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Electrical Tracking Performance of Thermoplastic Elastomer Nanocomposites Material under High Voltage Application

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Abstract— Thermoplastic Elastomer (TPE) nanocomposites are polymeric materials which made up of thermoplastic and elastomer containing a small amount of nanometer-sized fillers. From the stand-point as outdoor electrical insulation under high voltage application, the most common cause of polymeric insulation failure is electrical tracking. In view of this, the paper deals with application of nanofillers added to TPE material in order to obtain high endurance to tracking degradation. The blend of ratio 4:1 of high density polyethylene (HDPE) and epoxidized natural rubber-50 (NR) added with and without MMT, Al2O3 and SiO2 nanofillers were presented. The electrical tracking test using the inclined-plane tracking method was conducted to analyse the leakage current performance and carbon track characteristics on the material surface. The leakage current data patterns were monitored using computer-based system and the carbon track propagation are visually observed. The results revealed that the leakage current of TPE without nanofillers is lowest among the samples thus inhibited electrical tracking growth. In addition, carbon track propagation of different material compositions is also visually observed.

Index Terms— Carbon track, Dry band, Electrical tracking, Leakage current, Nanocomposite, Nanofillers, Thermoplastic elastomer.

1 INTRODUCTION

Thermoplastic Elastomer (TPE) nanocomposites are formulated to upgrade the quality of polymeric materials as an electrical insulation in high voltage application. TPE nanocomposites are based on a hard thermoplastic and a soft elastomer containing a small amount of nano-sized filler [1,2]. In the conventional compounding polymeric, alumina trihydrate (ATH) filler is used with a large amount of fillers usually more than 50 wt% [3-6]. In case of nanofillers, the benefit is the amount less than 10 wt% nanometer-sized filler is enough to enhance polymer properties [2]. However, there are some disadvantages of polymeric material particularly for use as outdoor insulators under high voltage application. This material has a problem with tracking and erosion susceptibility. They cannot maintain their surface hydrophobicity when exposed to electrical aging and environmental stresses [5,7,8].

Developing better understanding of polymeric materials, the electrical tracking test seems to be a useful tool to determine the leakage current activity and to indicate the surface degradation due to environmental agents. Electrical tracking develops on the surface due to flow of leakage current and influence under wet and contaminated conditions [6,9,10]. Leakage current starts to develop when the surface hydrophobicity is lost. Consequently, the insulator breakdown when the carbonised tracks bridge the distance between the electrodes [10].

In spite of this, different materials and formulations were used in order to improve their performance in outdoor service. Nanofillers, for instance, have potential to enhance the tracking resistance that it can disperse in organic nanoparticles into polymer matrices [2],[14] as well as to improve mechanical performance [4,11,15,18-19]. Typical nanofillers used are montmorillonite, silicon dioxide (SiO2), aluminium oxide (Al2O3) and rutile (TiO2). Many reports was discussing the effect of nanofillers on the electrical insulating characteristics in polyethylene (PE), silicon rubber (SiR), epoxy resin (ER) and cross-linked polyethylene (XLPE). The incorporation of nanofiller in polymer materials prevents surface degradation and increase dielectric breakdown strength [2,14-19].

In this paper, the performances of electrical tracking development on TPE nanocomposites under high voltage application are reported. TPE that are composed of high density polyethylene (HDPE) and epoxidized natural rubber-50 (NR) added with and without organoclay-montmorillonite (MMT), aluminium oxide (Al2O3) and silicon dioxide (SiO2) are employed. The leakage current was measured by electrical tracking test of IEC 60587 and recorded using Lab View software package. In addition the carbon track development on the surface material was visually observed.

2 EXPERIMENTAL SETUP

2.1 Material used

The HDPE in the form of extruded pellets obtained from Titan Petchem (M) Sdn. Bhd., Malaysia. The melt flow index (MFI) at 190 degree celcius and 2.16 kg load and the density of HDPE were 26 g/10 min and 0.941 g/cm3, respectively. The NR type of ENR-50 received from Research Rubber Institute of Malaysia (RRIM) in bale form. Organoclay-montmorillonite (MMT), silicon dioxide (SiO2) and aluminium oxide (Al2O3) used to study the electrical tracking resistance. The organoclay-montmorillonite (MMT) grade Nanomer 1.30P NanocorInc., USA with 16 - 20 microns mean dry particle size is used. The silicon dioxide typically known as silica (SiO2) received in form of powder was produced by Sigma-Aldrich, UK. The mean dry particle size of the silicon dioxide is 5 – 15 nm (TEM). The aluminum oxide typically known as alumina (Al2O3) was produced by Sigma-Aldrich, UK. The mean dry particle size of the alumina is < 50 nm (TEM).

The experimental samples were prepared based on differ-

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ent formulations of the virgin compounds. Four groups of samples were made by dispersing nano-scale MMT, SiO2, Al2O3 powdered into thermoplastic elastomer material with the weight ratios of 2 phr (part per hundred). The samples of thermoplastic elastomer with and without nanofillers are shown in Table 1.

TABLE 1
TEST SAMPLES DESIGNATION

Sample	Composition	Wt%		phr*		
		HDPE	NR	MMT	Al2O3	SiO2
S1	HDPE/NR	80	20	-	-	-
S2	HDPE/NR/MMT	80	20	2	-	-
S3	HDPE/NR/Al2O3	80	20	-	2	-
S4	HDPE/NR/ SiO2	80	20	-	-	2

2.2 Test sample preparation

The tracking test was set up based on the inclined-plane tracking method of IEC-60587 [9]. Fig. 1 illustrates the schematic diagram of the tracking process. The sample was mounted at an angle of 45 degree with the flat surface on the underside. The stainless steel electrodes are separate of 50 mm apart. The electrical tracking test at 2.5 kV root-mean- sample for 4 hours with aluminum chloride, NH4C1 as the contaminant of 0.15 ml/min flow rate from peristaltic pump.

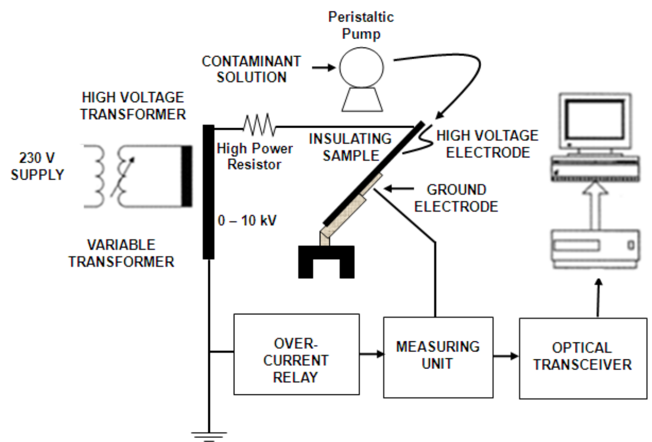

Fig. 1. Schematic representation of tracking process.

During the test, the range of leakage current was recorded after 4 hours or earlier if major erosion was observed on the material surface. An on-line leakage current monitoring system was developed to monitor the test every minute throughout the experiment. The electrical performance was quantified by counting the number of peak leakage current values for every 15 minutes. The electrical tracking performance was carried out by measurement of surface leakage current and the length of carbon track. At the end of the test, the range of leakage current, test duration and the length of carbon track were recorded for tracking analysis.

3 Result And Discussions

Table 2 shows the variation in the leakage current during electrical tracking test. All samples were subjected to the same test procedure with test voltage 2.5 kV and flow rate of 0.15 ml/min [9].

TABLE 2
VARIATION IN LEAKAGE CURRENT OF THE SAMPLE

Sample	Average Leakage Current (mA)	Max. Leakage Current (mA)
S1	14.563	17.232
S2	15.975	25.424
S3	13.667	16.952
S4	14.844	17.531

The different magnitudes of the leakage current data are recorded using computer-based monitoring system that was quantified by counting the number of peak leakage current values for every 15 minutes in 4 hours test run. Leakage current values in range of 10 mA to 30 mA were observed for all samples and less than 1 mA is not counted as it is considered noise in this test [6]. It is observed that the leakage current had started when the contaminant flow on the sample surface and promote to dry band bridged the electrodes. Small spike are observed across the dry band due to the surface resistivity dropped. The absorption of contaminated water increases the leakage current and sometimes had seriously depended on material properties [6,10,16].

The sample without nanofiller kept unchanged during the tracking test. The TPE added with different types of nanofiller have a different characteristic of leakage current [19]. It can be said that the addition of nanofiller increased the leakage current characteristics unless for the sample with aluminum oxide (S3). In this study, the results indicated that the additional of monmorillonite (MMT) in the compounding has no degradation occurred for 4 hours electrical tracking test. However, the sample with aluminum oxide experienced failed due to burning takes place just before 4 hours test and has to stop early. For the sample with silicon dioxide (S4) was observed degraded zone on the surface. It is believed that the proper process of nanofiller is also important to avoid the agglomeration of the polymer [2]. From the results, it can be seen that the compounds without nanofiller (S1) and added with MMT nano-filler (S2) offers the best surface tracking properties. However, the peak leakage currents for S2 can be achieved until 25.424 mA compared to S1 with 17.232 mA. Perhaps the contents of 80% HDPE and 20% NR in the compound could impart high electrical tracking and fire retardant. It is believed that the nanofillers are not necessary for certain composition of compounds for improving surface tracking properties. In this study, the application of nanofiller to TPE in order to obtain high endurance to tracking degradation is not significant. Hence, the type of nanofillers and polymer formulation is important to preserves the good material properties and obtain high endurance to tracking degradation.

This explanation is supported by visually inspection on carbon track propagation of the four different samples of material compositions as shows in Fig. 2 to Fig. 5. It was found that the samples of S1 and S2 were observed with no tracking formation on the material surface although they had experienced high leakage current. However, for the sample of S3 was observed burned in the next 2 hours test as well as the sample S4 was observed tracking formation.

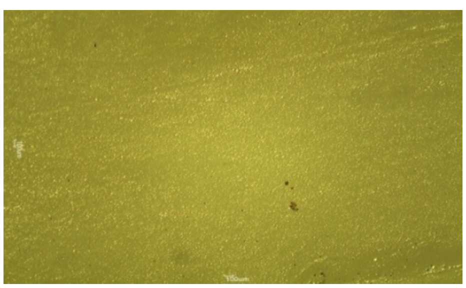

Fig. 2. View of the samples S1 after inclined-plane tracking test.

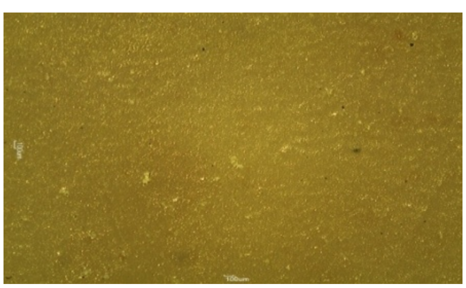

Fig. 3. View of the samples S2 after inclined-plane tracking test.

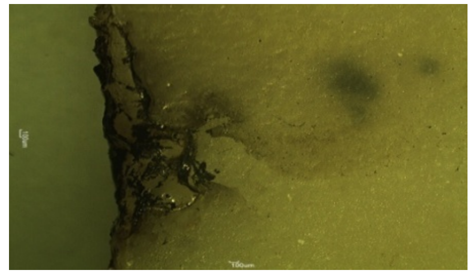

Fig. 4. View of the samples S3 after inclined-plane tracking test.

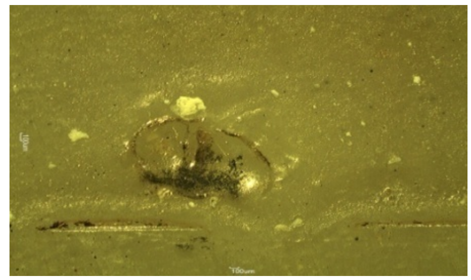

Fig. 5. View of the samples S4 after inclined-plane tracking test.

4 Conclusion

In this paper, TPE nanocomposites with weight percentage of 80% HDPE and 20% ENR-50 have been used as a base composition. MMT, Al2O3 and SiO2 with 2 phr have been added in the compositions in order to clarify the leakage current characteristics and carbon track formation on the surface material. The electrical tracking test under high voltage application was used to measure the electrical tracking performance of TPE nanocomposites. The effect of nanofillers to thermoplastic elastomers (TPE) nanocomposites was determined by measured the average leakage current. Dry band or carbon track development was visually observed on the surface sample. The compound of 80% HDPE and 20% NR without nanofiller loadings shows the best in surface tracking properties due to lowest average leakage current value. It is shown that nanofillers are not necessary for the thermoplastics elastomer composition for the purpose of improving surface tracking properties. Although all samples were subjected to the same test procedure, the compound of ratio 1:4 (NR: HDPE) is the best in surface tracking.

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