ELECTRICAL PROPERTIES OF POLYETHYLENE AND POLYPROPYLENE BLEND NANOCOMPOSITES WITH FILLERS FOR HIGH VOLTAGE INSULATION

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

School of Electrical Engineering
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JANUARY 2020

DEDICATION

This project report is dedicated to my parents, who taught me that even the largest task can be accomplished if it is done one step at a time.

ACKNOWLEDGEMENT

In the Name of Allah, the Beneficent, the Merciful

Praise to Allah for give me a chance and strength to complete this thesis. I was blessed to the people who always guided and helped me to accomplish the research and presentation of this thesis. Firstly, I want to thank my supervisor, Dr. Noor Azlinda Ahmad for accepting me as her thesis student and guided me throughout this process. She really inspired me with her effort and patience to make sure I give my best to the thesis. She always supported me to improve the quality of my work.

I am also grateful to all the people whom associates with this project. All the technical staff of IVAT, UPMU and School of Chemical and Energy Engineering who assists and help me during in lab session. Thank you for assisting and guiding me to use all the equipment throughout my experiment for this thesis.

Finally, I am really thankful to my beloved family especially my parents Hizamul-din Bin Abd Rahman and Wan Siti @ Wan Norhayati Binti Wan Muhamad as well as my siblings for all their love and encouragement that really help me to face the hard time during the process to finish this thesis. I also want to thank my friends and classmates for their support, help and motivation. With all of their support, I managed to complete this thesis.

Thank you, sincerely from the bottom of my heart.

Hanis Hamizah Binti Hizamul-din

January 2020

ABSTRACT

This study investigated the electrical properties of polypropylene and low density polyethylene (PP/LDPE) nanocomposite filled with zirconium dioxide and silicon dioxide and compare the test results of these two fillers. All samples are tested in four different test to get the optimum results. The first test is conducted using Differential Scanning Calorimetry (DSC) to examine their melting point and degree of crystallinity. Next, Scanning Electron Microscopy (SEM) is utilizes to observe and compare their structure analysis. After that, direct current breakdown test is carried out and the results are analysed through Weibull analysis. Lastly, permittivity test is conducted using Gamry Instrument. According to results obtained, polymer nanocomposites with fillers shows significant improvement on their performance compared to the one without fillers. Besides that, zirconium dioxide shows better results than silicon dioxide throughout the tests.

ABSTRAK

Kajian ini dilakukan bertujuan untuk menyiasat sifat elektrik polipropilena dan polietilena ketumpatan rendah (PP / LDPE) nanocomposite yang diisi dengan zirkonium dioksida dan silikon dioksida dan membandingkan hasil ujian kedua-dua pengisi ini. Semua sampel diuji dalam empat ujian yang berbeza untuk mendapatkan hasil yang optimum. Ujian pertama dijalankan menggunakan *Differential Scanning Calorimetry* (DSC) untuk memeriksa titik lebur dan tahap kristalografi. Seterusnya, *Scanning Electron Microscopy* (SEM) digunakan untuk memerhatikan dan menganalisisa struktur mereka. Selepas itu, ujian pecahan arus terus dijalankan dan keputusannya dianalisis melalui analisis Weibull. Akhir sekali, ujian *permittivity* dilakukan menggunakan *Gamry Instrument*. Menurut hasil yang diperolehi polimer nanocomposites dengan pengisi menunjukkan peningkatan yang ketara pada prestasi mereka berbanding dengan tanpa pengisi. Selain itu, zirkonium dioksida menunjukkan hasil yang lebih baik daripada silikon dioksida sepanjang ujian.

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LIST OF ABBREVIATIONS

LDPE	- Low Density Polyethylene
HDPE	- High Density Polyethylene
PP	- Polypropylene
PMMA	- Poly(methyl methacrylate)
SEBS	- Styrene-(Ethylene-co-Butylene)-Styrene tri-block copolymer
sPP	- syndiotactic Polypropylene
XLPE	- Cross Linked Polyethylene
HVDC	- High Voltage Direct Current
wt%	- Weight Percentage
UTM	- Universiti Teknologi Malaysia
SiO_2	- Silicon Dioxide
ZrO_2	- Zirconium Dioxide
ZnO	- Zinc Oxide
BNN	- Boron Nitride Nanosheets
DC	- Direct Current

LIST OF SYMBOLS

α - breakdown strength

β - shape parameter

Z - impedance

ε_r' - real part of the permittivity

f - frequency of the electric field

C_o - free space capacitance between the electrode

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Polymers are widely used and known as a good insulating materials compared to porcelain and glass because of their stable physical and chemical properties [2]. Besides that, the advantages of polymers are it has better contamination performance, light weight and superior vandal resistance [1]. However, in polymeric materials, it is common to degrade due to changes in their chemical, physical and mechanical properties. The degradation of polymer can be caused by chemical attack, stress loading, solar light or heating, water absorption and many more. Polyethylene and polypropylene are most used in high voltage insulation and their application usually being under outdoor services environments [3].

There are many problems can occur when polymers that act as insulator are degraded. One of the problems is due to contraction of surface layer, where the surface of polymer will form cracks and causes serious deterioration in its mechanical properties [3]. Other than that, when surface of an energized insulator is covered by the presence of moisture and contamination, corona discharges and dry band arcing will occur. This can cause the material degradation and formed tracking or erosion [1]. Therefore, some researches have been made to improve or modify the mechanical and electrical properties of polymers.

This thesis presents a method where by adding fillers, the mechanical strength of the polymers will increase and changes the electric conductivity. Addition of nanoparticles as fillers into polymers will be different compared to bulk material since their size is smaller and thus surface area will increase [2]. There are many advantages of polymer nanocomposites compared to the traditional polymer such as strength increased without degrading other mechanical properties, heat resistance improved,

electrical conductivity increased and gas permeability reduced [4]. The fillers that will be used in this paper are silicon dioxide and zirconium dioxide.

Silicon dioxide (SiO_2) is an excellent insulator and have high thermal stability. Furthermore, it has a wide band gap and a high dielectric strength [5]. While for zirconium dioxide (ZrO_2), it has a high strength, excellent thermal stability and chemical resistance and high fracture toughness and hardness. Based on previous researches [6], ZrO_2 able to reduce the thermal expansion coefficient of polymer and increase the dielectric permittivity of conductive polymer.

With that being said, by adding the nanoparticles as fillers in polymers, the performance of polymers as high voltage insulator will be improved and enhanced. The degradation of polymers is expected to reduce with the addition of nanoparticles. The comparisons of these two different fillers will be shown and analysed in the test results.

Various types of research have been made regarding the methods of improving the performance of polymers as an insulator in high voltage application. More studies and researches are expected to be made in future in enhancing the mechanical and electrical properties of polymers.

1.2 Problem Statement

This study will combine two different group of polymers which are low density polyethylene (LDPE) and polypropylene (PP). Many studies [7,8] show that the weak properties of LDPE which are lack of mechanical and thermal resistance can be improved by mixing it with other polymers that have high temperature resistance such as PP. These blends had improved the impact and tensile strength. In many research papers of PP/LDPE blends were mainly focused on the mechanical properties, thus making information on the electrical properties of PP/LDPE blends is hardly found in the literature.

In this study, the electrical properties of PP/LDPE compounds will be investigated which include DC breakdown and permittivity. From previous studies

[7,8,13], they added 30%, 50% and 70% of LDPE into PP and found that the dielectric strength of PP/LDPE compounds were lower than those of pure LDPE samples. Lower dielectric strength is undesirable in designing high voltage insulating material and needs to be improved significantly. In this study, the amount of LDPE is increased to 80% in comparison of PP amount.

Many of the previous studies [3,4,6] have investigated the effect of addition of nanofillers for example zinc oxide and aluminium oxide in different composite such as polyester, polyethylene (PE) or polypropylene (PP). Those studies shows that addition of nanofillers did enhance the breakdown properties of polymer composites. However, no study has been conducted to explore the effect of nanofillers in PP/LDPE compounds blend. This has motivated us to investigate the effects of SiO_2 and ZrO_2 in PP/LDPE compounds blend.

Most studies state that the addition of nanofillers into nanocomposites below 5%wt can improve their breakdown performance and electrical properties [3,4]. Therefore, in current study, three different weight percentage of nanofillers are used and added into polymer blends. From these results, the optimum percentage of nanofillers that need to be added into the polymer blends will be determined.

1.3 Research Objectives

The objectives of this study are :

1. To investigate the electrical properties of PP/LDPE nanocomposite filled with zirconium dioxide and silicon dioxide.
2. To determine which nanofillers contribute to the best enhancement of electrical properties of polymer base.

1.4 Scope of Study

The scope of this study are :

Fabrication of polymer blends :

(i) 80% Low Density Polyethylene (LDPE) + 20% Polypropylene (PP)

Addition of nanofillers into polymer blends in (i) :

(ii) Silicon Dioxide (0.5%, 1%, 4%) wt

(iii) Zirconium Dioxide (0.5%, 1%, 4%) wt

Parameter tested :

1) DC breakdown test
2) Permittivity test
3) Structural analysis test using SEM
4) Thermal profile test (melting and crystallization behaviour) using DSC

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