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Analysis of Surface Tracking of Micro and Nano Size Alumina Filled Silicone Rubber for High Voltage AC Transmission

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Abstract – This paper discusses the experimental results in an effort to understand the tracking and erosion resistance of the micro and nano size Al_2O_3 filled silicone rubber (SIR) material which has been studied under the AC voltages, with ammonium chloride as a contaminant, as per IEC 60587 test procedures. The characteristic changes in the tracking resistance of the micro and nano size filled specimens were analyzed through leakage current measurement and the eroded masses were used to evaluate the relative erosion and tracking resistance of the composites. The fundamental, third and fifth harmonic of the leakage current during the tracking study were analyzed using moving average current technique. It was observed that the harmonic components of leakage current show good correlation with the tracking and erosion resistance of the material. The thermogravimetry- derivative thermo gravimetric (TG-DTG) studies were performed to understand the thermal degradation of the composites. The physical and chemical studies were carried out by using scanning electron microscope (SEM), Energy Dispersive X-ray analysis (EDAX) and Fourier Transform Infra-red (FTIR) Spectroscopy. The obtained result indicated that the performance of nano filled SIR was better than the micro filled SIR material when the % wt. of filler increased.

Keywords: Leakage current, Nano filler, Outdoor insulator, Silicone rubber, Tracking resistance, Third harmonic and fifth harmonic

1. Introduction

This Power transmission at high voltages has been acquired considerable prominence in recent times. The glass and ceramics were the preferred materials for insulators, bushings, cable terminations and surge arrestors for many years. Recently, polymeric insulators are increasingly being used in both the distribution and the transmission system and are steadily capturing a wider share of the market, because of their better dielectric properties, low weight, easy handling, vandal resistance, and cost effectiveness [1]. With the advancement of power transmission capability, it has become more important to design and develop a compact, cost effective and reliable insulation structures. Outdoor insulation is simultaneously subjected to a variety of stresses, e.g., electrical, thermal, mechanical, etc., which causes degradation or aging of the insulating material. Aging leads to a gradual loss of electrical and mechanical strength of the insulator and to material deterioration. Another problem yet to be overcome is the tracking and erosion of outdoor polymer structures. Tracking is a peculiar phenomenon, which occurs on the surface of the insulation structure because of the creepage discharge resulting from surface contamination. The worlds over researchers are trying to mitigate the tracking and erosion process in outdoor polymeric insulators by their extensive research.

Once tracking occurs, the surface electrical insulation property is lost completely and it never recovers. In order to improve the reliability and the performance of the insulation materials, the tracking phenomenon is being investigated worldwide. In order to solve the problem of surface degradation and to reduce the effects of tracking and erosion of the material, inorganic micro sized fillers were incorporated into the polymer materials and the results were reported in many papers [2, 3]. Choosing proper filler is one of the most important aspects of silicone composite formulation and is based on the filler properties such as particle size, surface area, thermal and electrical conductivities. It was reported that micro filler contents from 30 to 65% by weight are necessary to achieve the required electrical properties for outdoor insulation applications [4].

Recent approaches to fulfilling an ever-increasing requirement for high performance outdoor insulation material tend to focus on polymer nano-composites. Nanotechnology has introduced the applications of nano fillers to enhance the electrical and mechanical properties of the insulating materials. One of the advantages of nano sized fillers is their large specific surface area when compared with micro sized fillers. Considering these facts, in the present study, a due emphasis was given to understand the tracking and erosion resistance of the micro sized alumina filled and nano sized alumina filled silicone rubber material, by performing experiments according to

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IEC-60 587 [5], under AC voltage, with ammonium chloride as the contaminant. The effect of filler concentration on the leakage current signals was analyzed by using high sampling rate data acquisition system (National Instruments). The characteristic variations in the fundamental and harmonic component of leakage current signals of both micro and nano size filled silicone rubber material were studied. Erosion and tracking resistance measures of micro and nano size filled composites were also studied. The TG-DTG and SEM with EDAX and FTIR were used to explain the mechanism by which the nano-fillers improve the tracking and erosion resistance of silicone composites.

2. Material and Sample Preparation

High temperature cured Silicone Rubber (SIR) material (Dow Corning, USA) was used in the present study as a base material. It is ensured that the base material has no filler of any type which may influence the experimental results. Aluminum oxide (Al_2O_3) of size<80nm, purity >99% supplied by Hefei Jiankun Chemical Industry was used for making nano size filled silicone rubber specimens. Commercially available Al_2O_3 of size 5-10 µm were used to prepare the micro size filled silicone rubber specimens.

The samples were prepared at different filler concentrations such as 5, 10, 20 and 30 % by weight of the micro and nano size fillers. The base silicone rubber and fillers were weighed accurately and mixed thoroughly. After the addition of curing agent, the mixture was stirred again, poured into a mould and degassed. Two stages of curing process such as primary and post curing were carried out. In the primary curing, mould with the material was allowed to cure at 200˚C for 2 hours. During the post curing process, it is kept in oven at 170˚C for 16 hours. Two rectangular samples of size 34 cm (L) X 34 cm (B) X 5 mm (H) were prepared from each composition and were cut into the appropriate size according to IEC 60587 test procedures.

3. Experimental Setup

Fig. 1 shows the schematic diagram of the experimental setup and the electrode configuration used in the present study. The tracking resistance test on the silicone rubber material was carried out following the IEC-60 587 inclined plane test method. The gap distance between the high voltage and the ground electrode was adjusted to be equal to 50 mm. The specimen was mounted at an angle of 45º and the contaminant was allowed to flow from high voltage to ground electrode over the surface of the plate specimen. 0.1% NH_4Cl was used as a contaminant. 0.02 % weight non-ionic wetting agent (TritonX-100) was added to the contaminant to increase the surface wetting of the insulation material under test.

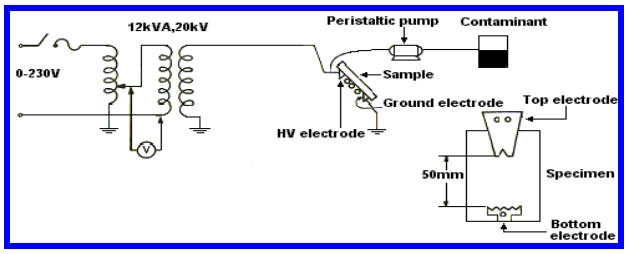

Fig. 1. Schematic Diagram of Experimental Setup

The conductivity of the contaminant was measured using a EuTech conductivity meter. AC voltage of 4KV is connected to the top electrode and the bottom electrode is solidly grounded. The flow rate of the contaminant solution was maintained at 0.6 ml/min using a peristaltic pump and the conductivity of the contaminant was maintained at 2500 µS/cm. A set of six specimens were used to arrive at the tracking resistance of the material at a specified experimental conditions and the time to failure is the average of six failure times. The deviation in failure times in this set of experiments were within 3 % of the mean of the failure times.

The leakage current measurement was carried out using a high frequency current transformer connected in the ground lead. A 1.25 Mas (Mega samples) sampling rate data acquisition system (National Instruments) was used in the present study. A software system developed for this data acquisition system provides the user with the complete LC waveforms, which are therefore available for further processing.

4. Thermo Gravimetric and Derivative Thermo Gravimetric Analysis(TG-DTG)

Thermal stability of the material is important as it influences the tracking and erosion performance (which directly depends on the thermal decomposition) of the material during the inclined plane test. Thermo-Gravimetric (TGA) analysis and Derivative Thermo Gravimetric (DTG) analysis help to understand the thermal stability of the material. TGA gives the change in weight loss of a sample with respect to temperature. A DTG curve shows 1st order derivative weights (Wt. % /min) on the y-axis and temperature on the x-axis. The DTG is constructed using the TGA data and it indicates the rate of weight loss or degradation of the material with temperature. A Perkin Elmer Pyris Diamond TG/DTA instrument, USA was used for the studies. Sample weight of about 15 mg was used for the TGA studies. The measurement was made in a nitrogen gas atmosphere at warm room temperature to 700 ºC with a rate of 20 ºC/minute. The temperature was increased from 100ºC to 800ºC.

5. Scanning Electron Microscopy Analysis (SEM)

SEM has been used for studying the filler dispersion in the silicone rubber. SEM Instrument make JEOL model: JSM 6390 with energy dispersive X-ray analysis (EDAX) attachment, JAPAN has been used to obtain the images.

6. Fourier Transform Infra-Red (FTIR) Spectroscopy

FTIR spectroscopy has been used to identify the functional groups on the surface. These functional groups on the surface of the nano-fillers help to understand the interaction between the filler and the silicone rubber at the interface in the composite. Thermo Electron Corporation USA, Nickolet-model 670 was employed to obtain the IR spectra.

7. Results and Discussion

7.1 Evaluation of erosion and tracking resistance

Fig. 2 Tracking time of silicone rubber material shows the variations in tracking time of the silicone rubber specimen with micro and nano sized filler. The nano size Al_2O_3 filled SIR has showed improved tracking resistance when compared with micro size Al_2O_3 filled SIR at all filler concentration. No failure of specimen has occurred due to tracking in the case of nano size filled SIR at concentration more than 10 % wt. It was noticed that the tracking resistance characteristics of 30% micro size filled specimen is comparable with 5% nano size filled specimen. This clearly showed that when the filler particle is of nano size, then significant reduction in %wt. filler concentration was achieved to get the same tracking resistance of the material with micro fillers. To understand the eroded volume of the materials due to tracking test, the weight of the sample before and after tracking test were measured.

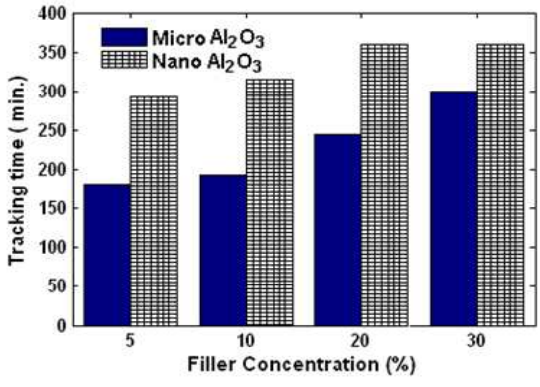

Fig. 2. Tracking Time of Silicone Rubber Material

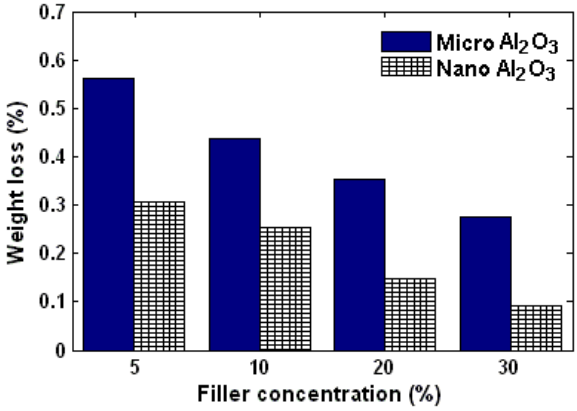

Fig. 3. Weight Loss of Silicone Rubber Material after Tracking Test

Fig. 3 shows the weight loss of the silicone rubber material after tracking test. It was clear that irrespective of the type of filler, when the % wt. filler concentration increases, the % wt. loss of the material reduces.

However, when compared with micro filled specimens, the nano filled specimen showed less weight loss, which is closely related with the tracking time results. Fig. 4 shows the photograph of tracked path of 10 %, 30 % of micro and nano filled sample after the inclined plane tracking and erosion resistance test. It was noticed that the significant difference in eroded depth and length between the10 %, 30 % of micro and nano filled SIR matrix. The erode track length and depth of nano filled SIR was less when compared with micro filled SIR was noticed. The reasons for the improved erosion resistance of the nano composite were due to the better thermal stability of the nano systems.

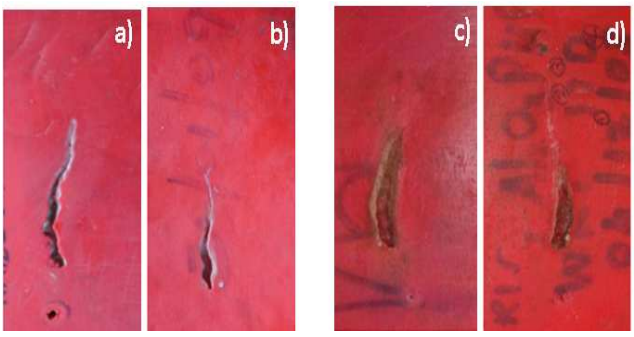

Fig. 4. Photograph of Tracked Path of SIR Specimens: (a) 10 % micro filled; (b) 10 % nano filled; (c) 30 % micro filled; (d) 30 % nano filled

7.2 Analysis of leakage current

To understand the surface degradation of the silicone rubber insulating material, it is better to carry out frequency domain analysis of leakage current signals. In this work, FFT algorithm was adopted to understand the frequency contents of the signal. It was reported in earlier

papers that the presence of third order harmonic and fifth order harmonic components play a major role in order to predict the surface degradation of the silicone rubber insulating material [6-8]. Since the harmonic components were mainly involved in the thermal stress and surface degradation of the material, it is necessary to carry out the time series trend analysis of the harmonic components with respect to fundamental component. In this work, the trend followed by the fundamental, third and fifth harmonic component during the tracking process was evaluated using the moving average technique

Fig. 5 shows the moving average fundamental component of LC signal of micro and nano filled SIR matrix during tracking test. It was noticed that the fundamental component of LC signal does not give any significant information with respect to % wt. of filler concentrations. Since the trend followed by the fundamental component of LC is highly intermittent in nature, it was very difficult to differentiate the micro size and nano size filled silicone rubber materials. Therefore, trend analysis of harmonic components was also carried out in order to extract useful information.

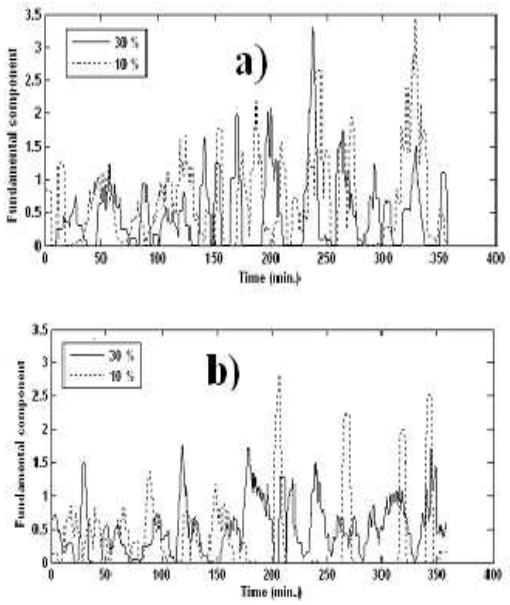

Fig. 5. Moving Average Fundamental Component of LC Signal of: (a) micro size; (b) nano size Filled SIR

Fig. 6 shows the moving average third harmonic component of LC signal of micro and nano filled SIR matrix during tracking test. It was observed that, whenever there was a surface discharge due to the formation of dry bands on the surface of the insulating material, then the third harmonic significantly increases and this was the major cause for surface deterioration of the material. In general, it was observed that the magnitude of the third harmonic component is high with micro size filled SIR specimens when compared with nano size filled specimens. It was also noticed that with respect to increase in % wt. of filler concentration, the magnitude of third harmonic component significantly reduced in both micro and nano filled specimens. These results were well correlated with the tracking resistance and weight loss characteristics of micro and nano filled SIR material.

Fig. 7 shows the moving average fifth harmonic component of LC signal of micro and nano filled SIR matrix during tracking test. Considerable difference in fifth harmonic magnitude is noticed with respect to different % wt. of filler concentrations in both micro and nano filled specimens. It was noticed that when compared with micro filled material, the magnitude of fifth harmonic component with nano filled material is low. This also confirms the

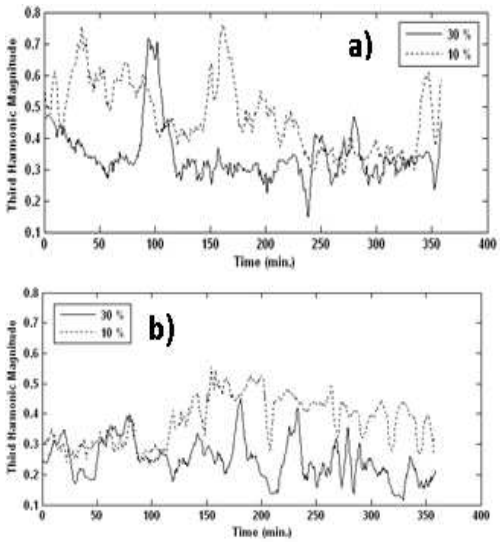

Fig. 6. Moving Average Third Harmonic Component of LC Signal of: (a) micro size; (b) nano size filled SIR

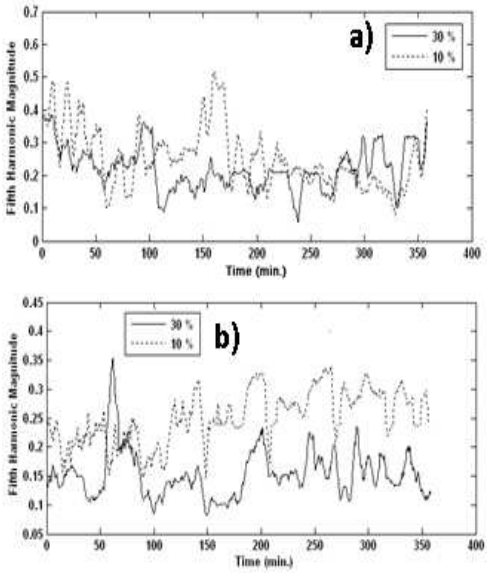

Fig. 7. Moving Average Fifth Harmonic Component of LC Signal of: (a) micro size; (b) nano size filled SIR

results obtained with IEC 60587 tracking resistance tests.

7.3 TG and DTG analysis

Thermo Gravimetric Analysis (TGA) is a technique in which the weight change of a material is monitored as a function of increasing temperature and is therefore a measure of its thermal stability. As the temperature increases, a weight loss takes place due to the release of moisture or gases from the decomposition of the material. The erosion and tracking is mainly due to locally developed temperature caused by continuous leakage current.

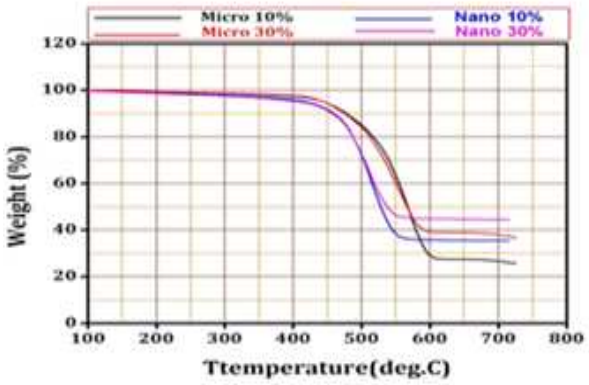

Fig. 8. TGA Analysis of micro and nano size Al_2O_3 Filled SIR Samples

To explore the possible improvement in erosion and tracking resistance of the micro and nano filled sample, initially the TGA analysis was conducted. TG curves of the solid residues under the heating rate of 20ºC /min in nitrogen gas atmosphere. Fig. 8 shows the TGA curve of 10 % and 30 % of micro and nano filled SIR samples. The TGA curve of 10 % and 30 % of nano filled SIR lies below the 10 % and 30 % micro filled SIR samples, which indicates that the rate of degradation of nano sized Al_2O_3 filled SIR samples is higher than the micro sized Al_2O_3 filled SIR samples. The % wt. of the sample after the TGA test gives the residual weight which is also an indicator of the thermal stability apart from the rate of degradation during TGA. The residual % wt. of nano filled SIR after the TGA test was higher than the micro filled SIR even though the rate of degradation was high. The resultant residual weight calculated by subtracting the filler weight from the residual weight of 10 % and 30 % of micro and nano alumina filled SIR. The measured weight loss and calculated residual weight, resultant residual weight is shown in Table 1. Unless there is some significant interaction between the nano fillers and SIR matrix, it is not possible to get such a high residual weight and resultant residual weight in TGA for the nano composites. Table 1. also shows the weight loss, residual weight and resultant residual weight of nano filled SIR has less difference in % wt. while increasing the % wt. of filler from 10 % to 30 % in SIR matrix. On the other hand, the weight loss, residual weight and resultant residual weight of micro filled SIR were significant difference in % wt. While increasing the % wt. of filler from 10 % to 30 % has been noticed. It clearly shows that the thermal stability of micro filled SIR is naturally improved by increasing the filler concentration [9]. But in the case of nano filled SIR, thermal stability improvement is due to filler and silicone rubber interaction not because of filler concentration as in the case of micro filled SIR has been observed.

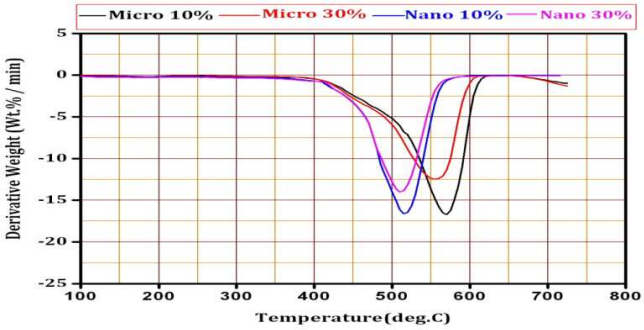

Fig. 9. Derivative Weight loss Analysis of micro and nano size Al_2O_3 Filled SIR.

Fig. 8 shows the gradual weight loss in 10 % micro filled SIR was at 210-609 ºC and considerable weight loss continuing after 680 ºC, whereas the nano filled SIR gradual weight loss was at 200-560 ºC and there was no weight loss after 560ºC. Similarly, the gradual weight loss in 30 % micro filled SIR was at 250-597 ºC and considerable weight loss continuing after 652ºC, where as the nano filled SIR gradual weight loss was at 230-560ºC and there was no weight loss after 558ºC. It was noticed that the second set of weight loss taken place at 680ºC in 10 % and at 652ºC in 30 % of micro filled SIR matrix. But there was no second set of weight loss taken place in nano filled SIR matrix was observed, it was only due to the

Table 1. 1 % Weight Loss, Residual Weight after Conducting the TGA Test and Resultant Residual Weight of 10 % and 30 % micro and nano filled SIR.

Filler Concentration by % weight	% Weight loss in micro filled SIR	% Weight loss in nano filled SIR	% Residual weight in micro filled SIR After TGA	% Resultant Residual weight in nano filled SIR	% Resultant Residual weight in micro filled SIR	% Resultant Residual weight in nano filled SIR
10	73	64	27	36	24.3	32
30	61	55	39	45	27.3	31.5

influence of nano fillers in SIR matrix.

Derivative Weight Loss Analysis of micro and nano size Al_2O_3 filled SIR (Fig. 9) gave similar results of TG. The wide degradation temperature range of 10 % and 30 % micro filled SIR somewhat imply the poor dispersibility of micro Al_2O_3 fillers in SIR matrix. The value of derivative for 10 % micro and nano filled SIR was higher than those of 30 % filled SIR matrix. It presents the inorganic components can restrain polymer from thermal degradation while increasing the filler weight percentage. It also showed that the addition of filler % wt. can slow down the rate of degradation. The Table 2. shows the highest temperature corresponding to maximum weight loss rate of the micro and nano filled SIR matrix. From the DTG curve, it can be accepted that the presence of micro and nano fillers has improved the thermal stability of the silicone rubber matrix while increasing the filler wt. % from 10 % to 30 % in SIR matrix. However, the thermal stability of nano filled SIR was more than the micro filled SIR was observed from the Table 1. The TGA weight loss results of micro and nano filled SIR samples were agreed with the inclined plane test results.

Table 2. Maximum Temperature and Weight Loss Rate of micro and nano Filled SIR

Sample	Maximum temperature	Weight loss rat (%/min)
Micro 10%	569 ºC	16.6
Micro 10%	518 ºC	16.4
Micro 30%	554 ºC	12.3
Micro 30%	511 ºC	13.7

7.4 Surface analysis using SEM with EDAX

To examine the dispersion of micro and nano Al_2O_3 fillers on the silicone rubber matrix, a detailed scanning electron microscopy (SEM) investigation was conducted on micro and nano filled SIR samples. Fig.10 shows the filler dispersion of 10 % and 30 % of micro and nano filled SIR matrix. It is observed that here was a significant difference in the dispersion of the micro and nano particles. The particles were isolated and scattered uniformly over the area of specimen with less number of particles in micro filled silicone rubber, where as good filler dispersion over the entire area of the specimen with large number of particles in nano filled SIR was noticed. The good filler dispersion in nano filled SIR may be due virtue of their size and they were effectively mixed with silicone matrix than micro filler. The fine dispersion was visualized as it may lead to strong bonding between the nano fillers and silicone rubber. This strong bonding may help to reduce the weight loss in the nano filled SIR while increasing the temperature. This result was observed in TG-DTG analysis. Therefore, it can be stated that the dispersion of the fillers aided to resist further the weight loss when increasing the temperature in the SIR material.

Energy dispersive X-ray spectroscopy analysis (Fig.11) was used to find the spatial distribution of elements or compounds in the surface layer of the composites with micro and nano size Al_2O_3 fillers. The elements Si, O, C were the predominant elements which have been detected on the surface of the SIR specimens. The high level of Si and low level of O detected in the X-ray counts originate from (Si-O-Si) backbone of the silicone chain in both micro and nano filled SIR. Aluminum (Al) was detected only in nano filled SIR matrix where as Al was not found in micro filled SIR, this may be due to the deficiency of filler on SIR surface or may be due to silanization of Al_2O_3 filler during the manufacturing processes.

Table 3. Shows both the weight percentage (Wt. %) and atomic percentage (At. %) measured from EDAX analysis. A distinct difference between micro and nano filled SIR was found. An increase in both the silicone and oxygen concentrations was observed in micro filled SIR compare to nano filled SIR sample and Al were not present in micro filled SIR, this was due to deficiency of filler in micro filled SIR. A deficiency of filler was indicated by a decrease in Al count rate and an increase in the Si and O count rate [10] was observed from the energy dispersive X-ray spectrum in Fig.11. The weight percentage (Wt. %) and atomic percentage (At. %) of Al element in 10 % and 30 % of nano filled SIR specimen were different. It may be due to the higher filler concentrations which will result fewer organic molecules exposed at the surface of the sample [10].

Table 3. EDAX Analysis of micro and nano Filled SIR

Sample	Si		O		Al	
	Wt%	At%	Wt%	At%	Wt%	At%
Micro 10%	61.67	47.82	38.33	52.18	-	-
Micro 10%	45.09	34.49	39.84	53.51	15.07	12.00
Micro 30%	56.99	43.01	43.01	56.99	-	-
Micro 30%	51.79	39.80	39.39	53.15	8.82	7.06

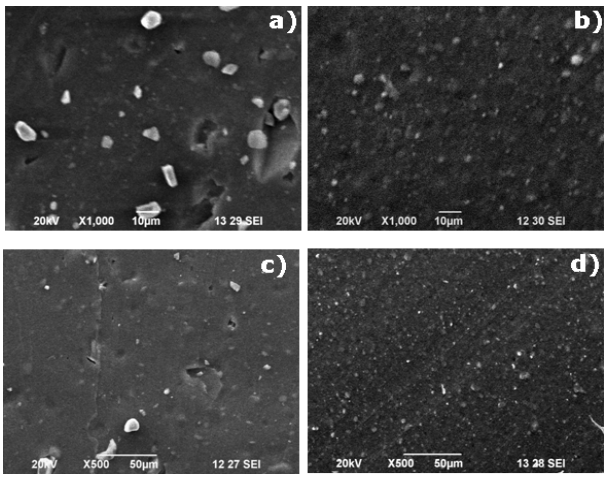

Fig. 10. SEM Images of SIR Samples: (a) 10 % of micro filled; (b) 10 % of nano filled; (c) 30 % of micro filled; (d) 30 % of nano filled.

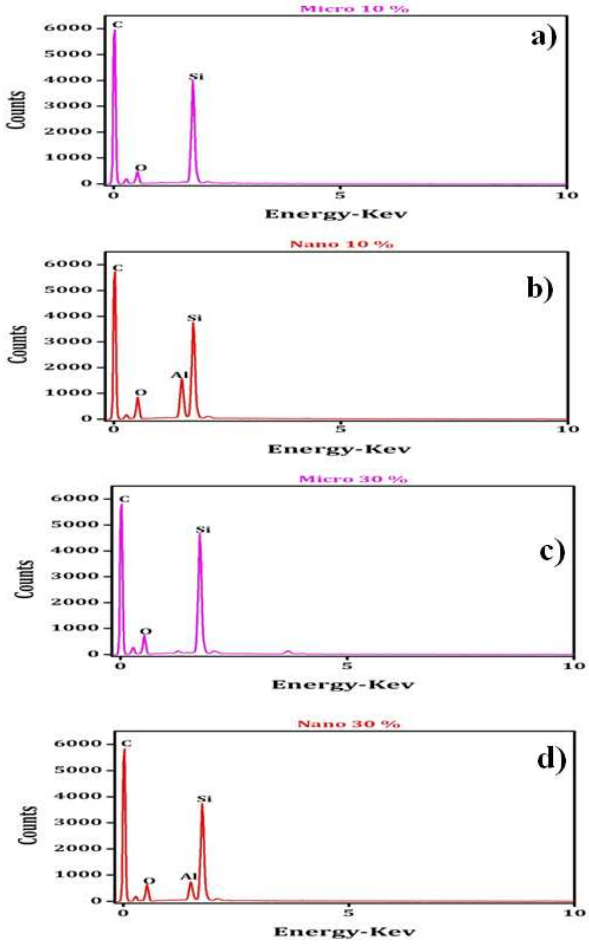

Fig. 11. Energy Dispersive X-ray Spectrum of SIR Samples: (a) 10 % of micro filled; (b) 10 % of nano filled; (c) 30 % of micro filled; (d) 30 % of nano filled

7.5 Surface analysis using FTIR

Fourier Transform Infrared Spectroscopy (FTIR) Technique was used to identify the functional groups present in the SIR specimen. Fig. 12(b) shows the FTIR spectrum of 10 % nano filled silicone rubber. It was observed that a small peak around 3446 cm^{-1} which was due to hydroxyl groups on the prepared nano particles that were bound either to absorbed water molecules or to each other (hydrogen bonding) in the nano filled SIR matrix [11]. The two peaks at 2903 cm^{-1} and 2829 cm^{-1} corresponding to asymmetrical and symmetrical stretching of CH_3 and CH_2 [11]. The peaks around the 2353 cm^{-1} may be due to the absorbed carbon dioxide on SIR surface [12]. The peak at 1680 cm^{-1} is due to the weakly absorbed (C=O) carbonyl group [13] and the peak at 1645 cm^{-1} indicates the deformation of OH groups or water molecules present in the SIR. The side chain Si-CH_3 at wave number 1280 cm^{-1} and the backbone Si-O peak at wave number 1087 cm^{-1} has been noted [14]. The stretching vibration spectrum at 1520 cm^{-1} corresponds to Al-OH bond. The Al-O bond with

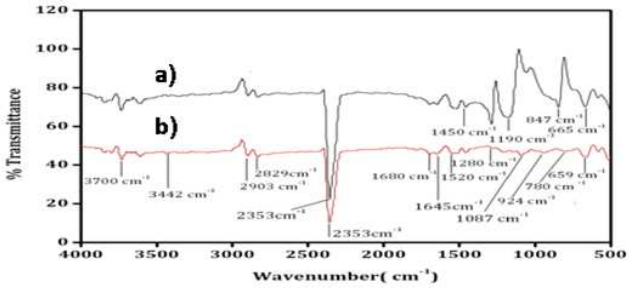

Fig. 12. FTIR Spectra of SIR Samples: (a) 10 % of micro filled; (b) 10 % nano filled

small peak found in nano filled SIR matrix is around 924 cm^{-1}. But the peak at 659 cm^{-1} and 780 cm^{-1} corresponds to stretching vibration of Al-O in octahedral and tetrahedral coordination [15].

In Fig. 12 (a) the 10 % micro filled SIR was similar to that observed for 10 % nano filled SIR matrix. The OH ions produced the same bands reported for this ions in10 % nano filled SIR. But the small band around at 3442 cm^{-1} completely disappeared, indicating that the hydroxyl groups (OH) on the surface of the micro particles that were significantly less than the nano particle [16]. The band region between 1450 cm^{-1} to 659 cm^{-1} was an increased transmittance as compared to the nano filled SIR. This was due to decreased silicone that diffused on the surface in this region and the above results were supported by the EDAX analysis. The difference observed in transmission intensities between the two samples was most likely due to the chalking of the Al_2O_3 on the surface of the sample [17]. The peak around at 924 cm^{-1} corresponds to Al-O bond which was completely disappeared, indicating that the absence of Al-O bonds. The above results were also supported by EDAX observation. But the peaks around 659 cm^{-1} and 780 cm^{-1} in nano filled SIR were shifted to 665 cm^{-1} and 847 cm^{-1} in micro filled SIR with high intensity. This shift was initiated by a stronger Al-O bond. The side chain Si-CH_3 at wave number 1280 cm^{-1} has high intensity than nano filled SIR matrix, it indicated that the transmittance was high and absorption was less due to silicone diffused on the surface. An increase in the absorption means that a larger amount of silicone is present on the surface. This was due to increased silicone that diffused to the surface [18]. The changes in Si-O-Si bonds occurring in between 1100 cm^{-1} -1000 cm^{-1} were due to the formation of 2 or 3 dimensional Si-O bonds [14].

Fig.13(a, b) shows the 30 % micro and nano filled SIR, this was similar to that observed for 10 % nano and micro filled SIR matrix with the smaller changes in the peak positions and intensity of the bonds. This may be due to the increased in filler percentage levels from 10 % to 30 % by weight. It was observed that the nano filled SIR matrix has higher intensity when increasing the filler concentration levels than the micro filled SIR matrix. It may due to the

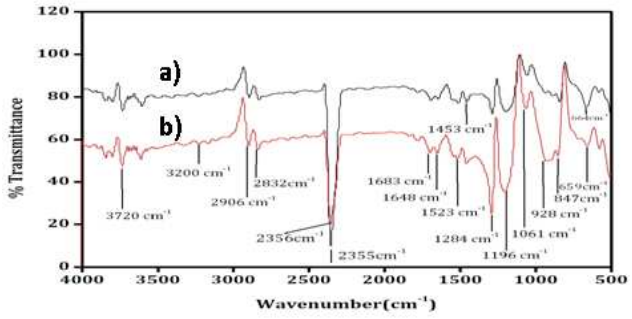

Fig. 13. FTIR spectra of SIR Samples: (a) 30 % of micro filled; (b) 30 % of nano filled

virtue of their size and the interfacial effects introduced by the nano fillers with SIR matrix, this will support the surface behavior of SIR matrix.

8. Conclusion

Experimental results on tracking and erosion resistance characteristics of silicone rubber filled with micro and nano size Al_2O_3 fillers have been compared using an inclined plane tracking and erosion resistance test. Physical (SEM), chemical (EDAX, FTIR) studies, thermal (TGA and DTG) and electrical studies (leakage current) have been used to carry out the studies. The above analytical results were in good agreement with the erosion performance during the inclined plane test. From the obtained results, it can be stated that the nano filled SIR erosion performance was good as compared to micro filled SIR. It was also noticed that the erosion performance was good when the filler % by weight increased. The physical studies on the micro and nano filled SIR samples were carried out in which the nano filler and the SIR matrix attributed to the better bonding between them than the micro filler with SIR matrix. The significant improvement in nano filled SIR in terms of weight loss and thermal stability when comparing with the micro filled SIR samples when increasing the filler % wt. and the results were agreed with the inclined plane test results. The variations in third harmonic and fifth harmonic leakage current were closely related to the surface degradation of the material at both micro and nano size filled silicone rubber and the superior performance of the nano filled SIR was achieved. The EDAX and FTIR studies also resulted in the idea that the nano particles interact with the SIR matrix and thereby, played a role in the erosion performance of the SIR matrix. The different % by weight of nano Al_2O_3 filled SIR were promising the better flexibility, ease of processing during the product manufacturing and at the same time better electrical, physical, chemical and thermal performance was attributed than the micro Al_2O_3 filled SIR.

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