UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DIELECTRICAL PROPERTIES OF ALUMINA NANOPARTICLES REINFORCED EPOXIDIZED NATURAL RUBBER COMPOSITES FOR ELECTRICAL INSULATION: A CRITICAL REVIEW

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

by

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Tajuk: **DIELECTRICAL PROPERTIES OF ALUMINA NANOPARTICLES REINFORCED EPOXIDIZED NATURAL RUBBER COMPOSITES FOR ELECTRICAL INSULATION: A CRITICAL REVIEW**

Sesi Pengajian: **2019/2020 Semester 2**

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I hereby, declared this report entitled "Dielectrical Properties of Alumina Nanoparticles Reinforced Epoxidized Natural Rubber Composites for Electrical Insulation: A Critical Review" is the result of my own research except as cited in references.

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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:

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ABSTRAK

Kabel elektrik adalah saluran penghantaran elektrik ke rumah yang memberikan perlindungan dan kemudahan kepada pengguna. Pada dasarnya, kabel terbuat dari bahan berasaskan petroleum seperti polietilena dan polipropilena di mana ini boleh menjadi keburukan pada masa akan datang sekiranya terdapat kekurangan sumber petroleum. Juga, kabel boleh dibuat dari pelbagai jenis bahan an kelestarian hijau yang sesuai di mana penyelidikan ini berdasarkan komposit getah asli. Walau bagaimanapun, getah asli yang tidak berkutub mempunyai kemampuan sifat dielektrik yang terhad dan kurang tahan panas untuk bertindak sebagai saluran penghantaran manakala seramik alumina pula mengandungi pemalar dielektrik yang tinggi. Oleh itu, kajian ini membuka harapan untuk meneroka potensi komposit getah asli terepoksida yang merupakan polimer berkutub bertetulang alumina sebagai penebat elektrik. Dalam kajian ini, keupayaan nanokomposit getah asli terepoksida bertetulang nanozarah alumina (ENRAN) yang dihasilkan dengan pencampuran lebur dipostulasi menggunakan tinjauan kepustakaan kritis. Ia didalilkan terhadap kesan pembebanan nanozarah alumina yang berbeza sebanyak 5%, 4%, 3%, 2%, 1% dan 0%. Data sedia ada dari jurnal sebelumnya dianalisa dan dibincang untuk postulasi sifat dielektrik bagi nanokomposit getah ENRAN yang dicadangkan. Didapati, sifat dielektrik komposit ini meningkat dengan peningkatan pembebanan alumina dan dipostulasi menjangkau nilai pemalar dielektrik dalam lingkungan 1.9 ke 2.9. Ia adalah dijangka lebih tinggi dari komposit getah asli bertetulang. Morfologi permukaan melalui kemikroskopan elektron imbasan (SEM) bakal menunjukkan taburan dan penyerakan nanozarah alumina yang lebih baik apabila alumina dicampurkan ke dalam getah ENR yang berkutub. Nilai optimum akan menghasilkan pemalar dielektrik yang maksima. Sifat dielektrik ini juga dijangka menunjukkan ciri-ciri komposisi dan struktur yang sejajar dengan peningkatan nilai yang diperhatikan melalui analisa spektroskopi inframerah penjelmaan dan Fourier (FTIR). pembelauan sinar-x (XRD).

ABSTRACT

Electrical cable is part of transmission lines which provide protection and facilities to the consumers. Basically, cable is made of petroleum-based material like polyethylene and polypropylene in which this can be a disadvantage in the future if there is depletion of petroleum source. Also, the cable can be made up from various green sustainability material in which this research is based on natural rubber composite. However, non-polar natural rubber has limited dielectrical properties and heat resistance to be used in transmission line while, alumina ceramic contains high dielectric constant. Therefore, this study is to explore the potential of polar epoxidized natural rubber reinforced with alumina composite as electrical insulation. In this study, the potential of alumina reinforced epoxidized natural rubber nanocomposite (ENRAN) to be produced by melt compounding would be postulated via a critical review. It is postulated against different alumina nanoparticles loading of 5%, 4%, 3%, 2%, 1% and 0% . The existing data from previous journal are analyzed and discussed to predict the dielectrical properties of suggested ENRAN composites. It is found that the dielectric properties of these composites increase with increasing alumina loading and are postulated to reach the dielectric constant of 1.9 to 2.9. It is expected to be higher than reinforced natural rubber composites. Surface morphology will show better distribution and dispersion of alumina nanoparticles when alumina is mixed into polished ENR rubber. The optimum value will produce the maximum dielectric constant. These dielectric properties are also expected to exhibit compositional and structural characteristics in line with the increase in the values observed through Fourier transform infrared (FTIR) spectroscopy and X-ray diffraction (XRD) analyses.

DEDICATION

This report is dedicated to my beloved family,

who educated me and enable me to reach this level.

To my honoured supervisor,

Prof. Madya Dr. Noraiham Binti Mohamad

for her advices, support, and patience during completion of this project

and to all staffs & technicians,

for their advices and cooperation to complete this project.

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LIST OF ABBREVIATIONS

AFM	-	Atomic force microscope
ASTM	-	American society for testing and materials
DMA	-	Dynamic mechanical analysis
DSC	-	Differential scanning calorimetric
DWCNTs	-	Double walled carbon nanotubes
ENR	-	Epoxidized Natural rubber
ENRAN	-	Alumina nanoparticles reinforced epoxidized Natural Rubber composite
FTIR	-	Fourier transform infrared
MWCNTs	-	Multi walled carbon nanotubes
NR	-	Natural Rubber
NPs	-	Nanoparticles
RTM	-	Resin transfer moulding
SEM	-	Scanning electron microscope
SOP	-	Standard operation procedure
ZnO	-	Zinc oxide
S	-	Sulphur
XRD	-	X-ray diffraction

LIST OF SYMBOLS

cm	-	Centimetre
m	-	Metre
%	-	Percent
g/cm^3	-	Grams per centimetre cube
wt. %	-	Weight percent
mm	-	Millimetre
°C	-	Degree Celsius
TPa	-	Tera Pascal
K	-	Kelvin
nm	-	Nanometre
phr	-	Part per hundred resin
l_e	-	Embedded fibre length
kg	-	Kilograms
mm/min.	-	Millimetre per minute
rpm	-	Revolution per minute
W_f	-	Fibre mass
T_i	-	Thickness before immersion
T_f	-	Thickness after immersion
m	-	Mass
v	-	Volume
V	-	Measured voltage
I	-	Constant current
R	-	Resistance
E	-	dielectric strength
VBD	-	Voltage breakdown value
t	-	Thickness of sample
r	-	revolution
kV	-	kilovolt

CHAPTER 1
INTRODUCTION

1.1 Research Background

Electrical insulation such as cable electrical insulator is defined as a material that has internal electric charges that do not move freely in which very little electric current will flow through it under the influence of an electric field. Electrical insulator contains much higher resistivity than semiconductors or conductors. This shows that insulator is different compared to semiconductors or conductors. Besides, the function of insulator is to hold the conductors without letting current through themselves while supporting the weight of the cable.

From the research paper (Zul and Makmud, 2016), electrical industry has used natural rubber-based insulations as electrical cables since the preliminary of electrical industry. Natural rubber can be improving its mechanical and physical properties due to the desired properties by diffusing natural rubber with synthetic rubbers at a lower cost. Furthermore, by blending natural rubber with polymers and other fillers can modified its electrical insulating properties (Zul and Makmud, 2016).

The main factors that affecting the electrical performance for insulation of wire lines in terms of degradation or improvement are such as electrical conductivity, relative permittivity, dielectric losses, partial discharges, space charges, electrical and water tree resistance behavior and electric breakdown (Plesa et al., 2016). The combination of natural rubber and nanocomposites may increase the ability of mechanical and electrical properties for electrical insulation.

1.2 Problem Statement

Electrical cable is the component of an electrical system that is commonly made of polymeric materials. According to (Teyssedre and Laurent, 2013) many types of plastic materials such as polyethylene, terephthalate, polycarbonate, polystyrene, low- and high-density polyethylene, polypropylene, polytetrafluoroethylene and fluorinated ethylene-propylene copolymer have been produced due to wide amount of information and increase in knowledge about chemistry of insulating materials and improved processing. They are significant to perform their role in transferring electricity. Electrical cable is the component of an electrical system that is commonly made of polymeric materials which is petroleum-based materials. This is not sustainable due to the depletion of petroleum source. Nowadays, there are high demands for the green sustainability material, so therefore we try to propose our own natural resources, Natural Rubber.

Generally, these electrical cables play an important role in transmission lines that use to store charges at certain time and at certain amount of capacity (Teyssedre and Laurent, 2013). Hence, a study of dielectrical properties of alumina nanoparticles reinforced epoxidized natural rubber composite as electrical insulation is important for providing the information of dielectrical characteristic.

The insulation material used in electrical cable is mainly focus in the utilizing of polymer composite. However, the natural rubber has poor ability in posing excellent dielectrical properties and heat resistance to the transmission line which is not adequate to transfer electric in an electrical system while alumina ceramic contains high dielectric constant. Hence, a combination of alumina nanoparticles with epoxidized natural rubber (ENR) which is a polar polymer to form the alumina nanoparticles reinforced epoxidized natural rubber composites (ENRAN) is hypothesized to increase the dielectric properties. This limitation of the insulation for rubber materials lead researchers to determine any possible outcome for advanced materials to fulfil the aspect of good electrical insulation thus reducing costs and in the same time prolonging the service life.

ENR rubber has possessed good strength and elastic behavior as its natural rubber host. However, when utilizing rubber in electrical insulation for a certain period of time, the chains structural ability will be affected and rubber would age. The rubber material will experience embrittlement, begin to stiffer and decrease in damping capability (BoQiao, 2015). Hence, combination of highly dielectric constant alumina nanoparticles and polar epoxidized natural rubber can bring a new type of polymer composite which has recently drawn considerable attention because nanocomposites or nanostructured polymers have the potential of improving the electrical, mechanical, and thermal properties as compared to other types of polymers. Hence, a study on the effect of filler loading could identify the extent for the incorporation of alumina into the ENR matrix. It will alter the dielectrical functional properties of the matrix and the suggested ENRAN composite could serve the purpose for an electrical insulation.

1.3 Objectives

The objectives are as follows:

(a) To suggest methodology for the preparation of alumina nanoparticles reinforced epoxidized natural rubber composites (ENRAN) via melt compounding method for the effect of filler loading

(b) To hypothesize the dielectrical properties of ENRAN via critical review for the effect of filler loading

(c) To correlate the hypothesized dielectrical properties of ENRAN with its morphological, compositional, and structural properties review data

1.4 Scopes of the Research

The scopes of research are as follows:

(a) Characterization of alumina nanoparticles reinforced epoxidized natural rubber composites (ENRAN) through filler loading

(b) Methodology to plan for the preparation of ENR matrix reinforced with 1wt%, 2wt%, 3wt%, 4wt% and 5wt% alumina nanoparticles (ENRAN composites) through melt compounding according to ASTM D-3192

(c) Dielectrical properties of ENRAN was hypothesized via critical review for the effect of filler loading (1wt%, 2wt%, 3wt%, 4wt% and 5wt%)

(d) Study the potential of using alumina nanoparticles as filler in epoxidized natural rubber composites for the purpose of better dielectrical properties for electrical insulation. The dispersion of alumina nanoparticles may improve the properties of ENR.

(e) Hypothesized dielectrical properties of were supported through existing failure morphology observation by SEM, FTIR spectroscopy analysis and structural characteristics by XRD analysis via critical review.

(f) Alumina nanoparticle reinforced epoxidized natural rubber composite will be tested by electrical resistivity via critical review.

(g) The alumina nanoparticles reinforced epoxidized natural rubber composites are analysed using scanning electron microscopy (SEM), fourier transform infrared (FTIR), structural analysis using x-ray diffraction (XRD) analysis via critical review.

1.5 Rational of Research

The rational of research as follows:

a) Alumina nanoparticles reinforced epoxidized natural rubber composites might achieve their improved properties such as improvement in dielectrical properties.

b) Generate scientific information and deep understanding on the role of alumina as filler for epoxidized natural rubber composites. Gather the useful information on technical data of epoxidized natural rubber composites performance after running the experiment approach.

c) To gain new knowledge behind the experimental research by improve the dielectrical properties of ENR composites quality and bring the engineering field to higher level especially for electrical transmission lines insulation industry. Develop a new idea by manipulating the parameters of different level of filler loading for insulation cable to conclude a good dielectrical properties.

1.6 Research Methodology

The suggested methodology are as followings:

a) Stage 1: Characterization of alumina reinforced epoxidized natural rubber composites
b) Stage 2: Preparation of sample alumina nanoparticles reinforced epoxidized natural rubber composites via melt compounding
c) Stage 3: Determination of dielectrical properties of alumina nanoparticles reinforced epoxidized natural rubber composites
d) Stage 4: Data analysis using SEM, FTIR spectroscopy and XRD.

1.7 Thesis Organization

The organization of this thesis is as following. Chapter 1 is beginning with research background, problem statement, objectives, and scope of the research, rational of research are delineated in order to better define particular aspects of filler loading and strength performance addressed in this thesis. Chapters 2 literature review comprises previous study or research about the alumina nanoparticles reinforced epoxidized natural rubber composite and the close field regarding this topic. Chapter 3 describes the suggested methodology describes all the preparation of samples, characterization of samples and testing of dielectrical properties and also data analysis needed to carry out the experimental research. Chapter 4 covers the analysis of the information collected after journals review, postulation of properties and further evaluation on structure to properties relation. In Chapter 5, conclusion and recommendation about this research are listed.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter focuses on theory and research from journal and articles. All the references showed in this chapter have been defined and approved years ago. The important and relevant information from previous studies are extracted and filtered as guideline and reference so that the content achieved the objective of this chapter. Basically, all the collected information is categorized into five categories. Firstly, it will describe the polymeric insulator and it consists of definition and the functions. Secondly describes the natural rubber composites. It is followed by example of natural rubber nanocomposites that contains the type of fiber used and alumina nanoparticles. After that is the processing of natural rubber nanocomposites and how it is produced. Lastly is the electrical and dielectrical properties of this composites.

2.1 Polymeric Insulator

An electrical insulator is a material whose internal electric charges do not flow freely; very little electric current will flow through it under the influence of an electric field. Polymeric insulators materials can be made from elastomer such as Silicon rubber, thermoset like epoxy-resin and thermoplastic like polyethylene or polypropylene in nature. Polymeric insulator has entered the market and used in many utilities. The utilities involved are like transmission line insulators, indoor or semi-enclosed power systems. The purpose of using polymeric insulator is because of its good performance in contaminated environment, light weight, easy handling, maintenance free, and considerably low cost etc (Sharma, 2015).

Since early this century, high voltage insulators have developed rapidly for outdoor transmission insulator. But there were also weaknesses like easily fractured and increase in weight. This is because the materials are made of glass and porcelain. However, these materials have impressive insulating properties and good weather resistance (Shuhaimy, 2014). Polymeric insulator has been used in 1960s and the composite insulator has been developed and widely used in 1980s (Kobayashi et al., 2000). The insulator used is like silicon rubber (SiR) which has good weather resistance and has strong hydrophobic properties. These features will minimize the leakage of current which is good properties for an insulator (Sundar et al., 1992).

Polymers such as polyethylene (PE), ethylene-propylene rubber (EPR) or ethylene propylene-diene-monomer rubber (EPDM) are possible to use for high and very high voltage cables with addition of low level of partial discharges, easy maintenance and exceptional durability could be obtained.

2.1.1 Elastomer Insulator

Elastomers are amorphous polymers which consist of linear polymer chains that are lightly crosslinked (Gent, 2001). Elastomer has good elastic recovery due to its chains structure. When after stretching to many times, under ideal circumstances it will return to its original shape and length. Elastomers has many applications, e.g. tyres, vibration and shock isolation and damping. The global usage of vulcanized elastomer is around 17.2 million tons/year. Approximate 40% of that is natural rubber.

Every general elastomer, like natural rubber (NR) exhibit very low electrical conductivity and therefore suitable for electrical insulator. The level of electrical conductivity for elastomers can be altered by addition of insulating fillers or conducting substances, especially carbon blacks and anti-static plasticizers (Hanhi et al., 2007). Another type of unsaturated rubbers like Styrene butadiene rubber (SBR) is also elastomer which was used in low voltage applications as a jacket and insulation material. It then was replaced by ethylene-propylene elastomers (Vaidya, 1998).

2.1.2 Thermoplastic Insulator

Thermoplastic is a plastic polymer material that can be malleable or moldable at a certain high temperature and solidify upon cooling. In high-voltage industry, continuous development always occurs where power grid systems need to be reliable, cost-effective and environmentally friendly (Gubanski, 2016).

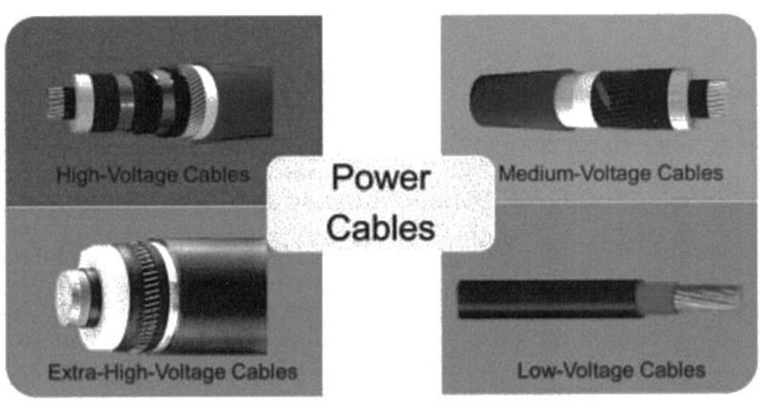

Figure 2.1: Different types of power cables used for electricity transmission and distribution (Gubanski, 2016)

PE was the most suitable insulation material in the late 1960s and early 1970s however it cannot operate at maximum temperature of 70°C. Due to the new solution which has been founded by crosslinking of PE (yielding XLPE) can improved the thermal resistance and ageing stability (Barber et al., 2013).