# EFFECT OF GRAPHENE OXIDE (GO) IN IMPROVING THE PERFORMANCE OF HIGH VOLTAGE INSULATOR

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*Dedicate to my beloved family:*

*Isa bin Puteh (father)*

*Aminah binti Othman (mother)*

*Farahida binti Isa (sister)*

*You are all my inspiration and my strength*

*What I have been through, you were there all the time.*

*and*

*All my friends in MEP programme*

*for their support and encouragement*

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# ABSTRACT

Research work of polymer nanocomposites in high voltage insulator becomes interest nowadays. Polymer based and nanofillers are the core components in polymer nanocomposites. In previous works, by adding such a big amount of nanofiller it will enhance the electrical and mechanical properties of polymers. However as for today, a little percentage of nanofiller concentration could dramatically enhanced the properties of the polymeric material. Partial discharge in insulator material is one of a big issue in high voltage system that leads to electrical degradation and thermal losses. Recent research of graphene oxide (GO) nanofiller has brought to this project interest. Hence, this work focused into the development and simulation of PMMA (poly methyl methacrylate)/GO nanocomposites followed by PD test according to CIGRE METHOD II. The PMMA/GO and pure PMMA was synthesized by using radical polymerization and solvent dissolution method meanwhile simulation process was conducted using COMSOL Multiphysics software. From this work it could be noticed that the PMMA/GO has better performance.

# ABSTRAK

Kerja penyelidikan nanokomposit polimer dalam penebat voltan tinggi menjadi kepentingan pada masa kini. Polimer asas dan nanofillers adalah komponen teras dalam nanokomposit polimer. Dalam karya-karya sebelum ini didapati bahawa dengan menambah jumlah yang besar daripada nanofiller ia akan meningkatkan sifat-sifat elektrik dan mekanikal polimer. Walau bagaimanapun untuk hari ini, dengan peratusan yang sedikit bagi nanofiller mampu memberi impak yang mendadak dalam peningkatan sifat bahan polimer. Pelepasan separa dalam bahan penebat adalah salah satu isu besar dalam sistem voltan tinggi yang membawa kepada degradasi bahan elektrik dan kehilangan haba. Penemuan-penemuan terbaru daripada graphene oksida (GO) nanofiller telah membawa kepada tumpuan pengkajian untuk projek ini. Oleh itu, projek ini fokus kepada pembangunan PMMA (poli metil metakrilat) / GO nanokomposit diikuti dengan ujian PD mengikut CIGRE KAEDAH II. Fabrikasi PMMA / GO telah disintesis dengan menggunakan pempolimeran radikal dan diikuti dengan pembikinan PMMA melalui kaedah pelarutan pelarut sementara proses simulasi pula menggunakan perisian Comsol Multiphysics. Melalui penulisan ini, ia boleh dilihat bahawa PMMA / GO mempunyai prestasi yang lebih baik.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| GO | - | Graphene oxide |
| PMMA | - | Poly (methyl methacrylate), |
| LDPE | - | Low Density Polyethylene |
| PD | - | Partial Discharge |
| TEM | - | Transmission Electron Microscopy |
| SEM | - | Scanning Electron Microscopy |
| SWNT | - | Single wall carbon nanotube |
| LAH | - | Lithium aluminium hydride |
| CRG | - | Chemically reduces graphene |
| TRG | - | Thermally reduces graphene |
| TGA | - | Thermogravimetric analysis |
| VASA | - | Vacuum-assisted self-assembly |
| IVAT | - | Institute of High Voltage and High Current |
| MMA | - | Methyl methacrylate |
| TGA | - | Thermogravimetric analysis |
| Mw | - | Molecular weight |
| DI | - | Deionized |
| EMI | - | Electromagnetic interference |
| OLED | - | Organic light emitting diodes |
| PANI | - | Polyaniline |
| PVA | - | Polyvinyl alcohol |
| ATRP | - | Atom transfer radical polymerisation |
| EMI | - | Electromagnetic interference |
| XRD | - | X-ray powder diffraction |
| HPCD | - | Hyroxypropyl-β-cyclo-dextrin |
| PEI | - | Polyelectrolytes |

| | | |
|---|---|---|
| PS | - | Polystyrene |
| SIS | - | Solid insulated switchgear |
| AIBN | - | Azobisisobutyronitrile |
| FTIR | - | Fourier transform infrared spectroscopy |
| PU | - | Polyurethane |

# LIST OF SYMBOLS

| | | |
|---|---|---|
| V | - | Voltage |
| I | - | Current |
| kV | - | kilo volt |
| *k* | - | constant |
| α | - | coefficient |
| μ | - | micro |
| A | - | Ampere |
| m | - | mili |
| vs | - | versus |
| E | - | Electric field |
| ρ | - | Charge density |
| εo | - | Permittivity |

# LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Background study

The interest of polymer nanocomposites in academic and industry research have emerged and lead to wide discoveries of various fields such as biomedical, chemical, electrical and electronics. Polymer composite is the science of mixing the polymers such as polystyrene, polyethylene, polypropylene with other chemicals (nanofillers) to produce a polymer composite. Nanofillers are used to reinforce the base polymer which can increase the physical properties or play the role of certain processing characteristics. The reinforcing type nanofiller can improve tensile strength, modulus, tear strength and corrosion resistance of a compound.

Graphene oxide is formed from the oxidation of graphite where graphite is a three-dimensional carbon based material made up of millions of layers of graphene. Thus, graphene oxide is potential advanced nanofiller which can dramatically improve the dielectric properties of polymer based composite. The outstanding electrical and physical properties of graphene derivatives have made an enormous impact among researchers during past few years. Integration of individual graphene oxide and polymer nanocomposite thus will take advantage as one of the well-matched integration as to improve insulating performance of the insulator.

## 1.2 Problem Statement

The internal discharge or also called partial discharge will result in a gradual erosion and reduction in the thickness of the insulator leading to breakdown. The occurrence of PD may alter the dielectric properties of electrical insulation, making them less effective as insulators. In order to overcome this problem, the dielectric materials need to make an improvement so that it can survive and withstand at long period. Besides, as in past few years of research, adding such a big amount of nanofiller will results in properties improvement however for recent research activities, by adding a little percentage of concentration is dramatically proved that it enhanced the properties of the polymeric material as for this case the material referred to insulators. Hence, for this project it is believe that it will act the same way. Also, less attention is focus into the investigation of graphene oxide compared to graphene even though both actually behave unique properties, so does graphene oxide as insulating materials can hold into account as increasing insulator performance or vice versa.

## 1.3 Objectives

1. To simulate the PMMA poly (methyl methacrylate)/GO nanocomposite
2. To study the characteristics of PMMA/GO nanocomposite.
3. To investigate the electrical performance of pure PMMA at different number of concentration as well as PMMA/GO at difference percentage loading of nanofiller.

## 1.4 Scope of work

There are several scopes outlined in order to achieve the objectives. For experimental, it will cover the fabrication of samples (pure PMMA and PMMA/GO nanocomposite) and the partial discharge test in IVAT (Institute of High Voltage and High Current) by injecting high voltage up to 11 kV. Plus, the simulation work was carried out by using Comsol Multiphysics software. For simulation, it will cover the investigation to determine the effect of void in polymeric material. Note that the GO/ PMMA nanocomposite will be fabricate using synthesis method and the preparation of work experiment is set according to CIGRE method II. The composite characteristics from the experimental results can be analyzed by using digital microscope that available in IVAT

## 1.5 Hypothesis

Modifying the host polymer by adding GO nanofiller is importance to result a new electrical insulation material. As encountered, nanofiller will enhance and improve polymeric material properties such as mechanical, chemical, thermal stability, and dielectrical. Moreover it was found that partial discharge is still the major problems in nanocomposite electrical insulation. Outstanding characteristics that are high surface area and high strength of new material-graphene oxide nanofiller thus would enhance the dielectrical properties of host polymer.

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