CHARACTERIZATION OF VARIOUS TYPES OF NANOFILLERS FILLED CROSSLINKED POLYETHYLENE COMPOSITES FOR CABLE APPLICATION

LIM KAI SHENG

UNIVERSITI SAINS MALAYSIA

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by

LIM KAI SHENG

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LIST OF ABBREVIATIONS

XLPE	Crosslinked polyethylene
LDPE	Low density polyethylene
HDPE	High density polyethylene
LLDPE	Linear low density polyethylene
ZnO	Zinc oxide
Al_2O_3	Aluminium oxide
OMMT	Organo-montmorillonite clay
KH550-ZnO	3-aminopropyltriethoxysilane treated zinc oxide
TCS-ZnO	Triethoxycaprylylsilane treated zinc oxide
AE-Al_2O_3	Aluminic ester treated aluminium oxide
FE-SEM	Field emission-scanning electron microscope
TGA	Thermogravimetric analysis
DSC	Differential scanning calorimetry
FTIR	Fourier transfer infrared spectroscopy
ASTM	American Society for Testing and Materials
DBS	Dielectric breakdown strength

LIST OF SYMBOLS

Symbol	**Description**
wt%	Weight percent
MPa	Mega pascal
√h	Square root of time in hour
M_m	Maximum moisture
K	Initial slope
T	Thickness
mm^2/h	Millimetres square per hour
mm/min	Millimetres per minute
kV/mm	Kilovolts per millimetres
α	Scale for dielectric breakdown distribution
Β	Shape for dielectric breakdown distribution
Ω cm	Ohm centimetres
T_m	Melting temperature
T_c	Crystallization temperature

PENCIRIAN PELBAGAI JENIS PENGISI NANO TERISI KOMPOSIT POLIETILENA TERSAMBUNG SILANG UNTUK APLIKASI KABEL

ABSTRAK

Kajian ini adalah untuk mengkaji kesan pengisi nano terhadap sifat mekanikal, fizikal, dielektrik dan terma matriks polietilena tersambung silang (XLPE). Pengisi nano yang tidak dirawat adalah zink oksida (ZnO) dan aluminium oksida (Al_2O_3). Pengisi nano yang telah dirawat adalah tanah liat (OMMT), ZnO dirawat dengan *3-aminopropyltriethoxysilane* (KH550-ZnO), ZnO dirawat dengan *triethoxycaprylylsilane* (TCS-ZnO) dan Al_2O_3 dirawat dengan *aluminic ester* (AE-Al_2O_3). Komposit nano XLPE telah disediakan dengan pencampuran leburan dengan ekstruder skru tunggal diikuti dengan penekan panas. Peratusan berat yang berlainan (0.5, 1, 1.5 dan 2 wt%) telah dikompaun bagi komposit nano yang tidak dirawat dan telah dirawat. Gabungan ZnO/Al_2O_3 dan ZnO/OMMT dengan nisbah yang berbeza (75/25, 50/50 dan 25/75) dalam jumlah 1 wt% berat pengisi telah dikompaun bagi komposit nano hibrid. Komposit nano telah diuji dengan mengikut kaedah piawaian ASTM dan dicirikan dengan pemeriksaan mikroskop elektron (SEM), analisis termogravimetrik (TGA) dan kalorimetri pengimbasan berbeza (DSC). Keputusan menunjukkan penambahan pengisi nano yang tidak dirawat dan dirawat meningkatkan sifat tegangan, kadar pembakaran, sifat dielektrik dan suhu penguraian. Walau bagaimanapun, ia menunjukkan kesan terhad terhadap sifat rintangan air, suhu leburan dan suhu penghabluran. Berat pengisi optimum adalah 1.5 wt% dan kesan Al_2O_3 lebih baik daripada pengisi nano ZnO dan OMMT berdasarkan kebanyakan sifat. Rawatan permukaan dengan ejen gandingan meningkatkan

kawasan antara muka pengisi dan matriks dengan ikatan kimia. Interaksi pengisi-matriks yang kuat meningkatkan lagi sifat komposit. Berat pengisi optimum adalah 1.5 wt% dan kesan AE-Al_2O_3 adalah lebih baik daripada pengisi nano KH550-ZnO dan TCS-ZnO berdasarkan kebanyakan sifat. Dalam komposit nano hibrid, nisbah pengisi yang terbaik adalah 50/50 bagi gabungan ZnO/Al_2O_3 dan 75/25 bagi gabungan ZnO/OMMT disebabkan oleh sifat sinergi. Secara keseluruhan, komposit nano AE-Al_2O_3(1.5)/XLPE mempunyai keputusan yang terbaik. Berbanding XLPE yang tidak terisi, ia telah menunjukkan peningkatan ketara dalam kekuatan tegangan (59%), pemanjangan pada takat putus (51%), modulus Young's (60%), sudut sentuh (4%), kekuatan pecahan dielektrik (35%), rintangan isipadu (55%), suhu penguraian dan pengurangan kadar pembakaran (14%). Ia sesuai untuk aplikasi penebat kabel kerana ciri-ciri mekanik, fizikal, dielektrik dan haba yang luar biasa.

CHARACTERIZATION OF VARIOUS TYPES OF NANOFILLERS FILLED CROSSLINKED POLYETHYLENE COMPOSITES FOR CABLE APPLICATION

ABSTRACT

This research is to study the effect of nanofillers on mechanical, physical, dielectric and thermal properties of the crosslinked polyethylene (XLPE) matrix. Untreated nanofillers used are zinc oxide (ZnO) and aluminium oxide (Al_2O_3). Treated nanofillers used are organoclay (OMMT), 3-aminopropyltriethoxysilane treated ZnO (KH550-ZnO), triethoxycaprylylsilane treated ZnO (TCS-ZnO) and aluminic ester treated Al_2O_3 (AE-Al_2O_3). XLPE nanocomposites were prepared by melt mixing with a single screw extruder followed by hot press moulding. Different weight percentages (0.5, 1, 1.5 and 2 wt%) were compounded in untreated and treated nanocomposites. Combinations of ZnO/Al_2O_3 and ZnO/OMMT with different ratios (75/25, 50/50 and 25/75) in total of 1 wt% filler loading were compounded in hybrid nanocomposites. Nanocomposites were tested as per ASTM standard methods and characterized with scanning electron microscopy (SEM), thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). The results showed that the addition of untreated and treated nanofillers improved tensile property, burning rate, dielectric property and decomposition temperature. However, it has limited effect on the water resistance property, melting and crystallization temperatures. The optimal filler loading was 1.5 wt% and the effect of Al_2O_3 is better than ZnO and OMMT nanofillers based on most properties. Surface treatment with coupling agent enhanced the interface between the filler and the matrix with chemical bonding. Strong filler-matrix interaction further improved the properties of composite. The

optimal filler loading was 1.5 wt% and the effect of AE-Al_2O_3 is better than KH550-ZnO and TCS-ZnO nanofillers based on most properties. In hybrid nanocomposites, the best filler ratio was 50/50 in ZnO/Al_2O_3 and 75/25 in ZnO/OMMT combinations which induced synergistic properties. Overall, AE-Al_2O_3(1.5)/XLPE nanocomposite has the best results. As compared with the unfilled XLPE, it has led to the significant improvement in tensile strength (59%), elongation at break (51%), Young's modulus (60%), contact angle (4%), dielectric breakdown strength (35%), volume resistivity (55%), decomposition temperature and reduced burning rate (14%). It is suitable for cable insulation application due to its extraordinary mechanical, physical, dielectric and thermal properties.

CHAPTER ONE

INTRODUCTION

1.1 Background of Research

Electricity is the key component to modern technology used for domestic appliances in our daily life. By the rapid of urban and city growth, demand of electrical energy is ever increasing and the power system is becoming more complex. The reliability of power supply to the consumers must be ensured with a trustworthy insulation system in order to has greater efficiency and cost effectiveness.

The growing of power cable technology had beginnings in the 1870 where the cables were insulated with natural rubber or porcelain (Ponniran, 2005). After that it was insulated with gutta-percha, oil and wax, jute, hemp and cotton. New evolution had beginnings in 1942 where polyethylene has been used as insulator in cable. It has been launch throughout the years until crosslinked polyethylene (XLPE) was first invented in Canada and United State in the late 1960s. Nowadays, XLPE has been extensively used throughout the world as electrical insulating material in underground distribution and transmission class. In Malaysia, underground power cables are the primary pathway of distributing electrical energy to the houses or industry area. Tenaga Nasional Berhad (TNB) is the largest electricity utility in Malaysia which responsible in keeping the lights on for all residents (Zainal, 2016). TNB has been switched to XLPE cable for the 11 kV underground systems since 1990s (Osman et al., 2005). It was reported that huge number of failures for underground cable system from year 2010 to 2015 as shown in Figure 1.1.

Figure 1.1: Number of failure report for underground cable system from year 2010 to 2015 in Malaysia (Zainal, 2016)

Based on Figure 1.1, it shows the reduction failure number for the past years for medium voltage underground cable. Recently, much effort has been carried out to find the solutions to overcome the problems in particularly insulation part. The existing cable mainly failed due to the breakdown of insulation and cable joint. At high water ground area, function failed due to the water ingression of internal part of cable.

A good insulation system is often considered by its electric strength as a dominant characteristic. Nevertheless, thermal and mechanical properties are crucial factors which could critically affect the performance or even failures of electrical insulation (Nelson, 2010). The approach towards seeking the long-term solution to the choice of cable insulation technology is to develop a better insulation system. It has been raised the risk and get attention from the Institute of Electrical and Electronics Engineers (IEEE) and also Dielectrics and Electrical Insulation Society (DEIS) where they are currently focus on the research of improving insulation by adding additives including nanofillers to existing materials. Even little gains in performance can bring commercial significance on electrical insulation usage.