SILICONE RUBBER FILLED WOLLASTONITE MINERAL FILLER FOR HIGH VOLTAGE INSULATION APPLICATION

SAHRIL BIN RIZALI
B051410192

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
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This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering

by

SAHRIL BIN RIZALI
B051410192
950211-01-5771

FACULTY OF MANUFACTURING ENGINEERING
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I hereby, declared this report entitled "Silicone Rubber filled Wollastonite Mineral Filler for High Voltage Insulation Application" is the result of my own research except as cited in references.

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Date : 25 MAY 2018

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 (Engineering Materials) (Hons). The member of the supervisory committee are as follow:

…….....

(Dr. Jeefferie Bin Abd Razak)

Abstrak

Getah Silikon dianggap sebagai salah satu penebat yang paling kukuh dalam industri voltan tinggi. Getah Silikon mempunyai keupayaan fungsi seperti ringan, rintangan haba yang tinggi dan ciri-ciri penebat elektrik. Penyelidikan yang dinamik telah dijalankan di seluruh dunia untuk meneroka perlakuan unik penebat Getah Silikon tetapi, tidak banyak perhatian yang diberikan kepada analisis terhadap kerintangan permukaan, kepelbagaian relatif dan Getah Silikon walaupun kedua-duanya penting dalam menentukan prestasi Getah Silikon secara elektrik. Kerintangan permukaan yang tinggi melamabngkan keteguhan Getah Silikon dari luar manakala pembacaan ketelusan relatif yang baik terutama pada frekuensi tinggi mewakili keupayaan pukal bahan tersebut untuk menahan tekanan elektrik yang tinggi. Oleh itu, dalam kajian ini, empat faktor bahan mentah dan parameter pemprosesan telah diperkenalkan untuk mengkaji kesannya ke atas prestasi elektrikal Getah Silikon. Faktor-faktor tersebut adalah isipadu getah silicon, isipadu $CaSiO_3$, kelajuan pengadun dan masa pencampuran bahan untuk menganalisis sumbangannya ke arah meningkatkan kerintangan permukaan dan ketelusan relatif Getah Silikon. Keputusan ujian dianalisis dengan menggunakan kaedah reka-bentuk eksperimen (DOE) yang menggunakan dua tahap faktorial penuh daripada perisian Design Ekspert v10 untuk mencari perkaitan antara faktor faktor yang dikaji dan sumbangan setiap faktor dalam meningkatkan kedua-dua rintangan permukaan dan ketelusan relatif bahan Getah Silikon.

Abstract

This thesis presents the preparation of artificial reinforcement filler for polymeric composite insulation for high voltage outdoor application. Silicone Rubber (SiR) is considered as one of the most established insulator in High Voltage (HV) industry. SiR possesses great function ability such as its lighter weight, great heat resistance and substantial electrical insulation properties. Dynamic researches were performed all around the world in order to explore the unique insulating behaviour of SiR but not much of attention was given to the analysis of the surface resistivity, relative permittivity and inclined plane tracking and erosion testing of SiR despites of their importance in determining SiR performances electrically. Therefore, this three testing was performed in this research. High surface resistivity represents the sturdiness of SiR from outside while good relative permittivity reading especially at high frequency represents the ability of the material's bulk to withstand high electrical stress. Inclined plane tracking and erosion represent the electrical resistivity of the of material. Compounding process using open two roll mill and vulcanized process using hot press was the method used to produce SiR/$CaSiO_3$ composites. The characterization used in this research are Particle size analysis (PSA), X-ray diffraction (XRD) and Scanning electron microscopy (SEM). SiR/40wt.% $CaSiO_3$ composites shows the good performance as insulator performance for high voltage insulation application compare to other composites equal to 4.70 relative permittivity, 3.7 x 10^{13} Ω/sq for surface resistivity, the lowest mass losses (0.02g) for erosion and pass the inclined plane test.

DEDICATION

Dedicated to
my beloved father, Rizali Bin Deman
my appreciated mother, Ambun Tani Binti Bujang
my adored brother, Mohamad Azri Bin Rizali
my helpful friends and housemates,
for giving me moral support, money, cooperation, encouragement and also understandings
Thank You So Much & Love You All Forever

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LIST OF ABBREVIATIONS

IP	-	Incline Plane
ASTM	-	American Society for Testing and Materials
SEM	-	Scanning Electron Microscopy
TNB	-	Recently, Tenaga Nasional Berhad
SiR	-	Silicone Rubber
AW	-	Artificial Wollastonite
HTVSR	-	High Voltage Temperature Vulcanized Silicone Rubber
HPTT	-	Hexakis-cyclotriphoslhazene-triazine-triamine
HVA	-	High Voltage Application
IPT	-	Inclined Plane Tracking and Erosion Test
HTV	-	High-Temperature Vulcanized
ATH	-	Aluminum Hydroxide
Pt	-	Platinum
NS	-	Nitrogen-containing Silane
GNR	-	Graphene Nanoribbon
GO	-	Graphene Oxide
SRAAM	-	SiR/ammonium polyphosphate/aluminium hydroxide/mica composites
SiR/AW	-	Silicone rubber/Artificial Wollastonite
$CaCO_3$	-	Calcium Carbonate

SiO_2	-	Silica
XRD	-	X-Ray Diffraction
PPHR	-	Part Per Hundred Rubber
LC	-	Leakage Current
DCP	-	Dicumylperoxide
Ca	-	Calcium
Si	-	Silicon
PSA	-	Particle Size Analyzer
$CaSiO_3$	-	Wollastonite

LIST OF SYMBOLS

wt.%	-	Weight Percentage
℃	-	Degree Celsius
μm	-	Micro Meter
°	-	Degree
Ω	-	Ohm
g	-	Gram
cm	-	centimetre
kV	-	Kilo Volt
sq	-	square

CHAPTER 1

INTRODUCTION

This chapter explain briefly about the study of this subject. This chapter includes background of study, problem statement, scope, significant of study, thesis overview and summary of the chapter one.

1.1 Background of Study

Insulator is a material that the electron cannot flow freely. Therefore, it is very high resistance. Insulator does not only provide mechanical support to conducting part, but it also used to separate conductors to wipe out conduction amongst them and to store a charge when voltage is connected (Kuffelet *et al*., 2001). Thus, insulator is called dielectrics. Dielectric strength means the ranking of a material to the voltage breakdown. Therefore, to produce the good insulator, the material must have highest dielectric strength. Recently, insulator act as cable protection under DC conditions has got more consideration because of the quick improvement of high voltage DC and it would offer extraordinary help on enhancing the security and unwavering quality for power transmission system (Zhang *et al*., 2017).

Glass or porcelain is the good material to act as insulator because the extraordinary heat resistance. However, according to Buontempo *et al*. (2016), the porcelain and glass

insulator has been replaced by polymeric insulator in the electrical insulation of power system in the last decades. Xie *et al*. (2017) stated that, the uses of silicone rubber composite insulators have increased on transmission and distribution voltage around the world. The some of the reason are the light weight, convenience for transportation and installation, hydrophobicity and resistance to vandalism. Since polymeric insulation are accepted in high voltage application, a lot of research studies had been performed to improve the polymeric insulation performance. One key to resolve the development of high performance is by improve the tracking resistance and flame retardancy of polymeric insulation.

Filler in matrix is important to increase the polymeric performance. As an insulator, the good candidate for the polymeric material is ceramic. The heat resistivity of the ceramic, can enhance the performance of the polymeric insulator. The proposed polymeric insulation material under study is SiR as a matrix with wollastonite ($CaSiO_3$) mineral filler as a reinforcement. SiR has excellent dielectric strength that can contribute for a superior high voltage. The addition of inorganic filler is the method in modifying polymer materials. Wollastonite as an inorganic filler is a unique functional mineral. Its acicular crystal habit, great hardness and produced polymer composites fortifying properties (Meng & Dou, 2008).

1.2 Problem Statement

Recently, Tenaga Nasional Berhad (TNB) uses a ceramic insulator as the high voltage insulation. Ceramic has good electrical resistance compare to other materials. However, every material of their own disadvantage. The disadvantage of ceramic insulator is the leakage current easily occur on the path of the system due to the dust that deposited on the wet glass which cause by the moisture condensed on the glass surface. Moreover, ceramic are poor hydrophobicity and low performance under contaminated environmental conditions.

Besides, the problem related to removal of the large number of waste glass and waste cockles shell are met. The serious action must be taken because of the continuous amount of the waste increase. Therefore, to overcome this problem, converting waste into wealth by recycling of both and it provide benefits to our environment and economy. Aman *et al*. (2013) have studied to applied a recycle waste material like glass and seashell with thermoplastic polymeric material to produce polymer composite as high voltage insulation. Therefore, this recycle material can reduce the environment effect to the society.

Polymeric materials such as silicone rubber (SiR) is increasingly being used as exterior insulator in electrical and electronic applications, such as high voltage transmission lines, bushings and cable terminations, due to its advantages of light weight, high insulation and superior resistance to contamination. However, when being employed as exterior insulator in polluted environment, the pollutant and moisture covered on the surface of SiR will result in leakage current and arc discharge. Due to dry band arcing, SiR is prone to tracking and even smouldering combustion, which severely threatens the reliability of the insulation system. Therefore, this research is going to solve the problem related to the high voltage insulation application.

Basically, for high voltage polymeric insulation materials, the surface resistivity was preferred to be high, as higher surface resistivity limits the leakage current of the conductor that is being insulated. Therefore, surface resistivity was chosen as one of the parameters to be analysed in order to determine the sturdiness of the SiR surface. Similarly, the relative permittivity of material was also preferable to be at a higher value as a higher permittivity indicates higher capacitance which means a higher capability of materials to store charge. In fact, it was mention that a material with high permittivity and resistivity is an excellent stress control. It is important to know the relative permittivity of the materials at high frequency in order to know the capability of the insulations materials under high frequency stresses.

1.3 Objective

The objectives of this research are:

i. To evaluate the physical insulation behavior at high voltage exposure of SiR/$CaSiO_3$ based composites.

ii. To evaluate the electrical properties insulation behavior at higher voltage exposure of SiR/$CaSiO_3$ based composites.

iii. To observe surface morphological of SiR/$CaSiO_3$ composites and correlate it with the resulted physical, and electrical properties using SEM observation.

1.4 Scope of Study

The scope of this study are:

i. Raw material with is the silicone rubber (SiR) polymeric materials and waste materials like glass and cockles to produce artificial wollastonite (AW) to establish the new polymeric composite.

ii. The methodology used is only open two-roll mill (compounding), Hot press (Curing), 60°C oven post-cured.

iii. Electrical properties of surface resistivity in laboratory test will be conducted as the standard of ASTM D 257, the relative permittivity will be conducted using a Vector Network Analyzer (85070E Dielectric Probe Kit) with 0.5 – 5 GHz of frequency range and inclined plane tracking and erosion testing in accordance to BS EN 60587.