ZINC OXIDE, ORGANOCLAY AND SILICA IN CROSSLINKED POLYETHYLENE COMPOSITE FOR CABLE INSULATION

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by

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LIST OF ABBREVIATION

ABC	Aerial bundle cable
AC	Alternate current
CCD	Charge coupled camera device
CNT	Carbon nanotube
DBS	Dielectric breakdown strength
DC	Direct current
FE-SEM	Field emission-scanning electron microscope
FTIR	Fourier transfer infrared spectroscopy
HDPE	High density polyethylene
HPFF	High-pressure fluid-filled
HV	High voltage
IEC	International electro technical commission
KH550-SiO_2	Silicon dioxide treated with 3-4 wt. % aminopropyltriethoxysilane
KH550-ZnO	Zinc oxide treated with 3-aminopropyltriethoxysilane
LDPE	Low density polyethylene
MV	Medium voltage
MWNT	Multi-wall nanotube
NR	Natural rubber
O	Oxygen
OMMT	Montmorillonite treated with 0.5-5 wt. % Aminopropyltriethoxysilane, 15-35 wt. % octadecylamine
PE	Polyethylene
PEI	Polyetherimide
PVC	Polyvinyl chloride

SBR	Styrene butadiene rubber
Si	Silicon
SiO_2	Silicon dioxide
SR	Silicone rubber
STRI	Swedish Transmission Research Institute
XLPE	Crosslinked polyethylene
XRD	X-Ray Diffraction

LIST OF SYMBOLS

ºC	Degree celcius
rpm	Revolutions per minute
psi	Pounds per square
wt. %	Weight percent
kV	Kilovolt
kV/mm	Kilo volt per milimiter
T_m	Melting temperature
%	Percent
γ	Gamma
º	Degree
λ	Wavelength
θ	Theta
β	Weibull shape parameter
α	Weibull scale parameter
vol %	Volume percent
MPa	Megapascal

ZINK OKSIDA, ORGANOCLAY DAN SILIKA DALAM KOMPOSIT POLIETILENA BERSAMBUNG SILANG UNTUK INSULASI KABEL

ABSTRAK

Kajian ini menyiasat prestasi pengisi nano terhadap sifat morfologi, elektrik, mekanikal dan fizikal matriks polietilena bersambung silang (XLPE). Dalam kajian ini, zink oksida (ZnO) dan silikon dioksida (SiO_2) digunakan sebagai pengisi nano tidak terawat, manakala pengisi nano terawat adalah ZnO terawat 3-aminopropiltrietoksilen (KH550-ZnO), SiO_2 terawat 3-4-aminopropiltrietoksilen (KH550-SiO_2) dan organoclay (OMMT). Pengisi nano dicampur dengan XLPE menggunakan pengadun dalaman, dan kemudian ditekan acuan pada 160 °C. Peratusan berat yang berlainan (1, 2, 3 dan 4 % bt.) dikompaunkan dalam pengisi nano tidak terawat, dan peratusan berat untuk pengisi nano terawat adalah 1 dan 2 % bt. Nisbah yang berbeza (75/25, 50/50 dan 25/75) dalam jumlah 2 % bt. pemuatan pengisi telah dikompaun dalam nanokomposit hibrid. Keputusan menunjukkan bahawa penambahan pengisi nano tidak terawat meningkatkan kekuatan pecah, kadar pembakaran dan sifat tegangan. Prestasi terbaik nanokomposit didapati pada 1 % bt. SiO_2/ XLPE berdasarkan ciri-ciri yang paling menonjol. Pengubahsuaian permukaan pengisi nano meningkatkan hubungan antara pengisi dan matriks melalui ikatan kimia. Pengisi nano diubahsuai permukaannya juga telah meningkatkan kekuatan pecahan, kadar pembakaran dan sifat tegangan. Dalam kajian ini, 1 % bt. OMMT / XLPE menunjukkan prestasi yang lebih baik berdasarkan ciri-ciri yang paling menonjol jika dibandingkan dengan pengisi nano terawat yang lain. Dalam

nanokomposit hibrid, nisbah pengisi terbaik adalah 25/75 ZnO / OMMT. Sebagai perbandingan dengan XLPE tanpa pengisi, peningkatan yang ketara telah dilihat dalam pemalar dielektrik (4 %), kekuatan pecahan (9 %), kadar pembakaran (13 %), kekuatan tegangan (57 %), pemanjangan putus (54 %) dan modulus Young (36 %). Oleh itu, ia sesuai digunakan untuk penebat kabel.

ZINC OXIDE, ORGANOCLAY AND SILICA IN CROSSLINKED POLYETHYLENE COMPOSITE FOR CABLE INSULATION

ABSTRACT

This study investigates the performance of nanofillers on morphology, electrical, mechanical and physical properties of crosslinked polyethylene (XLPE) matrix. In this study, zinc oxide (ZnO) and silicone dioxide (SiO_2) were used as untreated nanofiller, while treated nanofiller were 3-aminopropyltriethoxysilane treated ZnO (KH550-ZnO), 3-4-aminopropyltriethoxysilane treated SiO_2 (KH550-SiO_2) and organoclay (OMMT). The nanofillers were mixed with XLPE using internal mixer, and then, press-moulded at 160 °C. Different weight percentages (1, 2, 3 and 4 wt. %) were compounded in untreated nanofillers, and the weight percentages for treated were 1 and 2 wt. %. Different ratios (75/25, 50/50 and 25/75) in a total of 2 wt. % filler loading were compounded in hybrid nanocomposites. The results showed that the addition of untreated nanofillers improved breakdown strength, burning rate and tensile properties. The best performance of nanocomposite was found at 1 wt. % SiO_2/XLPE based on the most prominence properties. The addition of surface modified nanofiller enhanced the interface interaction between the filler and the matrix via chemical bonding. The surface modified nanofiller also improved the breakdown strength, burning rate and tensile properties. In this study, 1 wt. % OMMT/XLPE showed better performance based on the most prominence properties compared to other treated nanofiller. In hybrid nanocomposites, the best filler ratio was 25/75 ZnO/OMMT. In comparison with unfilled XLPE, significant improvement is observed in dielectric constant (4 %), breakdown strength (9 %), burning rate (13

%), tensile strength (57 %), elongation at break (54 %) and Young's modulus (36 %). Therefore, it is suitable for cable insulation.

CHAPTER ONE

INTRODUCTION

1.1 Overview

Electrical insulator is very important in the electric power systems for substations, distribution, and transmission lines. The first material that have been used as insulation was ceramics, glass, and then turn into porcelain. The polymeric insulators were introduced in 1940s and the progress in designing and manufacturing of the polymeric insulators nowadays has made them increasingly being used in the electric power utilities. The worldwide cable sheathing and insulation materials are polyethylene (PE) and Polyvinyl chloride (PVC). PE is commonly used as insulator, however, due to its structure PE cannot withstand high temperature, and made it insufficient in terms of the mechanical strength and hence restricted its application in many areas.

Therefore, the cross-linking in PE through the intramolecular covalent bond which form reticular structure and able to withstand high temperature. The advantages of crosslinked polyethylene (XLPE) cable are small dielectric loss, easy installation, light weight and simple terminal processing (Mo et al., 2013). Furthermore, it was reported that the XLPE cable has lower degree of maintenance, environmental friendly system and high mechanical resistance (Hammons, 2003). Interestingly, the addition of organic and inorganic nanofillers will enhance the XLPE performance.

Organic and inorganic nanoparticle-filled polymers are widely applied in XLPE insulated cables due to its resistance to degradation and improvement in thermo-mechanical properties without causing a reduction in dielectric strength.

Small amount of nanoparticles content which less than 10 wt. % has improved the properties of XLPE. These improvements of polymer properties was observed for nano-filled polymers could be due to several factors Roy et al. (2005): (1) the large surface area of nanoparticles which creates a large ‘interaction zone’ or region of altered polymer behaviour, (2) changes in the polymer morphology due to the particle’s surfaces, (3) a reduction in the internal field caused by decrease in size of the particles, (4) changes in the space charge distribution and (5) a scattering mechanism.

The presence of nanocharges seems to have a strong impact on medium-long term degradation processes of polymers (Sami et al., 2009). The incorporation of nanofiller not only restricted to one type, it more than one filler can be incorporated which is known as hybrid nanofiller. The enhancement in properties of hybrid nanocomposite is depending on the dispersion of particles and aspect ratio (Nurul and Mariatti, 2013).

Good dispersion of nanofiller gives tremendous effect on mechanical and electrical properties of polymer. In the correlation of polymer nanocomposites properties with nanoparticles surface modified is becoming a point of great interests because it produces excellent integration and improved interface between nanoparticles and polymer matrices. Rong et al. (2006) reported that surface modification of nanofiller is influences the mechanical, tribology, electrical and fire retardant performance of polymer based nanocomposites.

1.2 Problem Statement

The cable system must prevent contact of the high-voltage conductor with other objects or persons, and must contain and control leakage of current. Cable joints and terminals must be designed to control the high-voltage stress to prevent breakdown of the insulation. In real application, the XLPE insulated cable are subjected to thermal, electrical, mechanical, oxygen, humidity, chemical, radiation or microorganism aging during storage and operating service which can cause physicochemical properties and microstructure changes and obviously affect the electrical and mechanical properties of the cable insulation.

The mechanical damage such as hitting a cable while digging a trench is fairly obvious and the overvoltage and under voltage cause abnormal stresses within the insulation which can lead to cracking for the insulation (Zhang et al., 2015). Moreover, XLPE is a very weak conductive material which cause accumulation of immobile charge carrier in the insulation and produce additional electrical source field. The charge transport also produce molecular chain distortion which creates energy traps and can increase the accumulation of other charges. Thus, it changes the polarity, local distribution and concentration of space charge which lead to breakdown (Muhr et al., 2004).

Interestingly, the incorporation of nanofillers can improve the mechanical properties of XLPE by their large interfacial zone. The function of ‘trap and scatter’ of nanofillers also may improve the electrical properties of XLPE. When the material is packed with nanofillers, the fillers act as scattering site. The electrons or charge carriers injected from high voltage electrode transfer the energy to the nanoparticles and reduced the mobility. The energy of charge carriers is distributed more uniformly