PREPARATION AND CHARACTERIZATION OF PANI / GNPS NANOCOMPOSITES FOR FLEXIBLE WEARABLE TEXTILE ANTENNA APPLICATION

Submitted in accordance with the requirement of the University Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons.)

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DECLARATION

I hereby, declared that this dissertation entitled "Preparation and Characterization of PANI / GNPs Nanocomposites for Flexible Wearable Textile Antenna Application" is the results of my own research except as cited in references.

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Date : 26th June 2019

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons).

The members of the supervisory committee are as follow:

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ABSTRACT

Previously, the conductive patch of antenna is made from copper, which are inflexible, expensive, multi-fading phenomena, bulky, environmental sensitive and difficult to manufacture. Miracle nanotechnology of graphene owing to their extraordinary electrical conductivity and superior strength than metal, but flexible, has allowed them to be a potential candidate replacing uncompromising copper metallic. However, the main drawback of graphene is lack of energy band gap which close down many electronic device potential applications. Hence, in this research, GNPs is incorporated with polyaniline (PANI) conductive polymers. Wearable fabrics as flexible body signal receiver type antennas, are overwhelmed research topics for body centric communication in an industrial revolution 4.0 (IR4.0) era. Wearable textile antenna applications are expanding quickly, especially for mobile computing, tracking navigation and public safety. This study is to evaluate the potential of novel formulation of graphene nanoplatelets / polyaniline (GNPs/PANI) conductive nanocomposites for the new generation of flexible wearable textile antenna. GNPs/PANI nanocomposites solution has been synthesized by aniline polymerization in an acidic medium. The effects on GNPs loading (0.25 wt %, 0.50 wt %, 0.75 wt% and 1.00 wt %) on antenna radiating properties for GNP/PANI-textile nanocomposites has been characterized and evaluated, using standard morphological, physical and electrical characterization method. The combination of GNPs and PANI is perfecting each other, enhancing the existing electrical conductivity properties, while open up other potential characteristics, especially for robust wearable antenna development. The simulated and measured results showed that the proposed wearable textile antenna has constant gain which is 4.1809 dB, return loss at -13.154 dB and radiation pattern after the antenna is operated at 10.36 GHz. From this research, new materials formulation of GNPs/PANI textile nanocomposites and related fundamental understanding for such application, and standard methodological approach for smart clothing wearable antenna fabrication was established.

ABSTRAK

Sebelum ini, patch konduktif antena diperbuat daripada tembaga, yang tidak fleksibel, mahal, fenomena berbilang pudar, besar, sensitif alam sekitar dan sukar untuk dihasilkan. Nanoteknologi ajaib graphene kerana kekonduksian elektrik luar biasa dan kekuatan unggul daripada logam, tetapi fleksibel, telah membolehkan mereka menjadi calon yang berpotensi menggantikan logam tembaga tanpa kompromi. Walau bagaimanapun, kelemahan utama graphene adalah kekurangan jurang band tenaga yang menutup banyak aplikasi potensi peranti elektronik. Oleh itu, dalam kajian ini, GNP digabungkan dengan polimer konduktif polyaniline (PANI). Kain yang boleh dipakai sebagai antena jenis penerima isyarat fleksibel, adalah topik penyelidikan yang hangat untuk komunikasi sentris badan dalam era revolusi industri 4.0 (IR4.0). Aplikasi antena tekstil boleh pakai berkembang dengan pesat, terutamanya untuk pengkomputeran mudah alih, menjejaki navigasi dan keselamatan awam. Kajian ini adalah untuk menilai potensi penggubalan novel graphene nanoplatelets / polyaniline (GNPs / PANI) nanokomposits konduktif untuk generasi baru antena tekstil dapat dipakai fleksibel. Penyelesaian nanokomposits GNP / PANI telah disintesis oleh pempolimeran anilin dalam medium berasid. Kesan ke atas pemuatan GNP (0.25 wt %, 0.50 wt %, 0.75 wt% and 1.00 wt %) pada sifat radiasi antena untuk nanokomposit GNP / PANI telah dicirikan dan dinilai, menggunakan kaedah pencirian morfologi, fizikal dan elektrik standard. Gabungan GNP dan PANI menyempurnakan satu sama lain, meningkatkan sifat kekonduksian elektrik yang sedia ada, sambil membuka ciri-ciri berpotensi lain, terutamanya untuk pembangunan antena yang boleh dapat dipakai. Keputusan yang disimulasikan dan diukur menunjukkan bahawa antena tekstil yang dicadangkan mempunyai keuntungan berterusan iaitu 4.1809 dB, kehilangan kembali pada -13.154 dB dan corak sinaran selepas antena dikendalikan pada 10.36 GHz. Dari penyelidikan ini, bahan-bahan baru yang dirumuskan untuk nanokomposit GNP / PANI tekstil dan pemahaman asas yang berkaitan untuk aplikasi sedemikian, dan pendekatan metodologi standard untuk fabrikasi antena yang dapat dipakai pakaian pintar telah dibentuk.

DEDICATION

Dedicated to

My greatest father and mother, Omar Bin Ismail, Azlina Binti Basar

My supervisor, Dr. Jeefferie Bin Abd Razak,

My appreciated families and all my friends and colleagues for giving me moral support,

Cooperation, encouragement and also understanding.

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LIST OF ABBREVIATIONS

PANI	-	Polyaniline
GNPs	-	Graphene nanoplatelets
TVC	-	Titanium tetrapropoxide and vanadium pentoxide
PAMPSA	-	Poly (2-acrylamido-2-methl-1-propanesulfonic acid
PANIS	-	Natural silica
PANISA	-	Acid treated natural silica
PANIFG	-	Fiber glass
PANIPET	-	Poly (ethylene terephthalate) powder from waste bottle
CNT	-	Carbon nanotube
GRM	-	Graphene and related materials
CVD	-	Chemical vapour deposition
LCP	-	Liquid Crystal Polymer
2D	-	Two dimensional
XRD	-	X-ray Diffraction
SEM	-	Scanning Electron Microscope
IEEE	-	Institute of Electrical and Electronics Engineers
PNC	-	Polymer nanocomposites
VSWR	-	Voltage Standing Wave Radio
DUT	-	device-under-test
FCC	-	Federal Communications Commission
FTIR	-	Fourier Transform Infrared Spectroscopy

LIST OF SYMBOL

TPa	-	Terapascal
μm	-	Micrometer
g/m^3	-	Gram/cubic meter
%	-	Percentage
S/m	-	Siemens per meter
g/mL	-	Gram/millilitre
°C	-	Degree celcius
*w*t %	-	Weight percent
dBi	-	Decibels-isotropic
Ah/kg	-	Ampere hour per kilogram
W / m·K	-	Watt per metre kelvin
RH	-	Relative humidity
ε	-	Permittivity
F/m	-	Farad per metre
ρs	-	Surface resistance
Qt	-	Quality factor
mm	-	Millimetre
nm	-	Nanometre
kV	-	Kilovolt
mA	-	milliamperes

CHAPTER 1

INTRODUCTION

This chapter provides full explanation about background of study, problem statement, research objectives, scope of study, rationale of research and thesis organization. The relevancy of conducting this research is comprehensively justified and accomplished. Furthermore, in this chapter depth of investigation are covered in the research scopes.

1.1 Background of study

Antenna is a wireless communication that are able to access signal in variety frequency bands. The growing demand of wireless communication makes researchers to work hard to ensure enhance performance and applications of resulted antenna. Wearable antenna is an antenna specially designed to work when it comfortably worn on the body. Wearable fabrics or textile antennas are one of the dominant research topics for body centric communication. To date, many types of wearable antennas have been proposed, which are integrated microstrip antennas on textiles such as nylon, foam, cotton, conducting paint, polyester, shielded wire, Liquid Crystal Polymer (LCP) and others. The utilization of wearable textile antenna has expanding very fast in wireless applications. Wearable antenna was expected to be a piece of clothing fabric which utilized for correspondence purposes, including mobile computing, tracking and navigation and public safety. Planar structures and flexible building materials are specific application that requires flexible wearable textile antennas. Some of the properties of common antenna utilized affects material the characteristics of wearable antenna, such as electrical conductivity, return loss and antenna gain.

The purpose of this research is to fabricate a flexible wearable textile antenna made from polyaniline (PANI) / graphene nanoplatelets (GNPs) nanocomposites material whereby polyaniline (PANI) are used as a polymer composites and graphene nanoplatelets as a nanofiller which integrated into the selected fabric. GNPs has two dimensional (2D) carbon based nanofiller which possessed miracle properties for antenna application. The properties structure of GNP attracts researcher due to their arrangement of carbon atom that similar with honeycomb network structure which had displayed greater level of stiffness and strength (1.00 TPa). Besides, the addition of GNPs into polymer could improving the mechanical properties of resulted nanocomposites. In addition, it also able to conduct electricity better than copper and improve the surface barrier properties because of it platelet like morphology.

Polyaniline (PANI) is one of the most technologically important polymer materials because of its environmental stability, unique redox properties, and possessed higher conductivity. PANI also has been the subject of considerable recent interest because of their unique electrical behavior, good environmental stability in doped and neutral states, ease of synthesis and wide applications in different fields. Its surface modification can be an efficient way to introduce desired functional groups and to control its final properties, while keeping the bulk characteristics of PANI polymeric macromolecules. PANI based composite materials will possess the potential of multitude applications, such as in gas sensing, various sensors and inductors. Other than that, PANI also involves on the combination of electrical properties, typically as typical of semiconductors with materials parameters characteristics of polymer, like the development of plastic microelectronics, electrochromic devices and smart fabric.

To conduct this study, the amount of GNPs used are varied into 0.25 wt %, 0.50 wt %, 0.75 wt % and 1.0 wt. In this study, PANI and PANI-GNPS nanocomposites is synthesized via aniline oxidative polymerization in acidic medium method in phase 1. The content of PANI in this composite and its percentage results was determined by the GNP weight gain after modification has been prepared. There are several test being conducted regarding morphological analysis, physical and electrical conductivity testing. Scanning Electron Microcopy (SEM) is used to perform the morphological analysis. Furthermore, for physical analysis, there are consisted of X-ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR) and Raman spectroscopy. To analyse the conductivity properties of the samples, electrical testing is carried out.

Next, wearable textile antennas have been designed accordingly to the specifications dimension in phase two. This is phase where the preparation and characterization of flexible wearable textile antenna by using GNP / PANIs nanocomposites product that function as conductive ink take place. CST Microwave Studio is a simulation software that being used to design and simulation of the antenna. After that, the wearable textile antenna is performed two experimental test, mechanical testing and electrical testing in order to observe the antenna attribute. For mechanical testing, antenna attributes such return loss, antenna gain and radiation pattern are being measured and for electrical testing, electrical conductivity of the antenna is being analysed. To fabricate the wearable textile antenna, fabric cotton has been used as substrate while PANI and PANI-GNPs nanocomposites are used for radiating patch.

The obtained results will be further compared with another established results from other researchers. There are various promising application requires wearable type antenna, such as in military, medical, mobile devices, communication and etc. Hence, this research are feasible to be conducted considering their vast potential and in-line with material revolution in industrial 4.0 (IR4.0) era.

1.2 Problem statement

Up till now, the study of wearable textile antennas was actively carried out by researchers throughout the globe. Futurists and antenna designer for wide-band communication have been discussing the idea of wearable technology for nearly two decades. In wearable electronic, antenna plays a paramount role in optimal performance of wearable type devices. This research provides a fundamental kick start to explore and understand the potential of PANI / GNPs based nanocomposites material formulation for flexible wearable textile antenna utilizing cotton fabric as the substrate template. This study is novel and got no similarity with other previous work done by other researcher.

The first problem arising is there was no available wearable type of textile antenna which possessed good conductivity and other importance antenna attributes such as antenna gain, return loss, radiation pattern and many more. These attributes are really important for wearable textile antenna so that it can work as a device with optimum performance. Hence, this study will provide basic preliminary info or important data for the development of wearable antenna using nanocomposites integrated with textile fabric

Furthermore, current available antenna having standard shape and solid in their form, a rigid structure, a big size and expensive material such as FR4 board, Taconic fiber glass 5 and Roger hydrocarbon ceramic are not flexible or even wearable. As alternative, wearable antennas such as wired antenna, flexible substrate antenna and film antenna are introduced in making the antenna more flexible. Very few established antenna are wearable for personal usage as flexible body signal receiver. Thus, this research was trying to propose a novel antenna design which wearable with a specific dimension, which was made from the integration of GNPs / PANI conductive ink nanocomposites with cotton fabric textile.

Last but not least, in current time, there is no standard understanding on the wearable textile antenna properties that made up from polymer nanocomposites. Apart from that, this research take the initiative way to understand the effects of GNPs filler loadings, textile layer or thickness effects, printing procedure and so forth, towards the quality of resulted wearable antenna of PANI/GNPs. The main common problem however when dealing with polymer nanocomposites was the agglomeration issue of added nanofiller. In this research, the effects of GNPs nanofiller addition at various loading percentage will be evaluated with consideration of agglomeration condition that might happened due to larger surface area of graphene.

This work is intended to synthesize free standing films of doped PANI-Graphene nanoplatelet composites having high conductivity using conventional solution casting technique. Presence of GNPs in the PANI matrix has improved the electrical conductivity of the composite films due to the formation of three dimensional conducting networks and creation of additional charge carriers.

1.3 Objectives

The main objectives of this research are:-

1. To characterize the morphological, physical and electrical properties of PANI and PANI-GNPs nanocomposites, made from oxidative aniline polymerization process.

2. To measure the effects of GNPs loading on PANI-GNPs nanocomposites for their antenna performance and related attributes.

1.4 Scope

In order to achieve the above stated objectives, several steps have been considered to accomplish the proposed wearable textile antenna utilizing GNPs / PANI conductive nanocomposites ink at various material formulation. This includes a comprehensive literature review, which study about the previous design of antenna. It was also important to build the basic understanding towards the knowledge on designing the textile antenna and identify the expected result and limitation within the textile based antenna design. Then, flexible wearable textile antenna preparation and characterization as the main element of antenna design has been highlighted in this research.

In this research, the flexible wearable textile antenna is made up from the utilization of GNPs / PANI nanocomposites whereby polyaniline (PANI) are used as a polymer matrix for composites bodies and graphene nanoplatelets as a nanofiller. In this study, the amount of GNPs used are 0.25 *wt* %, 0.50 *wt* %, 0.75 *wt* % and 1.0 *wt* %, 3.0 *wt* %. For sample preparation of pristine PANI and PANI-GNPs nanocomposites, the modification of GNP with PANI was carried out by oxidative aniline polymerization in acidic medium.

Apart from that, the final content of pristine PANI and PANI-GNPs nanocomposites is being tested and characterize for the morphological, electrical and physical properties. The morphological analysis is conducted under the Scanning Electron Microcopy (SEM). X-ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR) and Raman spectroscopy

has been performed for physical analysis. To measure the electrical conductivity of the samples, electrical testing has been carried out for electrical testing.

When ready, this textile will be fabricated with the wearable antenna as according to the predefined antenna size and design which considering GNPs / PANI nanocomposites as radiating patch while fabric cotton as substrate. Two major tests, comprising of an electrical testing and physical testing will be carried out to the antenna that has been designed. Electrical tests are used to study the findings of the element electrical conductivity. For physical testing, it was used to get the result for return loss, antenna gain and radiation pattern.

1.5 Rationale of research

The rationales of research are detailed as follows:

1. To establish new knowledge about GNPs / PANI nanocomposites as potential advanced material for wearable antenna design in communication by carrying out some related testing and characterization.

2. To develop understanding towards the preparation of GNPs / PANI nanocomposites ink that is carried out by oxidative aniline polymerization in acidic medium.

3. To produce higher response for various typical antenna attributes comprised of electrical and physical characteristics.

1.6 Thesis organization

This research is organized into several sub-topic and chapters. The introduction had begun as Chapter One that provides the background of the research, problem statement, objectives, thesis scope, rationale of research and also thesis organization. Chapter Two briefly discussed about the literature review of the research including related theories and investigations related on antenna, wearable textile antenna, polymer nanocomposites, conductive based composite, polyaniline, graphene nanoplateletes and characterization related to wearable

flexible textile antenna properties by other previous researcher. All these information are important to understand the working principle of wearable textile antenna filled with GNPs / PANI nanocomposites. Chapter Three presents the basic methodology of research conducting the method chosen and the characterization used for various important testing. The flowchart of overall research methodology from beginning until the end was also included in this chapter. Chapter Four will showcase about the results and discussions that are from this research. Besides, all the data and related figures from the testing and characterization of producing the pristine PANI and PANI-GNPs nanocomposites were placed and further discussed in this chapter. Lastly, Chapter Five is about the conclusion and recommendation of this research. The entire discussion about this research will be exclusively summarized and concluded in this final chapter. The recommendation part is provided to suggest for the improvement of research for the next cycle of research studies.