STUDY ON $CaCO_3$ MINERAL FILLER LOADING EFFECTS INTO $SiR/CaCO_3$ BASED COMPOSITE AS DIELECTRIC RESONATOR FOR 5G APPLICATION

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

NOR SYAZANA ADILAH BINTI ZULKIFLI

B051510123

960310085352

FACULTY OF MANUFACTURING ENGINEERING

2019

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **STUDY ON $CaCO_3$ MINERAL FILLER LOADING EFFECTS INTO SiR/$CaCO_3$ BASED COMPOSITE AS DIELECTRIC RESONATOR FOR 5G APPLICATION**

Sesi Pengajian: **2018/2019 Semester 2**

Saya **NOR SYAZANA ADILAH BINTI ZULKIFLI (960310085352)**

mengaku membenarkan Laporan Projek Sarjana Muda (PSM) ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. *Sila tandakan (√)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysiasebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan)

☐ TIDAK TERHAD

Disahkan oleh:

__________________________ __________________________

Alamat Tetap:
NO. 502, JALAN USAHA 5,
TAMAN SRI LAMBAK,
86 000 KLUANG, JOHOR.

Cop Rasmi:

Tarikh: 26 JUNE 2019

Tarikh: ________________________

*Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled "Study On $CaCO_3$ Mineral Filler Loading Effects Into SiR/$CaCO_3$ Based Composite For 5G Application" is the result of my own research except as cited in references.

Signature : ……………………………………

Author's Name : NOR SYAZANA ADILAH BINTI ZULKIFLI

Date : 26 JUNE2019

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

……………………................................

(Ts. Dr. Jeefferie Bin Abd Razak)

ABSTRAK

Sedasawarsa ini, sering meniti dari bibir ke bibir setiap umat manusia di sluruh penjuru dunia tentang kelebihan bahan komposit. Oleh itu, kajian ini berkaitan dengan aplikasi penggunaan bahan komposit seperti antenna. Secara amnya, projek ini adalah tentang penyiasatan kesan pemuatan pengisi ke dalam komposit getah sebagai resonator dielektrik. Kebanyakan antena sebelumnya dibuat daripada seramik, yang merupakan bahan dielektrik yang baik. Walau bagaimanapun, bahan seramik memenuhi beberapa batasan ke arah sifat bahan seperti rapuh, tidak fleksibel, pembuatan yang sukar dan reka bentuk yang terhad. Revolusi teknologi pada masa kini juga meningkatkan pembangunan generasi baru dalam sistem komunikasi seperti aplikasi 5G. Kajian terdahulu telah menyatakan bahawa beberapa spesifikasi 5G tidak serasi dengan antena seramik. Contohnya, antena seramik dilakukan dengan keuntungan yang rendah dan jalur lebar sempit yang bertentangan dengan ciri-ciri sifat 5G yang dikehendaki. Oleh itu, idea yang dicadangkan bagi projek ini adalah membuat resonator dielektrik dari komposit untuk mengatasi masalah ini. Ini kerana gabungan seramik dan getah mempunyai sifat yang lebih baik daripada seramik itu sendiri. Sebagai contoh, produk komposit dari dua kilang gulung terbuka lebih mudah untuk bentuk sampel dan bentuk yang lebih fleksibel kerana ia tidak rapuh. Terdapat tiga ujian yang akan dijalankan dalam projek ini untuk menilai peratusan berat yang berbeza pengisi menjadi komposit sebagai resonator dielektrik. Kedua-dua ujian dielektrik adalah kerintangan permukaan dan ketelusan relatif dalam keinginan untuk menganalisis prestasi resonator dielektrik. Selepas melakukan ujian tegangan, sampel akan diperhatikan oleh SEM untuk mengaitkan morfologi permukaan patah dengan prestasi komposit DRA. Kebiasaannya, hasil yang dijangkakan ialah beban pengisi yang lebih tinggi meningkatkan sifat mekanikal dan fizikal komposit yang lebih baik untuk berfungsi sebagai reaktor dielektrik.

ABSTRACT

This study was related to the composite application for dielectric resonator antenna. It was about the investigation of filler loading effects into rubber composite as dielectric resonator. Most of antennas were made of ceramic, which are good dielectric properties material. However, ceramic materials had a few limitations such as brittle, inflexible, low manufacturability and limited design form. The revolution of technology nowadays also enhances the development new generation in communication system like 5G application. Previous studies have been stated that some of the 5G specifications are not compatible to the ceramic antenna. For example, the ceramic antenna performed low gain and narrow bandwidth which are totally opposite the desired 5G characteristics properties. Therefore, the proposed idea of this project was making dielectric resonator from composite to counter these problems. This is because the combination of ceramic and rubber has better properties than ceramic itself. For example, the composite product from two roll open mill easier to design sample and more flexible form as it not brittle. There were three testing that conducted in this project to evaluate different weight percentage of filler into composite as dielectric resonator. The physical properties testing were set first based on the densitometer and ater absorption test. Then, two dielectric testing performed, which were surface resistivity and antenna testing in desire to analyse the performance of the dielectric resonator. After performed the tensile test, the sample observed by SEM to correlate the fracture surface morphologies with resulted DRA performance of composites. The density value, hardness and tensile strength of 50wt% calcite filled silicone rubber composite achieved the highest value, but lowest ability in water absorption. However, the 50wt% filler content composite also got good return loss and gain value at -21.061 and 9.630dB respectively, as it showed the best resistivity value as well. This proved that the silicone rubber was one of the best substrate material for ideal antenna performances.

DEDICATION

Only
my beloved father, Zulkifli Bin Othman
my appreciated mother, Rohayati Binti Ahmad
my adored sisters and brothers,
all related lecturers, technicians and fellow friends
for giving me moral support, money, cooperation, encouragement and also understandings
Thank You So Much & Love You All Forever

ACKNOWLEDGEMENT

In the name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah that I can manage to complete this final year project successfully.

My respected supervisor, Ts Dr Jeefferie Bin Abd Razak for the great mentoring that was given to me throughout the project. Besides that, I would like to express my gratitude to him for the kind supervision, advice and guidance as well as exposing me with meaningful experiences throughout the study.

Last but not least, I would like to give a special thanks to my best friends who gave me much motivation and cooperation mentally in completing this report. They had given their critical suggestion and comments throughout my research. Thanks for the great friendship.

Finally, I would like to thank everybody who was important to this Final Year Project (FYP) report, as well as expressing my apology that I could not mention personally each one of you.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASTM	-	American society for testing and materials
SEM	-	Scanning electron microscope
SOP	-	Standard operation procedure
SiR	-	Silicone Rubber
HTVSR	-	High Voltage Temperature Vulcanized Silicone Rubber
HPTT	-	Hexakis-cyclotriphoslhazene-triazine-triamine
HVA	-	High Voltage Application
$CaCO_3$	-	Calcium Carbonate
DRA	-	Dielectric Resonator Antennas
LMDS	-	local multipoint distribution services
CST	-	Computer Simulation Technology
PCC	-	Precipitated calcium carbonate
GCC	-	Grounded calcium carbonate
XRD	-	X-Ray Diffraction
PSA	-	Particle Size Analysis
IoT	-	Internet of Things
PCB	-	Printed Circuit Board
CDP	-	Calcination Dissolution Precipitation

LIST OF SYMBOLS

cm	-	Centimetre
m	-	Metre
%	-	Percent
g/cm^3	-	Grams per centimetre cube
wt. %	-	Weight percent
mm	-	Millimetre
MPa	-	Mega Pascal
GPa	-	Giga Pascal
°C	-	Degree Celsius
TPa	-	Tera Pascal
W/mK	-	Watt per metre per Kelvin
K	-	Kelvin
nm	-	Nanometre
kg.cm3	-	Kilogram centimetre cube
pphr	-	Part per hundred resin
P	-	Peak force
l_e	-	Length
kg	-	Kilograms
mm/min.	-	Millimetre per minute
rpm	-	Revolution per minute
kN	-	Kilo newton
W	-	Sample width
W_m	-	Matrix mass
W_f	-	Fibre mass
T	-	Thickness
m	-	Mass
v	-	Volume
°C/min	-	Degree celsius per minute
Hz	-	Hertz

CHAPTER 1

INTRODUCTION

This chapter covers several subchapters such as the study background, problem statement, objectives, scopes and significant of study, also the thesis overview and related summary.

1.1 Background of Study

Nowadays, telecommunication technology is facing revolution and development to 5G. The 28 GHz spectrum of millimeter-wave signals has been widely used to produce better communication services like permanent wireless, broadband and single point to multipoint service, by the existence of local multipoint distribution services (LMDS). At this point, antenna technology has become more advanced.

Many researchers have started to investigate and explore dielectric resonator antennas (DRA) that are very good and attractive alternatives, as compared to conventional antenna. Previous antenna has low-gain antenna parameter, like monopoles, dipoles, and microstrip patches. However, there are quite lot obstacles in facing 5G design antenna. For example, the design dielectric resonator antennas must come with small dimensional sizes before its fabrication (Shahadan and Kamarudin, 2015).

Last few years, the dielectric resonator antenna (DRA) has attracted researchers' attention because the benefits like little dissipation loss, light, good dielectric strength, and great power handling capacity and small profile factor. DRA can be created in variety shape or geometrical pattern like rectangular, triangular cylindrical, half-split cylindrical, spherical, hemispherical and disk shaped. Practically, one of the main purposes in antenna design is to get a broad or wide range of bandwidth. This is because modified DRA shape and changing feed geometries would affect the bandwidth enhancement techniques.

Besides, advanced design solutions for enhancing gain for DRAs are studied. Gain is one of the DRA parameter. There are distinct antenna topologies to apply the required antenna property in terms of their gain, polarization, and frequency response. One of study had stated that DRAs realized best on silicon rubber as it can be characterized by favourable efficiency and gain (Keyrouz and Caratelli, 2016). The dielectric properties of material provide great influence and effect to the performance of DRA. The right material selection of DRA could be one of alternative solutions.

Generally, the previous antenna is made by ceramic materials. For this study, the proposed material for DRA was polymer composite of silicone rubber (SiR) as a matrix with calcium carbonate ($CaCO_3$) mineral filler as reinforcement. SiR rubber has the superior dielectric strength that lead to excellent high voltage performance. The SiR polymer could be further modified by adding inorganic mineral filler. Calcite or calcium carbonate as mineral filler has its unique property. It has great hardness, acicular crystal behaviour that could make the polymer composites fortifying properties (Meng and Dou, 2008).

Silicone rubbers (SiR) have fine chemical stability, good electrical properties and good flame retardancy, and superior resistance towards the temperature changes either under heat or cold exposure. Almost all industries have utilized SiR rubber because of its properties that could give many advantages. For example, quality and functionality of products were improved even at variety application such as electric and electronic equipment, automobiles, food products, automation tools, leisure products, and household items.

The performance of DRA will be observed and recorded from various related testing. The examples of dielectric properties testing are relative permittivity and surface resistivity. Thus, it provides significant contribution into knowledge of SiR filled calcium carbonate mineral filler composites as latest candidate of advanced materials for dielectric resonator antenna (DRA) in 5G telecommunication.

1.2 Problem Statement

Previously, an existing antenna is made from ceramic materials. Ceramic has excellent electrical resistance among other materials. Different engineering materials have different unique and attraction property. The materials can perform best for certain application that fit for their own properties. However, entire engineering materials have their own disadvantages. For example, the disadvantage of ceramic materials are it utilization limited due to inflexibility design, and its poor properties. Higher permittivity or permeability material like ceramic could exhibit magnetic behaviour at wall surface and close to air fields. The ceramic surface inference is more compatible than magnetic source excitation. This phenomenon leads to lower resonator action and higher radiation (James and Vardaxoglou, 2002).

Wireless antennas are facing revolution and development in its physical design from stamped metal and printed circuit board (PCB) to molded parts metallized with conductive inks. The ceramic has poor mechanical property like brittle, inflexible and hard to process. The types of antenna materials also go through revolution from ceramic to new advanced materials like composites. The high-volume manufacturer of wireless antennas has quickly matured about these technology changes for consumer market (Fasenfest, 2016). Silicone rubber (SiR) is widely used in electrical and electronic applications like bushings, cable terminations and high voltage transmission lines. This is due to its benefits of excellent resistance towards contamination, good insulation and very light weight (Chafidz, 2018) Then, $CaCO_3$ as functional mineral fillers was added up into SiR polymer matrix to produce filled composite materials for antenna applications. This is because composite helps in enhancing mechanical properties of antenna such as toughness and modulus of elasticity. Therefore, the proposed SiR/$CaCO_3$ composite chosen as new antenna materials could possibly replace previous ceramic antenna design.

In addition, the traditional ceramic antenna materials suffer from several dielectric property such as low gain (< 0 dBi), narrowband behaviour and low radiation efficiency (< 10 %). While today's telecommunication technology is facing revolution and development towards 5G application that requires totally demanding requirements and specifications such as higher broadband and higher gain. Basically, the surface resistivity must higher as it will limit the leakage current of presence conductor in antenna. Therefore, surface resistivity is parameters to be analysed in order to study the sturdiness of SiR based composites as new candidates for dielectric resonator antenna (DRA) for 5G applications.

The relative permittivity of produced SiR/$CaCO_3$ composites need to be higher, as higher permittivity indicates more capability of materials to store charge. In fact, it was mentioned that antenna with higher permittivity and resistivity is an excellent electrical stress control. It is important to know the relative permittivity of produced antenna at higher frequency in order to know the capability of produced DRA to perform task at higher frequency stress conditions.

In this study, the loading of ceramic filler into the rubber composite evaluated. The calcium carbonate loading varied into 0, 10, 20, 30, 40, 50 (wt%) that corporate into the silicone rubber as composite by using open two roll mil process. In short, to achieve the first objective, the density and water absorption test carried out for physical properties. Later, the hardness and tensile testing were performed for mechanical properties. The rubber composite performance such as gain, loss and radiation pattern analyse from antenna testing. The fractured surface morphologies from tensile testing are observed by SEM technique then.

1.3 Objective

The objectives of this research are:

i. To evaluate the physical and mechanical properties of SiR/$CaCO_3$ composites at different weight percentages of mineral filler addition (0, 10, 20, 30, 40, 50wt%).

ii. To analyze the SiR/$CaCO_3$ composites performance as dielectric resonator antenna.

iii. To correlate the fracture surface morphologies with resulted DRA performance of SiR/$CaCO_3$ composites, by using SEM observation.

1.4 Scope of Study

The scopes of this research are:

i. Utilization of raw materials like silicone rubber (SiR) polymeric materials and calcium carbonate ($CaCO_3$) mineral filler to establish the new advanced materials for dielectric resonator antenna (DRA) in 5G applications.

ii. Electrical properties of surface resistivity and electrical conductivity was conducted as the standard of ASTM D 257, the gain, loss and radiation pattern will be performed by using a Vector Network Analyzer with 1 – 10 GHz of frequency range

iii. The tensile test will perform first to evaluate the mechanical properties. The SEM and XRD analysis was conducted to characterize the raw materials and to correlate the physical-morphological properties of produced SiR/$CaCO_3$ filled composites.

1.5 Significant of Study

The significant of this study can be summarized as follows:

i. The new material can potentially replace the ceramic insulation limitation due to low manufacturability and design inflexibility, also poor material properties such as brittle, small radiation efficiency (< 10 %), small gain (< 0 dBi) and narrowband behaviour for dielectric resonator antenna development by using SiR/$CaCO_3$ filled composites as flexible dielectric materials.

ii. To reduce the energy, power consumption, the marketing ceramic filler like calcium carbonate powder is used. It also help to reduce the time preparation for ceramic powder.

iii. Lastly, this polymeric composite is cheap and low cost which could reduce the cost to manufacture dielectric resonator based antenna for application in 5G communication.