A STUDY OF EPOXY NANOCOMPOSITES INSULATING MATERIALS AND ITS EFFECTS ON ELECTRICAL TREE PROPAGATION

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A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical - Power)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JANUARY 2013

Special dedicated to

My beloved parents (Ummi & Walid)

Haji Saad Bin Arifin

&

Hajjah Siti Esah Binti Yusoff

My Siblings

Muhammad Redzuan, Muhamad Adzahan, Mohd Faiez Sofwan, Intan Fatim Munirah, Luqman Farhan, Syafiq Aiman

For your unwavering love, sacrifice, patience, encouragement and inspiration

ACKNOWLEDGEMENT

ALHAMDULILLAH, with the helped from Allah (S.W.T) the Almighty, this project was completed successfully. All praises, my sincere and deepest thankful be to Allah (S.W.T), and may His peace and blessings be upon the Prophet Muhammad S.A.W (peace be upon him).

First and foremost, in particular, I wish to express my special appreciation to my master's project supervisor, Dr. Yanuar Zulardiansyah Arief for his encouragement, guidance, friendly advice and motivation I received from him especially in my master programme and as my lecturer. I am very grateful to have him as my supervisor in helping me for the completion of this project and thesis. May Allah (S.W.T.) reward and bless him greatly.

Special thanks are dedicated to all who have helped me in this project from any kind of angle: Mr. Mohd Hafizi Ahmad, Mr. Aulia, Mr. Abdul Azim, Miss Wan Akmal Izzati, all lecturers, supporting staffs from IVAT, faculty managements and also my colleagues who always act as my backbone when I needed them most during my trouble.

Last but not least, I would like to express my sincere appreciation to my beloved family and siblings for their financial support and encouragement that made me strong and motivated enough to accomplish my master degree. Finally, thank you for all the people that contribute direct or indirectly to finish this thesis. May Allah bless and return your good deeds.

ABSTRACT

Polymeric insulating materials have attracted wide interest especially in high voltage equipments due to its potential properties enhancement. One of the main phenomena of partial discharges occurred in polymeric insulating material is electrical treeing phenomena. This kind of phenomena will cause excessive electric field stress at points where void and defects located. This thesis presents the thorough analysis of electrical treeing phenomena in epoxy nanocomposites. Epoxy resin nanocomposites containing 1 wt% and 3 wt%, of nanofillers sized organically modified montmorillonite (OMMT) nanoclay and silicon dioxide (silica) nanofillers were prepared and investigated, with unfilled epoxy resin served as reference material. The nanocomposites were prepared by using leaf-like specimen's method and online monitoring method was used to test the samples. Electrical insulating properties, mainly the electrical tree resistance were investigated based on to IEC 1072:1991, "Methods of Test for Evaluating the Resistance of Insulation Materials against the Initiation of Electrical Trees". There are three main parameters were collected during experiment was conducted which are tree inception voltage (TIV), tree breakdown voltage (TBV) and tree propagation time (TPT). Field emission scanning electron microscope (FESEM) was performed to determine the dispersion state of nanoclay epoxy resin nanocomposites. Based on the results, it was found that the existence of OMMT and silica nanofillers in polymer matrix could exhibit electrical tree growth. Furthermore, the presence of OMMT nanoclay in epoxy resin make tree growth faster compared the presence of silica nanofillers in epoxy resin.

ABSTRAK

Polimer bahan penebat telah menarik minat yang luas terutamanya dalam peralatan voltan tinggi kerana potensinya untuk menambahbaik ciri-cirinya. Salah satu fenomena utama dalam pelepasan separa penebat pada bahan penebat polimer adalah fenomena elektrik treeing. Fenomena ini akan menyebabkan tekanan medan elektrik yang berlebihan di tempat-tempat di mana wujudnya ruang kecil dan kecacatan pada bahan tersebut. Tesis ini membentangkan analisis yang menyeluruh mengenai fenomena elektrik treeing pada epoksi nanokomposit. Epoksi nanokomposit yang mengandungi 1% dan 3% tanah liat bersaiz nano (nanoclay) dan silikon dioksida (silica) bersaiz nano telah disediakan dan disiasat, di mana epoksi tanpa nanoclay dijadikan sebagai bahan rujukan. Nanokomposit telah disediakan dengan menggunakan kaedah *leaf-like* spesimen dan kaedah pemantauan terus untuk menguji sampel. Sifat penebat elektrik, terutamanya rintangan elektrik treeing telah disiasat berdasarkan IEC 1072:1991, "Kaedah Ujian untuk Menilai Rintangan Bahan Penebat terhadap Permulaan Elektrik Treeing". Terdapat tiga parameter utama dikumpul semasa eksperimen dijalankan iaitu voltan penubuhan treeing (TIV), voltan pecahan treeing(TBV) dan masa perambatan treeing (TPT). *Field emission scanning electron microscope* (FESEM) telah dijalankan untuk mengkaji keadaan campuran nanoclay di dalam epoksi nanokomposit. Berdasarkan keputusan yang diperolehi melalui eksperimen dan analisa yang dibuat, telah didapati bahawa kewujudan nanoclay OMMT dan nano silica di dalam matriks polimer boleh menyekat pertumbuhan elektrik treeing. Tambahan pula, kehadiran nanoclay OMMT dalam epoksi membuatkan pertumbuhan elektrik treeing lebih cepat berbanding kehadiran nano silica di dalam epoksi nanokomposit.

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LIST OF ABBREVIATIONS AND SYMBOLS

ER	-	Epoxy Resin
OMMT	-	organo-Montmorillonite
SiO_2	-	Silicon Dioxide/ Silica
TIV	-	Tree Inception Voltage
TBV	-	Tree Breakdown Voltage
TPT	-	Tree Propagation Time
DC	-	Direct Current
AC	-	Alternating Current
FESEM	-	Field Emission Scanning Electron Microscopy
SEM	-	Scanning Electron Microscopy
TEM	-	Transmission Electron Microscopy
NaOH	-	Sodium Hydroxide
wt%	-	weight percentage
CCD	-	Charge Coupled Device
IEC	-	International Electrotechnical Commission
kVA	-	kilo-Volt Ampere
kA	-	kilo-Ampere
kV	-	kilo-Volt
kg	-	kilogram
L	-	Litre
Mpa.s	-	Megapascal-second
lb/cu.ft	-	pounds per cubic foot
mm	-	mili-meter
µm	-	micro-meter
°C	-	degree celcius
±	-	tolerance plus minus

mmHg	-	millimeters of mercury
rpm	-	rounds per minute
Ω	-	ohm
W	-	watt

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Cables have been used in power system networks since the early day of the existence electrical power industry. Electrical power industry will transmit and distribute electricity either by overhead line cables or underground cables. Nowadays, in urban areas, it is become an essential to transmit the electricity by using high voltage underground cable due to safety, reliability, low maintenance cost, better general appearance and so on. As a result, the development of the insulating and manufacturing techniques has improved over the years.

The cable insulation usually consists of impregnated paper, synthetic polymers and compressed gases. Polymer insulated cables was first introduced in the 1960s [1]. At present, polymeric cable are widely used as insulating material in various industries. However, for long periods of time, polymeric cables may be exposed to the aging and degradation of electrical insulation system. This can happen when exposed to continuous high voltage excitation for a long time. Such phenomena cannot be tolerated and efficient steps should be taken to prevent any damage.

1.2 Problem Statement

Polymeric insulators are preferred in many applications as they are easy to fabricate in complicated shapes and also area tough, lightweight, and posses' excellent dielectric properties. However, their service on high voltage networks is coupled with the processes of degradation due to erosion and defects. Early stage detection of ageing and degradation is very important parameter to measure the performance of insulator in various polymeric insulating materials.

Nowadays, it is found that, a variety of polymeric insulating material has been developed. This includes three classes of materials are in significant use: epoxy resin, hydrocarbon elastomers and silicone elastomers. Additionally, the usage of nanofillers mix with base resin attracted wide interest among researchers. It is proved that most of polymer nanocomposites are very good insulator to retard electrical treeing activity. However, in term of electrical properties, the partial discharges characteristics of epoxy resin mix with OMMT nanoclay as insulating material in not clear reported yet. Therefore, the investigation of electrical tree propagation in ER/OMMT polymer nanocomposites is really necessary and much remains to be explored.

1.3 Objectives

The objectives of this project have been classified as follows:

i. To develop the polymer nanocomposite of epoxy resin (ER) with organo-Montmorrilonite (OMMT) nanoclay for treeing phenomena analysis.

ii. To develop the polymer nanocomposite of epoxy resin (ER) with silicon dioxide (SiO_2) nanofiller for treeing phenomena analysis.

iii. To investigate the effects of nanofillers in polymer nanocomposites ER-OMMT and ER- SiO_2 based on the inception and propagation of electrical treeing under HVAC stress.

iv. To make comparative analysis between ER-OMMT and ER- SiO_2 in term of electrical analysis and morphological analysis.

1.4 Scope of Project

Before doing any analysis and experiment setup, literature review is needed to provide a good theory and understanding. The input knowledge can be obtained in various resources such as books, journals, internet, and papers. This project is primarily focused on developing the new polymer nanocomposites ER-OMMT and make comparison in term of electrical performance with existing ER- SiO_2.

After all the leaf like specimens sample was developed, the experiment will conducted using online monitoring technique and the electrical data will be collected. Electrical treeing parameter such as tree inception voltage, tree breakdown voltage and tree propagation time will be analyzed and comparative results will be made between nanocomposites.

In addition, morphological analysis will also be taken to review the fractured surface structure of material. Results obtained will be discussed in detail and finally, the involvement of the conference paper is taken into account.

1.5 Research Flow Chart

The research flow chart can be divided by two parts. First is research flow chart part 1 which is a framework for first semester while research flow chart part 2 is work plan for the second semester.

1.5.1 Research Flow Chart Part One

First of all, an in-depth literature study will be carried-out on electrical treeing initiation and growth, electrical insulation material degradation caused by discharges, nanofillers and microfillers that has been used by researchers globally. After that, solid insulating materials for test sample (ER-OMMT and ER-SiO_2) with different concentrations of nanofiller were made by using leaf-like specimen's method. Then, experimental setup was constructed using online monitoring method and base epoxy resin leaf like specimens were tested. Lastly, electrical treeing parameters will observe and all data collected will be discussed. The flow chart for part one can be shown in Figure 1.1

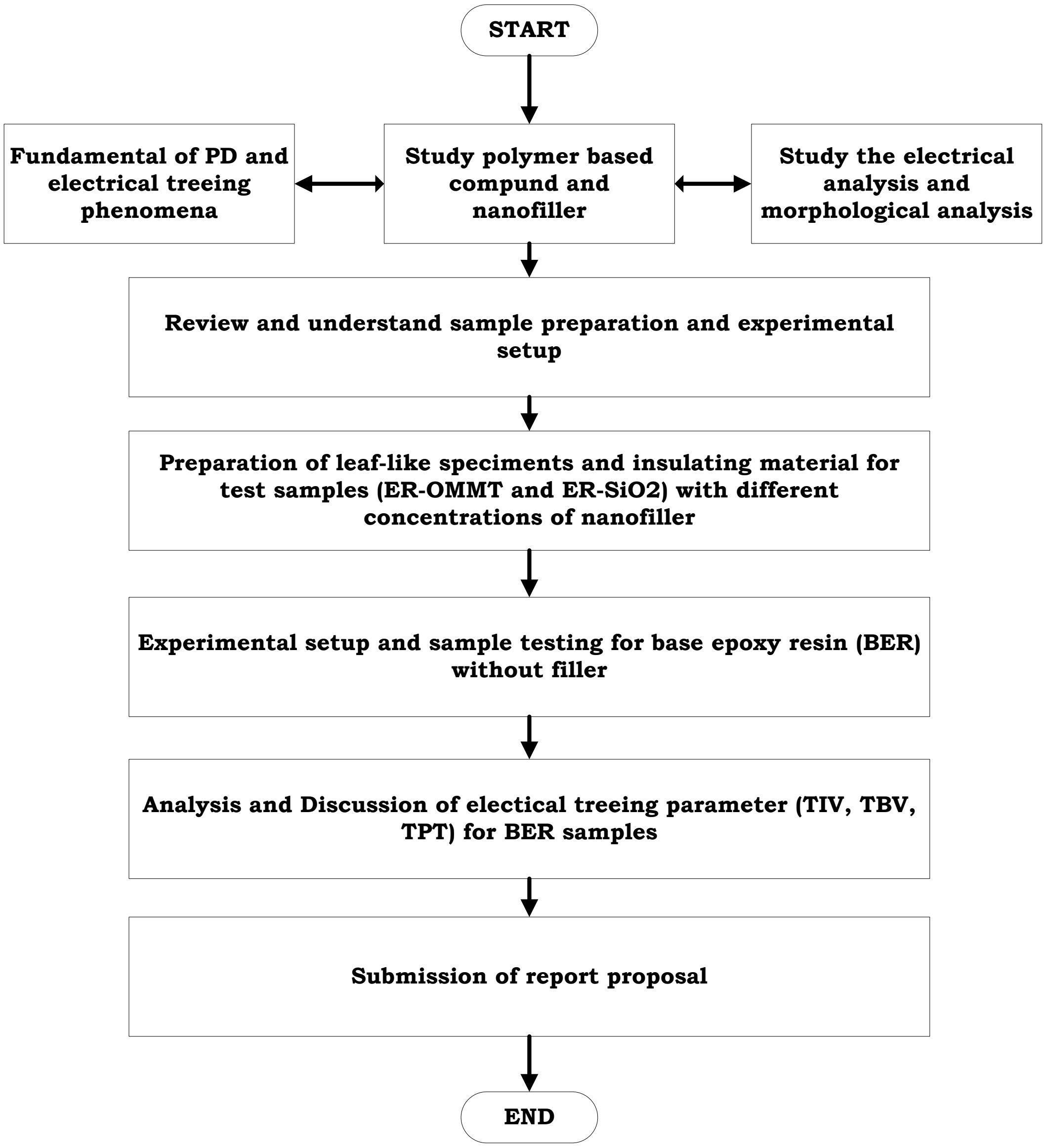

Figure 1.1: Flow Chart for part one.

1.5.2 Research Flow Chart Part Two

The work for part two will be started with experimental setup and testing for the remaining samples of filled ER/OMMT and filled ER/Silica. After that, electrical treeing parameters will observe and all data collected will be discussed. Then, the sample will observe using FESEM for dispersion state characterization purpose. With this characterization technique used, the condition of the prepare nanocomposites can be carefully observed, especially dispersion of nanoparticles in base polymer resin. After that, all data collected will be discussed and summarized. Lastly, preparation for paper or related publications will be made based on result obtained during experiment. Figure 1.2 shows the flow chart for part two.

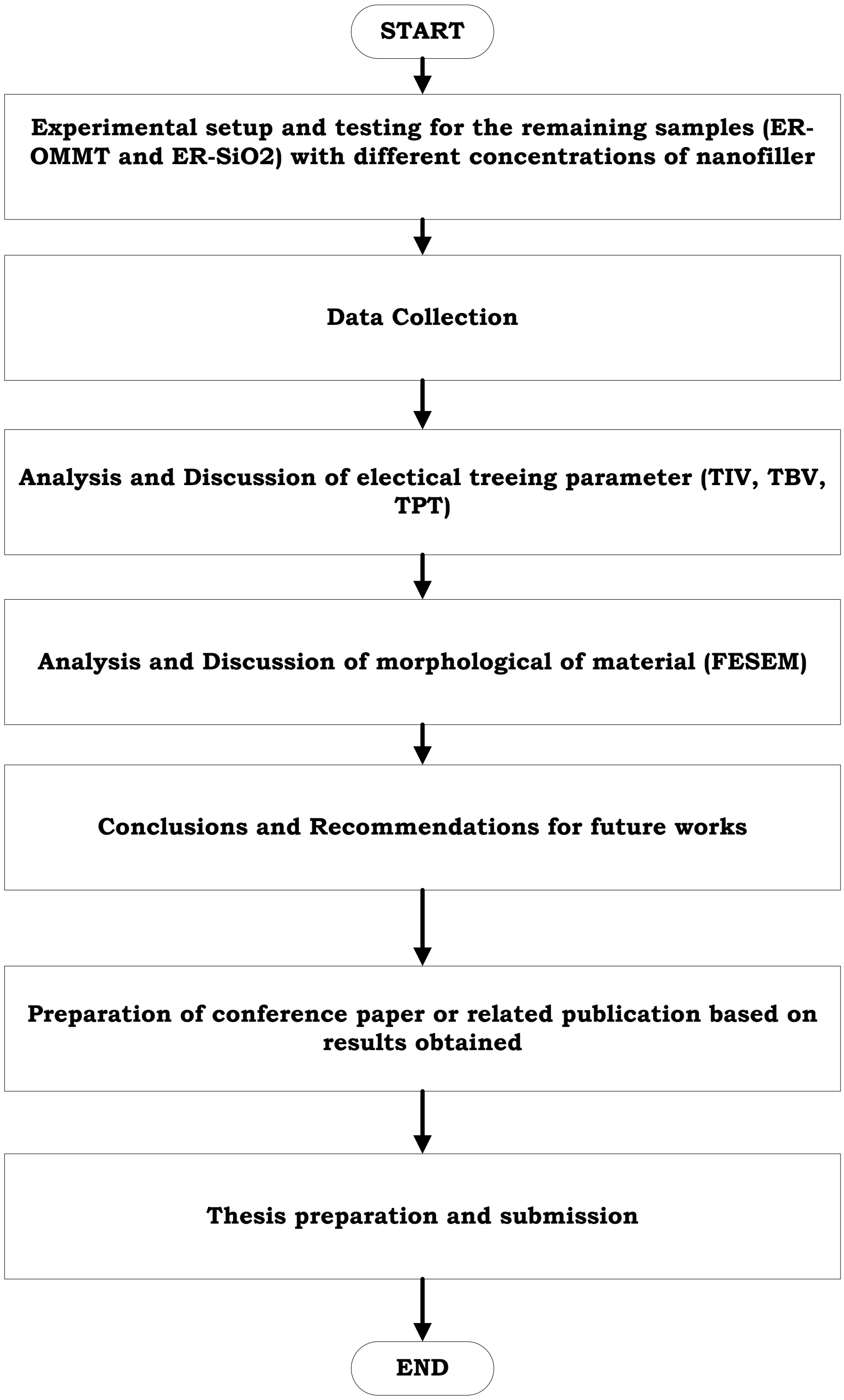

Figure 1.2: Flow Chart for part two.

1.6 Thesis Organization

Chapter 1: Introduction

This chapter describes the overview of this project. Besides that, problem statement of this project mainly described earlier at this chapter followed by objectives and the scope of project and lastly the research flow chart for both part 1 and part 2.

Chapter 2: Literature Review

Literature review contained all the basic information about partial discharge, and electrical treeing phenomena. Apart from that, there are also brief concept and context regarding research materials. This chapter also gives a brief introduction about morphological analysis in this project. Lastly, comparative studies were made based on previous research in polymer nanocomposites field.

Chapter 3: Methodology

This chapter describes about operation and methodology used in this project. The main content of this chapter is a details discussion on how the sample preparations were done and how the samples were characterized using FESEM. Lastly, this chapter also gives detail information on how the test and analysis were conducted in this project including the experimental setup and parameter used.

Chapter 4: Results and Discussions

The experimental results of electrical treeing test will be discussed thoroughly in this chapter. After that, the dispersion state obtained from under microscope observation and under FESEM equipments will be shown and discussed properly. Besides, discussion on data pattern will be displayed and comparisons between epoxy nanocomposites are then presented as well.

Chapter 5: Conclusions and Recommendations

Chapter 5 will concluded the work based on the result and discussion obtained from this project and suggested some recommendation for future work improvement and development related from this project.

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