure. It is also presents the research objective, scope and hypothesis.

Chapter 2 is about all of the related information from the literature review collection will be presented so that the comparison between the previous research, current and expected research can be made in order to ensure there is no similar research about this project has been made.

Research methodology will be displayed by stating the procedures taken in the experiment based on the flowchart constructed in chapter 3. This chapter will present from the beginning of the experiment until the testing process; electrical testing, microscopy and surface roughness measurement so that the analysis can be made.

In this Chapter 4, all parameter and the results from the previous chapter has been obtained, the analysis will be discussed in this chapter in terms of the behaviour of the ink;

resistivity, and microstructure plus the surface roughness in order to answer the questions in this research.

The highlights and major conclusions drawn from this research together with recommendations for future work are finally presented in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this study, it will spans the relationships between resistivity, surface roughness, and microstructure. To provide background for this work, this chapter will introduce the PVT technology used, review of conductive ink, methods of printing, heat treatment, material of substrates and conductive ink characterization conclude with an outline of the study.

2.2 Fundamental of Operation Photovoltaic Components

The fundamental components of a photovoltaic cell are an active layer, consisting of one or more semiconducting materials that absorb light and generate a photocurrent, and two contacts that collect the current. A common structure for thin-film PVT cells is shown in Figure 2.2 along with the basic principle of operation. Photons absorbed in the active layer generate electron-hole pairs (represented by "e-" and "h+" in the figure). To collect the electrons and holes as electric current, an electric field must be present across the device. This is accomplished by using multiple doping types in the active layer to create a p-n junction, or multiple materials to create a heterojunction, and/or by employing contacts with two different work functions. This built-in electric field causes photogenerated electrons and holes to flow in opposite directions until they are collected at their respective contacts, resulting in a net current. The back contact is typically a layer of a reflective metal, while