UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ELECTRICAL PROPERTIES OF NATURAL RUBBER REINFORCED TIN DIOXIDE NANOCOMPOSITES WITH DIFFERENT FILLER 98 LOADING FOR ELECTRICAL INSULATORS

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Muhammad Luqman Bin Azman

A thesis submitted
in fulfillment of the requirements for the degree of
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2022

DECLARATION

I declare that this Choose an item. entitled "Electrical Properties Of Natural Rubber Reinforced Tin Dioxide Nanocomposites With Different Filler 98 Loading For Electrical Insulators" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology with Honours.

Signature	:	
Supervisor Name	:	HAIRUL EFFENDY BIN AB MAULOD
Date	:	25/06/2022

DEDICATION

This report is dedicated to my beloved familyin perticular, for their endless love, support and encouragement. To my supervisor Ts. Hairul Effendy Bin Ab Maolud who has guided me along the way to finish this project. Thank you for all your support, and give me strength untill this project is finished.

ABSTRACT

The main objective of this study is on the electrical properties of Natural Rubber (NR) reinforced Tin Dioxide (SnO_2). Tin Dioxide (SnO_2) is an inorganic-based filler that is used when the melt compounding process is utilised for Natural Rubber (NR). Tin Dioxide was selected for use as a conducting agent for the electrical properties of natural rubber due to the properties it has that enable it to do so. The primary purpose of this is to determine the composition of Tin Dioxide that is most effective when combined with Natural Rubber. A few tests will be performed on the compound to identify its properties, including insulation resistance or conductance determination, volume resistance or conductance determination, surface resistance or conductance determination, and liquid insulation resistance. Because insulation resistance or conductance is a combination of volume and surface resistance or conductance, its measured value is most useful when the test specimen and electrodes are the same shape as required in actual use. Surface resistance or conductance changes quickly with humidity, whereas volume resistance or conductance changes gradually, though the final change may be greater. Under optical microscope, the structure of the compound will be analysed for its morphology. The combination of Natural Rubber compound and Tin Dioxide based on 100 phr of the natural rubber (NR) SMR-20 and different proportions of tin dioxide (SnO_2) at 0 per hundred rubber (phr), 0.5 phr, 1 phr,3 phr, and 7 phr was found to be the best compounding formulation for the fabricated compound. All of those rubber-based formulations called for the same amount of curing additives, which were as follows: 2.5 phr of sulphur (s), 5 phr of zinc oxide (Zn0), 2 phr of stearic acid, 1 phr of tetraethyl thiuram disulphate (TMTD), and 1 phr of 6PPD.

ABSTRAK

Objektif utama kajian ini adalah mengenai sifat elektrikal Getah Asli (NR) bertetulang Timah Dioksida (SnO_2). Timah Dioksida (SnO_2) ialah pengisi berasaskan bukan organik yang digunakan apabila proses sebatian cair digunakan untuk Getah Asli (NR). Timah Dioksida telah dipilih untuk digunakan sebagai agen konduktor elektrikal getah asli kerana sifat yang ada padanya yang membolehkannya berbuat demikian. Tujuan utama ini adalah untuk menentukan komposisi Timah Dioksida yang paling berkesan apabila digabungkan dengan Getah Asli. Beberapa ujian akan dilakukan ke atas sebatian untuk mengenal pasti sifatnya, termasuk rintangan penebat atau penentuan konduktans, rintangan isipadu atau penentuan konduktans, rintangan permukaan atau penentuan konduktans, dan rintangan penebat cecair. Oleh kerana rintangan penebat atau konduktans ialah gabungan isipadu dan rintangan permukaan atau konduktans, nilai yang diukur adalah paling berguna apabila spesimen ujian dan elektrod adalah bentuk yang sama seperti yang diperlukan dalam penggunaan sebenar. Rintangan permukaan atau konduktans berubah dengan cepat dengan kelembapan, manakala rintangan volum atau konduktans berubah secara beransur-ansur, walaupun perubahan akhir mungkin lebih besar. Di bawah mikroskop optik, struktur sebatian akan dianalisis untuk morfologinya. Gabungan sebatian Getah Asli dan Timah Dioksida berasaskan 100 phr Getah Asli (NR) SMR-20 dan perkadaran timah dioksida (SnO_2) berbeza pada 0 setiap peratus getah (phr), 0.5 phr, 1 phr, 3 phr, dan 7 phr didapati sebagai rumusan sebatian terbaik untuk sebatian yang direka. Kesemua formulasi berasaskan getah tersebut memerlukan jumlah aditif pengawetan yang sama, iaitu seperti berikut: 2.5 phr sulfur (s), 5 phr zink oksida (Zn0), 2 phr asid stearik, 1 phr tetraethyl thiuram disulphate (TMTD), dan 1 phr daripada 6PPD.

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LIST OF SYMBOLS AND ABBREVIATIONS

UTeM	-	Universiti Teknikal Malaysia Melaka
NR	-	Natural Rubber
SnO_2	-	Tin Dioxide
kg	-	Kilo gram
phr	-	Per Hundred Ratio
KEPCO	-	Korea Electric Power Corporation
SIR	-	Silicone Rubber
KERI	-	Korea Electrotechnology Research Institute
FET	-	Field-Effect Transistor
LED	-	Light-Emitting Diode
HVDC	-	High Voltage Direct Current
UV	-	Ultra Violet
TCO	-	Transparent Conducting Oxide
goop	-	sloppy or sticky semi-fluid matter
TMTD	-	Tetraethyl Thiuram Disulphate
rpm	-	revolutions per minute
°C	-	degrees Celsius
kgf/cm^3	-	kilogrammes force per cubic centimetre of space
ASTM	-	American Society for Testing and Materials
FTK	-	Fakulti Teknologi Kejuruteraan
TEM	-	Transmission Electron Microscope
WAXD	-	Wide-angle X-ray diffraction
SAXS	-	Small angle X-ray scattering
XRD	-	X-ray diffraction
°	-	Degree
MΩ	-	Mega Ohm
SEM	-	Scanning Electron Microscope
XRD	-	X-ray Diffraction
FTIR	-	Fourier Transform Infrared

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CHAPTER 1

INTRODUCTION

In this chapter, it will clarify about natural rubber's origins, its characteristics, and its behaviour. There is a foundation for this study in previous research, books, journals, and other on-line and off-line sources. As a result, the data and issues are gathered so that this study can be improved upon.

1.1 Background

There are trace quantities of proteins, carbohydrates, lipids and inorganic salts in the Hevea brasiliensis tree's milky sap or latex known as natural rubber (NR) , or cis-1,4-poly(isoprene). Acid coagulation separates it, washes it, and cuts it into sheets. The vulcanization process enhances rubber's flexibility and strength by infusing sulphur, accelerators, and other compounding materials. This results in a three-dimensional network. Vulcanized natural rubber (NR) has a high tensile strength and elongation at break due to the strain-induced crystallisation phenomena. This behaviour, described as a "self-reinforcing effect," is often linked to the uniform microstructure. Most applications mix NR with fillers to increase mechanical responsiveness, electrical and thermal conductivities, and barrier characteristics.

Stannic oxide is the chemical formula for SnO_2, or tin dioxide. Point defects, oxygen vacancies, and donor tin atoms in the interstices all contribute to the material's electrical conductivity. In terms of melting point, Tin Dioxide has a temperature of

2966 degrees Celsius. Tantalum Dioxide looks to be an inorganic substance with no discernible coloration. It weighs 6.95 g/cm2. When Tin Dioxide is pure, it is an n-type semiconductor. In resistors, NESA glass, and other electronic components, Tin Dioxide's unique qualities make it an excellent choice. Tin Dioxide has lately gained attention as a possible gas sensor material by researchers.

When Tin Dioxide is included into the NR, its electrical insulating characteristics will be tested. Material that blocks the flow of electric current is an electrical insulator. It is difficult to transport the electrons in an insulator because they are closely linked together. Wire insulation has evolved from simple rubber to more sophisticated polymers throughout the years. Natural rubber is supplemented with various materials in insulation engineering in order to get the desired results.

1.2 Problem Statement

A wide range of sectors, such as automotive and electrical, increasingly rely on natural rubber as a key component in their products. In recent years, rubber-based goods have seen an uptick in popularity. Rubber is frequently employed as an electrical insulator. Rubber's insulating and mechanical qualities make it an ideal material for a wide range of applications. Currently, natural rubber costs around RM11.51 per kilogramme, according to the Malaysian Rubber Board. As a result, using only natural rubber in rubber goods is not an option. Many components, including natural rubber, are required for this type of product to meet or exceed consumer expectations. In addition, the qualities of natural rubber can be enhanced by mixing it with other materials. Insulation engineering can benefit from using a material capable of conducting electricity in the insulator. Insulation alone isn't helpful for current flow since it results in a significant amount of current being wasted.

1.3 Research Objective

a) To fabricate samples of tin dioxide reinforced natural rubber.

b) To investigate electrical properties of tin dioxide reinforced natural rubber.

1.4 Scope of Research

Natural rubber reinforced tin dioxide is being studied for its electrical properties by melting the mixing material with a Haake internal mixer and then compressing it in a hot press before conducting electrical tests such as determining the insulation resistance or conductance and electrical insulation analysis by microwave vector network analyzer.

CHAPTER 2

LITERATURE REVIEW

2.1 Natural Rubber

Only Hevea rubber (NR), often known as natural rubber, is commercially available from nature. Figure 2.1 shows H. Brasiliensis, the top rubber-producing plant species now, which is distinguished by its high production and good rubber physical qualities. The tall softwood tree H. Brasiliensis is endemic to Brazil. However, NR is mostly produced in South-East Asia. Brazilian Hevea seeds were first planted in Sri Lanka, Malaysia and Singapore around 1870. They quickly took root and flourished in these nations, thanks to a unique combination of climatic and geographical conditions. (Ogawa et al., n.d.).

Figure 2.1: Rubber tree (H. Brasiliensis)

As a compounding technique, rubber compounding involves determining the right amount of various compounding materials and how they should be combined in order to create a rubber formulation that can be processed, fits the customer's prior product specifications, and is fairly priced.

Table 2.1 Generalized rubber Compound

Ingredient	***phr***
Crude rubber	100
Filler	50
Softener	5
Antioxidant	1
Stearic acid	1
Zinc oxide	5
Accelerator	1
Sulphur	2
Total	*165*

2.2 Introduction

A literature review is a summary of all the information gathered from many sources, including a book, the internet, journals, and articles. Natural rubber and tin dioxide properties, processes, and applications are discussed here. There is an in-depth study of each issue in each of the subchapters of this literature review.

2.2.1 Natural Rubber Properties

Molecular chains comprising one or more monomers, such as those found in rubber, form polymers, and polymers are the most common type of large molecular weight substance. Because the polymeric chains may be stretched and bounce back when tension is released, vulcanization (or curing) results in elasticity. Benzene, toluene, gasoline, and lubricants are just a few of the hydrocarbons in which rubber is soluble.

Rubber is impervious to acids, alkalis, and other harsh chemicals. Rubber may be utilised as an adhesive, coating composition, fibmolding compound, and electrical insulator because of its elasticity, toughness, impermeability, adhesiveness, and electrical resistance. In general, synthetic rubber beats natural rubber in the following areas: superior ageing and weathering, stronger resistance to oil, solvents, oxygen, ozone, and certain chemicals, and greater durability throughout a broader temperature range. To reduce heat accumulation, natural rubber is better than synthetic rubber when bending and when heated(Bormashenko et al., 2009).

Rubber has a wide range of chemical characteristics that make it different from other materials. As a result, rubber is commonly referred to as hyperelastic. As time passes, the rubber strain becomes more durable. The double bond in each repeating unit of natural rubber makes it vulnerable to vulcanization and ozone cracking. Stretching them out creates a linear pattern which can be specified by the number. Molecules are linked in some cases. Because the rubber band breaks when it's stretched too far.

Natural rubber's essential physical qualities include hardness, tensile strength, tensile modulus, elongation, tear resistance, abrasion resistance, compression set, resilience, and specific gravity. Rubber, unlike most other materials, does not expand when heated. Because of the heat, the molecules become entangled and this happens. When heated, knotted molecules in rubber bands get even more twisted. The rubber band's natural form is restored when the heat source is switched off.

2.2.2 Natural Rubber as Electrical Insulator

Insulation made from natural rubber has been used in electrical wiring for decades. In addition to Charles Goodyear's vulcanization agents, early rubber producers realised that different compounding materials, such as mineral fillers and process aids, might improve the properties of the rubber. During a reaction comparable to and probably inspired by Goodyear's vulcanization process, rubber for electrical insulation was regularly blended with a substance created by heating certain vegetable oils with sulphur. Old rubber compounds are sometimes referred to as "oil-based rubber," however the name "factice" or "pitch" really refers to these materials. Before the 1930s, natural rubber-based electrical insulation was the only polymeric material that could be utilised as a dielectric for wire and cable.

Dielectric losses of dry rubber are minimal, with a widened Debye type of characteristic overlaid on a continuous background loss at low temperatures and an ionic or conduction-loss type of characteristic at room temperature and above. When exposed to a damp environment, the losses are slightly higher. Dry crude rubber has dielectric losses that are remarkably similar to purified rubber. It is, nevertheless, possible to enhance the power factor greatly due to the presence of contaminants in crude raw rubber.

A growing number of people throughout the world are using composite insulators because of their many advantages over conventional insulators. Installation is simple, the product is lightweight, and it is resistant to vandalism, making it an excellent alternative to glass and porcelain insulators. To far, composite insulators have only been used by KEPCO (Korea Electric Power Corporation). Even in contaminated environments, the silicone rubber (SIR) surface of composite insulators maintains their hydrophobic qualities, making them very long-lasting. Korean Electrotechnology Research Institute (KERI) produced a 22.9kV SIR composite insulator and got satisfactory results using KEPCO-specified test codes.(Junian et al., 2019)

2.2.3 Structure and Characteristics of Natural Rubber

An unsaturated hydrocarbon linear polymer based on Isoprene (natural rubber) (2-methyl butadiene). A Natural Rubber polymer chain has anywhere from 11,000 to 20,000 isoprene units.

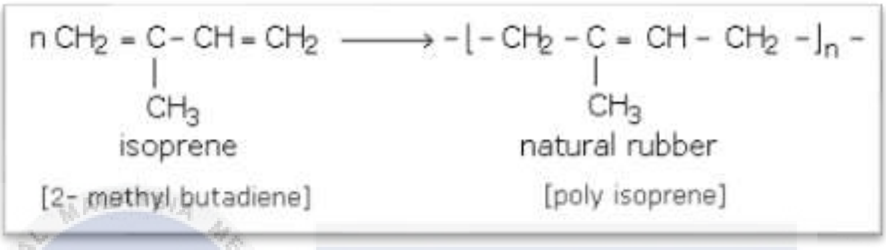

Figure 2.2 Polymer chain of Natural Rubber

Elastomers' core features of elasticity, flexibility, and durability make them valuable in a range of industrial fields. Additionally, each rubber has its own set of unique qualities. Even though rubber goods' manufacturing and final attributes are mainly dependent on the underlying elastomer, compounding factors can have a considerable impact on the properties.

Synthetic rubber is a man-made substitute for natural rubber. A first-group substance generated from the latex of different plants, natural rubber (NR), also known as cis-1,4 polyisoprenes, is widely used in a variety of industries. Anyhow, the most prevalent commercial source of NR is the Hevea brasiliensis tree. Natural Specific gravity ranges from 0.96 to 0.98, while the pH ranges from 6 to 7. Water is used to distribute the dispersed phase, which is mostly made up of rubber. Latex also contains small quantities of proteins, resins containing fats, fatty acids, other lipids,