DIELECTRIC STRENGTH AND ELECTRICAL SURFACE TRACKING CHARACTERISTICS OF SIR/EPDM CONTAINING ALUMINA AND TITANIUM NANO-FILLERS FOR HIGH VOLTAGE INSULATORS

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2016

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By

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Thesis submitted in fulfilment of the requirements

for the degree of

Master of Science

November 2016

DECLARATION

I hereby declare that the work reported in this thesis is the result of my own investigation and that no part of the thesis has been plagiarized from external sources. Materials taken from other sources are duly acknowledged by giving explicit references.

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Date: 18 November 2016

ACKNOWLEDGEMENTS

In the name of Allah, Most Gracious, Most Merciful

Alhamdulillah, all praises to Allah for the strength and His blessings for me to complete this thesis. Here, I would like to acknowledge some of individuals and parties who had give me the opportunity to gain invaluable experience during my postgraduate study. This research project would not be possible without their directly or indirectly assisted, helped and full supported.

First and foremost, I would like to express my sincere gratitude and deepest appreciation to my respectable supervisor, Associate Professor Ir. Dr. Mohamad Kamarol Mohd Jamil. He provided a good study environment and offered plenty of opportunities for me to explore and pursue my research interest. His encouragement and personal guidance has been instrumental in the concept of the present thesis. Not forget, my appreciation to my co-supervisor, Professor Ir. Dr. Mariatti Jaafar @ Mustapa from School of Material and Mineral Resources for her support and knowledge regarding material, compounding technique and SEM analysis.

My family members have been the largest supporters throughout my Master research. I am humbly indebted to my loving mother and father, Pn. Shaharon Bahatin and Mr. Muhamad Raslani Saad for their understanding and patience. Special thanks and gratitude to my wife Siti Rahayu Abdul Wahab for her patience, encouragement, and continuous support on this research work. To my loving daughters Balqis Maisarah and Arissa Maisarah, thanks for being my strength during my study. I would like to express my sincere thanks to my mother and late father-in-law for their continuous support, concern and encouragement which enabled me to complete my Master.

Next, I wish to express my deepest gratitude to School of Material and Mineral Resources (SMMR) USM for the equipment used in material experiments. I also would like to show my gratitude to SMMR technicians namely Mr. Shahril Amir Saleh and Mr. Mohd Suharudin Sulong (Rubber Lab), Mr. Muhammad Khairi Khalid (SEM Lab), and Mr. Mohd Azam Rejab (Electronic Materials Lab) for their guidance and assistance in the preparing and testing of polymer composites. My special thanks also dedicated to Electrical Discharge and Insulation Lab staffs at School of Electrical & Electronic Engineering (SEEE) USM especially to Mr. Ahmad Shauki Noor, Mr. Jamaluddin Che Mat, and Mr. Hairul Nizam Abdul Rahman for their contribution and effort on my research work. An enormous and great appreciation also presented to my friends, Mr. Mohd Hafiz Ismail, Dr. Mohd Sharizal Abdul Aziz, Dr. Khalid Gazi Ali, Mr. Adzli Yusof, Mrs. Noor Syazwani Mansor, Ms. Kiasatina Azmi, Mr. Faizal Abdullah, Mr. T.L. Tiang and Ms. Siti Hafsah for their sharing knowledge and willingness to help towards the success of this research.

I would like to express my appreciation to the Department of Polytechnic Malaysia for giving me the opportunity to study M.Sc under the 2014 Federal Training (H.L.P) sponsorship. As well as, financial support for this research work from USM and Malaysia Ministry of Higher Education under the Fundamental Grant Scheme (FRGS: 6071265). Last but not least, I gratefully appreciate all those who had helped and supported me in one way or another.

Muhamad Fairus Adzha Bin Muhamad Raslani

November 2016

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LIST OF ABBREVIATIONS

AC	Alternating current
Al_2O_3	Aluminium oxide
AlN	Aluminium nitride
ATH	Alumina trihydrate
BN	Boron nitride
DBA	Dry band arcing
DC	Direct current
DCP	Dicumyl peroxide
EPDM	Ethylene propylene diene monomer
HV	High voltage
HTV	High temperature vulcanized
IEC	International electrotechnical commission
IPT	Incline plane test
LC	Leakage current
LMW	Low molecular weight
MDR	Moving die rheometer
NH_4C1	Ammonium chloride
SiR	Silicone rubber
SiO_2	Silicone oxide
TiO2	Titanium oxide
UV	Ultraviolet
UnF	Unfilled
ZnO	Zinc oxide

LIST OF SYMBOLS

ε_1	Dielectric constant of nano-filler
ε_2	Dielectric constant of SiR/EPDM
ε_r	Dielectric constant
ρ_f	Density of nano-filler
ρ_m	Density of SiR/EPDM
Q	Electric charge
m_f	Mass of nano-filler
Ω	ohm
β	Shape parameter of breakdown
α	Scale parameter of breakdown
t	Time period
m_T	Total mass of nano-composite
ρ_m	Volume density for SiR/EPDM
ρ_n	Volume density for nano-fillers
V_f	Volume of nano-filler

CIRI-CIRI KEKUATAN DIELEKTRIK DAN PENGESANAN PERMUKAAN ELEKTRIK SIR/EPDM YANG MENGANDUNGI NANO-PENGISI ALUMINA DAN TITANIUM UNTUK PENEBAT VOLTAN TINGGI

ABSTRAK

Pada masa ini, kombinasi bahan-bahan polimer seperti SiR dan EPDM sebagai komposit getah-getah telah menjadi salah satu penyelidikan utama dalam membangunkan penebat polimer yang baharu dengan ciri-ciri yang unggul. Baru-baru ini, para penyelidik mendapati bahawa SiR/EPDM dengan formulasi peratusan nisbah berat 50:50 telah menghasilkan sifat-sifat elektrikal dan mekanikal yang optimum bagi komposit polimer. Walau bagaimanapun, sehingga kini kajian terhadap campuran seimbang ini dengan kemasukan nano-pengisi kepada ciri-ciri elektrik, mekanikal dan pengesanan permukaan adalah sedikit dan masih belum diterokai sepenuhnya. Oleh itu, dalam kajian ini, campuran SiR/EPDM telah disediakan dengan dua jenis nano-pengisi seperti Al_2O_3 dan TiO_2. Kepekatan muatan nano-pengisi untuk setiap spesimen adalah 1 Vol%, 2 Vol%, 3 Vol% 4 Vol% dan 5 Vol%. Kesan nano-pengisi Al_2O_3 dan TiO_2 dengan kepekatan muatan yang berbeza kepada sifat-sifat dielektrik, kekuatan tegangan, dan ciri-ciri pengesanan permukaan telah dikaji. Keputusan eksperimen menunjukkan bahawa kemasukan 1 Vol% kepekatan muatan nano-pengisi Al_2O_3 dan TiO_2 dalam SiR/EPDM telah meningkatkan kekuatan dielektrik dan tegangan berbanding dengan UnF SiR/EPDM. Sebaliknya, kedua-dua nano-komposit ini (pada semua kepekatan muatan) menunjukkan bahawa nilai pemalar dielektrik meningkat apabila kepekatan muatan nano-pengisi telah meningkat dari 1 Vol% hingga 5 Vol%. Manakala, nilai kehilangan dielektrik berkurangan apabila frekuensi pengujian meningkat.

Keputusan itu juga menunjukkan bahawa penambahan nano-pengisi dalam SiR/EPDM komposit dengan ketaranya telah meningkatkan prestasi rintangan pengesanan permukaan elektrik dengan melambatkan proses penuaan atau meminimumkan kerosakan pada permukaan. Keputusan eksperimen menunjukkan bahawa SiR/EPDM dipenuhi dengan nano-pengisi 1 Vo% Al_2O_3 mempunyai prestasi masa pengesanan yang lebih baik setanding dengan SiR/EPDM yang dipenuhi dengan nano-pengisi 2 Vol% TiO_2. Akhir sekali, ciri-ciri masa pengesanan dan kekonduksian terma kedua-dua nano-komposit adalah lebih tinggi daripada UnF SiR/EPDM.

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ABSTRACT

Nowadays, the combination of polymer materials such as SiR and EPDM as a rubber-rubber composite has become one of the main research in developing new polymer insulator with superior characteristics. Recently, the researchers found that SiR/EPDM with formulation of 50:50 weight percentages ratio blends had produced the optimal electrical and mechanical properties of the polymer composites. However, until now the study of these balanced blends with inclusion nano-fillers on the electrical, mechanical and surface tracking characteristics are still few and has not been fully explored yet. Hence, in this research, the SiR/EPDM blends were prepared with two types nano-fillers such as Al_2O_3 and TiO_2. The loading concentration of nano-fillers for each specimen is 1 Vol%, 2 Vol%, 3 Vol%, 4 Vol%, and 5 Vol%. The effects of Al_2O_3 and TiO_2 nano-fillers with different loading concentrations on the dielectric properties, tensile strength, and surface tracking characteristics were investigated. The experiment results revealed that the inclusion 1 Vol% loading concentration of Al_2O_3 and TiO_2 nano-fillers in SiR/EPDM have increased the dielectric and tensile strength as compared to UnF SiR/EPDM. On the other hand, both nano-composite (all loading concentrations) showed that the value of the dielectric constant increases when the loading concentration of nano-filler was increased from 1 Vol% to 5 Vol%. While the values of dielectric loss reduced as the frequency of testing increased. The results also demonstrated that the addition of nano-fillers in SiR/EPDM composite was significantly improved the electrical

surface tracking resistance performance which slowing the aging process or minimizes damage to the surface. The experimental results showed that the SiR/EPDM filled with 1 Vol% Al_2O_3 nano-filler has better tracking time performance comparable to SiR/EPDM filled with 2 Vol% TiO_2 nano-filler. Finally, the tracking time and thermal conductivity characteristics of both nano-composites are higher than UnF SiR/EPDM.

CHAPTER ONE

INTRODUCTION

1.1 Overview

In general, the high voltage overhead transmission lines transfer the electric power from the generating plants at the different place to the distribution system, which eventually supplied to the load for instance domestic, commercial, and industrial users. Most of the transmissions lines are installed for a long distance transmission (thousands of kilometres) for lines carrying power from the generation plants. The transmission line also interconnects the neighbouring power utilities by providing the economical delivery of power inside provinces during typical conditions and delivers the power between provinces during emergencies.

However, the main components of high voltage overhead transmission line comprises of the tower support structure, conductor and insulator. The first component is the structure to keeps the conductor at safe height from ground and able to provide the suitable distance between phase conductors to prevent the arcing. The steel towers usually use for high voltage transmission, in which more than several hundred kilo volts. The design and height specification of the tower are relies on several factors, for instance, the level of transmission line voltage, ground terrain, environment constrains and atmospheric conditions. The second component is the conductor transmission line is usually made of materials such as Aluminium and steel reinforcement. Whereas, the Aluminium material functions as the transportation of electric current flow and steel material also act as the support of mechanical strength. Meanwhile, the copper material is not used in high-voltage transmission line because it is very expensive even though it has a level higher conductivity than the Aluminium material. The overhead line conductors are normally bare without protected by any insulation. This is because of the bare conductors have an excellent heat dissipation characteristic to decrease the temperature during the electric current flows.

The third component for the overhead transmission line is the insulator, which is the most significant part in electrical power system. Practically, insulator for high voltage is installed together with the outdoor tower or pole. There are several types of insulators in overhead high voltage power line such as pin, suspension and strain insulator, but their main functions are identical to prevent electrical current flow directly to the ground through the tower or poles. Conventionally, the traditional insulator was made of ceramic and glass material, known as inorganic material.

Recently, the inorganic material has been replaced with polymer material due to several advantages such as better dielectric characteristic, lower installation cost, light weight and good vandalism resistance. Furthermore, it also has higher tensile strength compared to inorganic material and less cleaning maintenance because of the hydrophobic nature of the insulator [1]. The polymer insulator has been manufactured with variety types of polymer materials for example, with silicone rubber (SiR), epoxy resin, ethylene propylene diene monomer (EPDM), ethylene propylene rubber (EPR), high density polyethylene (HDPE) and an alloy of SiR/EPDM.

Apart from that, the polymer insulator material such as SiR has been extensively used because of its excellent electrical characteristic, e.g., high dielectric strength and volume resistivity. However, it suffers from poor mechanical strength and low tracking resistance, and expensive. EPDM has excellent resistance to tracking and erosion, and higher mechanical strength than SiR, but suffers from low volume and surface resistivity compared with SiR [2]–[7].

Nowadays, polymer composite with another type of polymer material has become one of the major research in developing new polymer material. By adding a suitable formulation into this composite, it offers a supremacy performance and low cost option compared to existing materials [4]. Therefore, the SiR and EPDM as a rubber-rubber composite is a valuable approached to produce a new polymer insulator component especially on the weather shed or housing part. It is believed that this new polymer composite may become an important technology due to its excellent mechanical characteristic from EPDM and the outstanding electrical characteristic from SiR [4]–[6].

In the past few years, Prabu et al. found that the developments of new polymeric synthesis on SiR/EPDM with 50:50 weight percentage ratios polymer composite yields the optimal electrical and mechanical characteristic [7]. They also reported that, when the EPDM content increased up more than 50 wt% in order to gain good mechanical characteristic, the electrical characteristic of the insulator have to be sacrificed. From this interesting finding, research on this polymer composite by this researcher was extended by adding fillers such as Silica (SiO_2) and Alumina Trihydrate (ATH) into the composite. Based on the result found, the implementation of suitable amount of fillers had improved the mechanical and electrical characteristic such as dielectric strength, volume and surface resistivity, arc resistance, tracking resistance and tensile strength [8].