SCHOOL OF MATERIALS AND MINERAL RESOURCES ENGINEERING

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FABRICATION OF STRETCHABLE ANTENNA

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DECLARATION

I hereby declare that I conducted, completed the research work and written the dissertation entitled “Fabrication of Stretchable Antenna”. I also declare that is has not been previously submitted for the award of any degree or diploma or other similar title of this for any other examining body or University

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%	Percentage
$^\circ$	Degree
n	Repeated unit n
T_g	Glass transition temperature
Ώ	Conductance unit, ohm
ρ	Density
R	Resistance
t	thickness
C	Conductance
tan δ	loss tangent
C_p	Capacitance

LIST OF ABBREVIATIONS

AC	alternating current
RF	radio-frequency
PDMS	Polydimethylsiloxane
UV	ultraviolet
OH	hydroxyl
FTIR	Fourier Transform Infrared Spectroscopy
DSC	Differential Scanning Calometry
PMMA	Poly(methyl methacrylate)
Hz	Hertz
ASTM	American Society for Testing and Materials

FABRIKASI ANTENA YANG BOLEH DIREGANG

ABSTRAK

Fabrikasi antenna yang boleh diregang sebagai satu peranti elektronik ini menggunakan Polydimetyhlsiloxana (PDMS) sebagai substrat dan dakwat silver sebagai bahantara yang dicetak di atas substrat. Selain itu, kajian ini juga bertujuan menganalisis prestasi antena ini yang berfungsi sebagai menerima dan memancarkan isyarat dalam reka bentuk yang terbaik. Dua reka bentuk yang telah dicadangkan dan setiap satu meberikan keputusan yang berbeza. Rekabentuk 1 dan rekabentuk 2 berbeza daripada segi dakwat perak dicetakkan. Rekabentuk 2 telah memberikan keputusan yang sepadan dan mempunyai lebar jalur yang besar yang membuatkan rekabentuk 2 adalah sesuai sebagai antena. Frekuensi salunan adalah pada 5.17 GHz. Untuk frekuensi kecekapan bagi simulasi ialah daripada 5.12 GHz hingga 5.26 GHz. Untuk experimen, Frekuensi salunan adalah pada bacaan 5.12 Hz dan untuk frekuensi kecekapan ialah daripada 4.4 GHz hingga 6.10 GHz. Antenna ini menunjukkan konduktiviti yang meningkat apabila diregang. Pada masa yang sama, sifat dan ciri-ciri silicon sebagai substrat dan perak dalam fabrikasi antenna yang boleh diregang ini dikenalpasti dengan mengunakan FTIR, DSC, Ujian kapasiti, dan pemalar dielektrik. FTIR menunjukkan ikatan OH sudah tidak wujud disebabkan ia telah lengkap proses pemeluwapan. Pemalar dielektrik bagi PDMS adalah daripada 2.3 hingga 2.9. PDMS juga menunjukkan nilai kapasiti yang rendah dan membuatkan PDMS sesuai sebagai subsrat.

FABRICATION OF STRETCHABLE ANTENNA

ABSTRACT

Fabrication of stretchable antenna as an electronic device was used Polydimetyhlsiloxane (PDMS) as a substrate and silver ink acted as resonator which printed on the substrate. Other aim for this research is to analyze the performance of antenna working in transmitting and receiving the data in the best design. Two design have been proposed which giving different result for each of it. Design 1 and Design 2 different in the way of silver ink is printed. Design 1 giving no input matching signal while for Design 2 gave matching and wide bandwith result which make it suitable as an antenna. The resonant frequency is around 5.17 GHz. For efficiency frequency obtain from simulation is from 5.12 GHz to 5.26 GHz. for experimental, the resonant frequency is at 5.3 GHz and the efficiency frequency is from 4.4 GHz until 6.10 GHz. This antenna showing increase in conductivity when the length streched is increased. At same time, the properties of silicone as substrate and silver in fabrication of strechable antenna is been characterized in polymer and electronic properties by using FTIR, DSC, Hardness Shore A, Capacitance test, dan Dielectric constant. FTIR result showing the OH bond that already not exist due to completely cured. Dielectric constant for PDMS is from 2.3 to 2.9. PDMS also shows low capacitance value which make it suitable to be a substrate.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Also called an aeria, an antenna is a device (usually metallic) or specialized transducer or conductor that converts radio-frequency (RF) fields into alternating current (AC) or vice-versa. It can transmit, send and receive signals such as microwave, radio or satellite signals. There are two basic types of antenna which is the receiving antenna, which intercepts RF energy and delivers AC to electronic equipment, and the transmitting antenna, which is fed with AC from electronic equipment and generates an RF field. A high-gain antenna increases signal strength, while a low-gain antenna receives or transmits over a wide angle. Anything that has a radio function will need an antenna. These include systems such as radio broadcasting equipment, broadcast television equipment, radar systems, two-way radio of any type, communication receivers, cell phones, satellite communication receivers and devices such as garage door openers, wireless microphones, wireless computer networks, baby monitors,Bluetooth enabled devices (Ankur A., 2005).

There are several critical parameters affecting an antenna's performance that can be adjusted during the design process. These are resonant frequency, impedance, gain, aperture or radiation pattern, polarization, efficiency and bandwidth. Transmit antennas may also have a maximum power rating, and receive antennas differ in their noise rejection properties. An antenna may be an isotropic radiator, a dipole, yagi-uda type, horn type or patch antenna. Antenna is the transitional structure between free space and a guiding device. The guiding device may be a coaxial line or a waveguide and it is used to transport electromagnetic energy from the transmitting source to the antenna or from antenna to the receiver (Ankur A. 2005).

Nowaday, some design is popularly made which is flexible and strechable. It give many benefit such as roll,stretch, twisted, compatible with human skin, wearable system and flexible. This is because wearable systems can be subject to a variety of stresses as human move around. New antenna design has proven its ability to withstand the bending and stretching that garments endure, while steadily communicating via Wi-Fi. For added restorative force it should not permanently bent out of shape the antenna by building top of a polymer layer called substrate such as silicone. On top of the silicone substrate, the conductive ink is embedded in the desired pattern as a conductor. To let the conductor and polymer substrate adhere together, one type of binder from silicone will be introduced.

Stretchable electronics is a technology that builds electronic circuits on top of a stretchable substrate or by embedding them in a stretchable matrix. For application as stretchable conductors, it is critical to render nanomaterials highly stretchable and conductive. For stretchability, a straightforward method is to deposit the nanomaterials on top of or to embed them inside elastomeric materials to form composites. Polydimethylsiloxane (PDMS) is a widely used elastomeric material. In order to enhance the adhesion between nanomaterials and a PDMS substrate, surface treatment by oxygen plasma, ultraviolet (UV) light, or chemicals has been used to modify the naturally hydrophobic PDMS surface with hydrophilic functionalities.

According to market analysis, the revenue of flexible electronics is estimated to be 30 billion USD in 2017 and over 300 billion USD in 2028. Their light weight, low-cost manufacturing, ease of fabrication, and the availability of inexpensive flexible substrates such as paper or textile make flexible electronics an appealing candidate for the next generation of consumer electronics. Moreover, recent developments in miniaturized and flexible energy storage and self-powered wireless components can be best choice for to commercialize such systems.

Nowadays, flexible and stretchable electronic systems require the invention of an antennas operating in specific frequency bands to provide wireless connectivity which is highly demanded by today's information application. The efficiency of these systems primarily depends on the characteristics of the integrated antenna. The nature of flexible and stretchable wireless technologies requires the integration of flexible, stretchable, light weight, compact, and low profile antennas. At the same time, these antennas should be mechanically robust, efficient with a reasonably wide bandwidth and desirable radiation characteristics.

1.2 Problem statement

These days, most electronic circuitry comes in the form of rigid chips. Also comercial antenna cannot be incorporate into wearable system to transmit data from sensors to receiver. In recent year, there a great deal of interest from both academic and industry in the field of stretch able electronics.

Flexible properties also have been applied onto antenna to make it more easier to bend it. But, with only flexible caharacteristic would not make the antenna in high performance. So nowaday, stretchable antenna is introduced to make it wearable system which is at high demand for medical devices. If bendable is good, strechable is even better, especially for high-performance conformable circuit of the sort needed for so-called smart clothes or body armor.

1.3 Research Objectives

1. To fabricate a stretchable antenna using silicone as a substrate and silver ink as a resonator.
2. To analyze the performance of antenna working in transmitting and receiving the data in the best design
3. To study the properties of silicone as substrate in fabrication of strechable antenna

CHAPTER 2

LITERATURE REVIEW

2.1 Antennae Design

Nowadays, stretchable electronic devices is becoming popular due to the advances application that needed the device to be more flexible and stretchable. Antennae is one of the electronic device which functioning as transmitting and receive data. An antenna is a device to transmit and/or receive electromagnetic waves. Electromagnetic waves are often referred to as radio waves. Most antennas are resonant devices, which operate efficiently over a relatively narrow frequency band. An antenna must be tuned (matched) to the same frequency band as the radio system to which it is connected, otherwise reception and/or transmission will be impaired. It having huge way of application. This research purposedly producing strechable antenna which will be one of the strechable electronic devices. Table 1 shows the common frequency bands used commercially.

Table 1: Chart of Common Frequency Bands (www.antenna-theory.com)

Frequency Band Name	**Frequency Range**	**Wavelength (Meters)**	**Application**
Extremely Low Frequency (ELF)	3-30 Hz	10,000-100,000 km	Underwater Communication
Super Low Frequency (SLF)	30-300 Hz	1,000-10,000 km	AC Power (though not a transmitted wave)
Ultra Low Frequency (ULF)	300-3000 Hz	100-1,000 km	
Very Low Frequency (VLF)	3-30 kHz	10-100 km	Navigational Beacons

Low Frequency (LF)	30-300 kHz	1-10 km	AM Radio
Medium Frequency (MF)	300-3000 kHz	100-1,000 m	Aviation and AM Radio
High Frequency (HF)	3-30 MHz	10-100 m	Shortwave Radio
Very High Frequency (VHF)	30-300 MHz	1-10 m	FM Radio
Ultra High Frequency (UHF)	300-3000 MHz	10-100 cm	Television, Mobile Phones, GPS
Super High Frequency (SHF)	3-30 GHz	1-10 cm	Satellite Links, Wireless Communication
Extremely High Frequency (EHF)	30-300 GHz	1-10 mm	Astronomy, Remote Sensing
Visible Spectrum	400-790 THz (4*10^14-7.9*10^14)	380-750 nm (nanometers)	Human Eye

Today's wearable healthcare tools are complex systems, based on advanced electronics. From a user point of view, the device should preferably be comfortable and unnoticeable. An interesting approach to achieve better wearability is by transforming the flat rigid device into a flexible or stretchable electronics device that can better follow the shape of the human body. Flexible and stretchable electronic device the irregularities of the human body. For increased user comfort, it would however be preferred that the electronics device can be deformed in more than one direction simultaneously. The device would then need to be conformable or stretchable. In the past years, a technology has been developed which enables the realization of stretchable systems from flexible foils (Jeroen V., 2015).

In industry, fabrication and component assembly are done on flat rigid or ultimately flexible subsrates. It is explained that the use of flat rigid assembled will become problematic when for a given application a circuit has to be implement on a nonflat surface. Very often, wearable and implantable circuits for biomedical applications, sports and leisure, safety, require nonflat assemblies, because preferably the circuit must follow the irregular shapes of the body parts, garments, or other curvilinear surfaces onto or into which the circuit is integrated. One option to achieve this degree of comfort is make it strechable and flexible to make sure the devices is wearable system with human (Takao S., 2012).

A high degree of mechanical compliance, good response to bending, compressing, and tensile strain, are all desired to impact a wider array of applications. Flexible materials suffer from the inability to either expand or contract, so the electronic device cannot move freely with moving parts, e.g. attachment to the movable human body parts. Thus, this lack of function underscores the need for stretchable electronics. Even though significant advances have been made in producing flexible electronic devices, less work has been devoted to producing stretchable electronic devices, i.e. response to tensile strain. Stretchability, or preferably reversible stretchability (or elasticity), without affecting its resulting electronic functionality is highly desirable. Hence, the advent of stretchable electronics would allow for highly portable, biocompatible devices that could function while being adhered to complex surfaces (Stephanie J., 2013)

There fews fundamental antennae types can be figured out. The most simplest antennae is called Short Dipole Antennae. Antennae can be devided into fews type which is Wire Antennae, Log-Periodic Antennae, Aperture Antennae, Travelling Wave Antennae, Reflector Antennae, and Microstrip Antennae. For this research, the antenna is included in Microstrip Antenna. Microstrip antenna actually known as patch antenna. This type of antenna consist of ground plate and metal flat surface. With a conducting ground plane, a microstrip patch antenna can be designed to operate in the vicinity of metal. These advantages make them preferable for numerous military applications and with compact design they are also used in personal mobile communication. Figure 1 below, illustrated Microstrip or Patch Antenna.

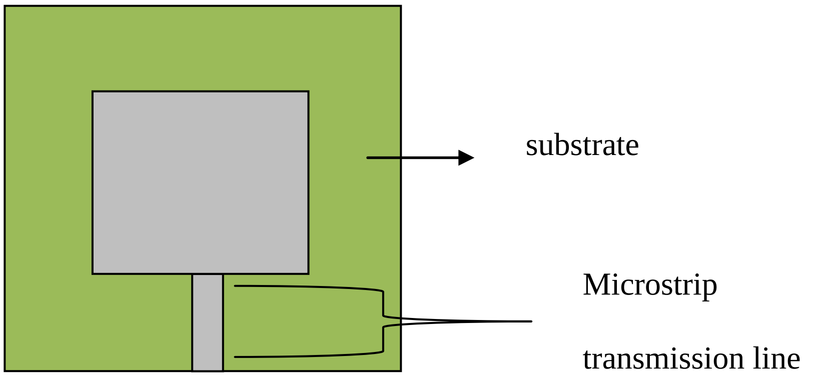

Figure 1: Microstrip or Patch Atennae

This PDMS antenna have two parts. One part is substrate and the other one is conducting line. PDMS can be either substrate or resonator. But due to the low dielectic constant of PDMS, it mostly suitable to be a substrate rather than a resonator. The silver will act as resonator to transmit and receive data. Resonator is a device or system that exhibits resonance or resonant behavior, that is, it naturally oscillates at some frequencies, called its resonant frequencies, with greater amplitude than at others. Resonators are used to either generate waves of specific frequencies or to select specific frequencies from a signal. For resonator materials, the dielectric constant for a resonator must be between 8 until over 100.

2.2 Choice of Antenna Substrate

To comply with flexible technologies, integrated components need to be highly flexible, strechable and importanyly mechanically robust, that material also have to exhibit high tolerance levels in terms of bending and stretching repeatability and thermal endurance due to it application which need to fold and stretch repeatly. Before this, paper is one of the example of substrate for antenna. However, paper based substrates are found to be not good and robust enough and introduce discontinuities when used in applications that require high levels of bending and rolling. Moreover, they have a relatively high loss factor (loss tangent (tan δ) is around 0.07 at 2.45 GHz) which compromises the antenna's efficiency.

Poly (dimetyhlsiloxane) hydroxyterminated (PDMS) is a main material used in making of the antennae. Besides that, the conductor lining is printed onto the substrate as conducting line which used silver ink. PDMS have colorless and transparent form which can be used in many way of application. It has low T_g which is around -125˚C to -135˚C. This will make the PDMS in liquid form at room temperature. It become solidify if the liquid is been crosslink by crosslinker. The main properties of PDMS which make it suitable to be a main material of stretchable antennae is it can be deformed enough such that conformable contact can even be achieved on surfaces that are non-planar on a micrometer scale.

PDMS is the most widely used silicon-based organic polymer since it is optically clear and generally inert, non-toxic, and non-flammable. In addition, it has low cost, ease of fabrication, and biocompatibility, thus it is widely utilized in various microfluidic applications (Ich L. N.,2016).

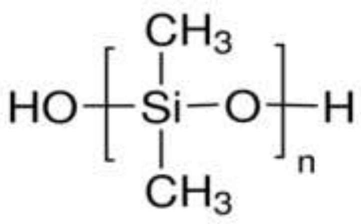

Figure 2: chemical structure of Poly (dimetyhlsiloxane) hydroxyterminated

Flexible electronics, the ability to bend, are desirable due to the potential roll-to-roll printing that can be employed, including inkjet printing, slot-dye coating, gravure printing, and patterning of device components. Implementation of roll-to-roll processing in large scale fabrication requires the substrates to be flexible. Most polymeric materials are intrinsically more flexible than inorganic crystalline materials. Flexible electronic devices made from organic materials are largely manufactured by deposition of materials onto flexible plastic substrates, such as polyimide or polyethylene terephthalate (PET) (Stephanie J., 2013).

Polysiloxane have found a widespread use in science and technology due to their unique physical properties, such as their thermal stability, high transparency, high UV stability, their hydrophobic character, their dielectric properties, and their chemical inertness. Furthermore, their biological inertness make them an ideal polymers for medical and cosmetic application. Many of the properties of polysiloxane can be deduced from their unique structure, comprising an inorganic backbone of silicon and oxygen and organic group that are covalently linked to the silicone atom. The character of the inorganic backbone delivers high flexibility of the chain and therefore low Tg and elastomeric behaviour while the organic substituent induce additional properties.

In recent years new polysiloxane materials are under development containing nanoscale entities, so called nanocomposite materials that expand the well-known properties of polysiloxane into new fields. Flexibility and stretchability can endow electronics with incomparable and fascinating features to promote the development of a new generation of products in the future. Flexibility and stretchability are required performances for new generation wearable electronics and devices (Jing Y., 2015).