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Experimental Investigation on Thedielectric Performance of Silicone Rubber Nanocomposites

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Abstract: The application of nanoparticles to meliorate the electrical properties of dielectric materials isa modern innovation. This paper presents the preparation of silicone rubber Nano composites using Zinc Oxide and Silica nanoparticles. Test specimens are prepared using Room Temperature Vulcanized(RTV) Silicone rubber, TSC3031. Specimens with and without nanoparticles were prepared indigenously. The erosion resistances of these samples are tested by standard Inclined Plane Test specified in IEC 60583. The tracking test results show that theNano composite samples required more tracking time and power than thespecimens without nanoparticles .The improvements in the electrical properties of the silicone rubber Nano composites for different weight percentage of nanoparticles are comparedand analyzed.
Index Terms: RTV Silicone rubber, Nanocomposites, Erosion Resistance, Inclined Plane Test(IPT).

Introduction

Silicone rubber is an elastomer containing silicone together with carbon, hydrogen and oxygen. RTV Silicone rubber is an excellent insulating material due to its broad energy gap and very narrow conduction bands. Silicones will have a high electrical resistivity and low dielectric loss factor [1].

This silicone rubber is widely usedin power industries as an insulator due to its eminent dielectric properties [2]-[3].However enhancement in the properties of the polymeric material can be achieved by suitably adding nanoparticles with the base polymer. It was reported by many researchers that adding inorganicnanofillers to polymers in small amount of 2 to 5 %wt can enhance electrical, thermal and mechanical properties [1]-[5]. TSE 3031 is a two part form RTV silicone rubberwhich is a lowviscosity, non-transparent material found as electrical insulating material in cables, outdoor insulators, insulator coatings etc.[6].

The application of nanoparticles in several polymer resins in electrical insulation conceptuality is well established. It has already been reported by many researchers that the addition of appropriate filler to commercial polymer resign can improve electrical properties such as breakdown strength, insulation resistance, partial discharge resistance and dielectric loss etc.[5]-[6].Zinc Oxide nanoparticles are basically a benign and the main advantage of large band gap is such materials will have a higher breakdown voltage. Nanosilica isa form of porous silicon whichwill have a higher resistance to chemical attack from chlorides, acids, nitrates and sulfates.Thus by adding Nano silica to RTV silicone rubber the enhancementin the aging factor of the insulatorscan be achieved [7]-[9].

This work mainly focuses on study of erosion resistance of the silicone rubber Nano composites prepared by suitable indigenous method.Tracking is a continuous degradation of the surface of a solid insulating material by local discharges to from conducting or partially conducting paths. For the prepared samples tracking test is done to measure erosion resistance at ambient conditions and power frequency. Tracking test for Polymers is usually done according to IEC60587 Inclined Plane Test (IPT) [10]-[12].

Preparation of Samples

The base material TSE3031 Part A (Base silicone rubber) is curried by a two part curing method with special curing agent of TSE3031 Part B (Alkoxy catalyst) with a ratio of 100:5 %wt. For the conventional samples, therequired amount of Part A base material first mixed with nanoparticles by using the high shear force mixer. Then Part B curing agent is added at room temperature and required mold for IPT test was prepared. Different such samples are prepared with different weight proportions of ZnO and Silica nanoparticles. The nanoparticles were added slowly in small portions during mixing and constant speed was maintained to ensure uniform dispersion of nanoparticles. The optimum mixing time was different for different samples. To dissipate the heatduring mixing process, the beaker was kept in coldwater. The prepared samples are shown in figure 1. Table 1 and Table 2 shows different weight composition considered during the preparation of silicone rubber composites

Figure.1 a) Samples with Zinc Oxide nanoparticles, b)Samples with Nano silica nanoparticles

Table.1 Preparation of Silicone Rubber mold With ZnO Nanoparticles

Material	% wt Composition	%wt Composition
TSE3031 (PART A)	91.8	92.15
TSE3031 (PART B)	4.2	4.85
Zinc Oxide nanoparticles	4	3

Table.2 Preparation of Rubber mold with silicone Nanoparticles

Material	% Wt Composition	% Wt Composition
TSE3031 (PART A)	92.15	93.1
TSE3031 (PART B)	4.85	4.9
Silicone nanoparticles	3	2

Inclined Plane Test

Inclined plane test deals with the measurement of tracking resistance of electricalinsulating material under severe polluting conditions. The specimen under test kept at 45° inclination and tracking studies are carried out in the presence of liquidcontaminant such as ammonium chloride. Inclined Plane Test (IPT) test is carried out by twomethods for insulators operating under power frequency. The two methods are under power frequency (50Hz).

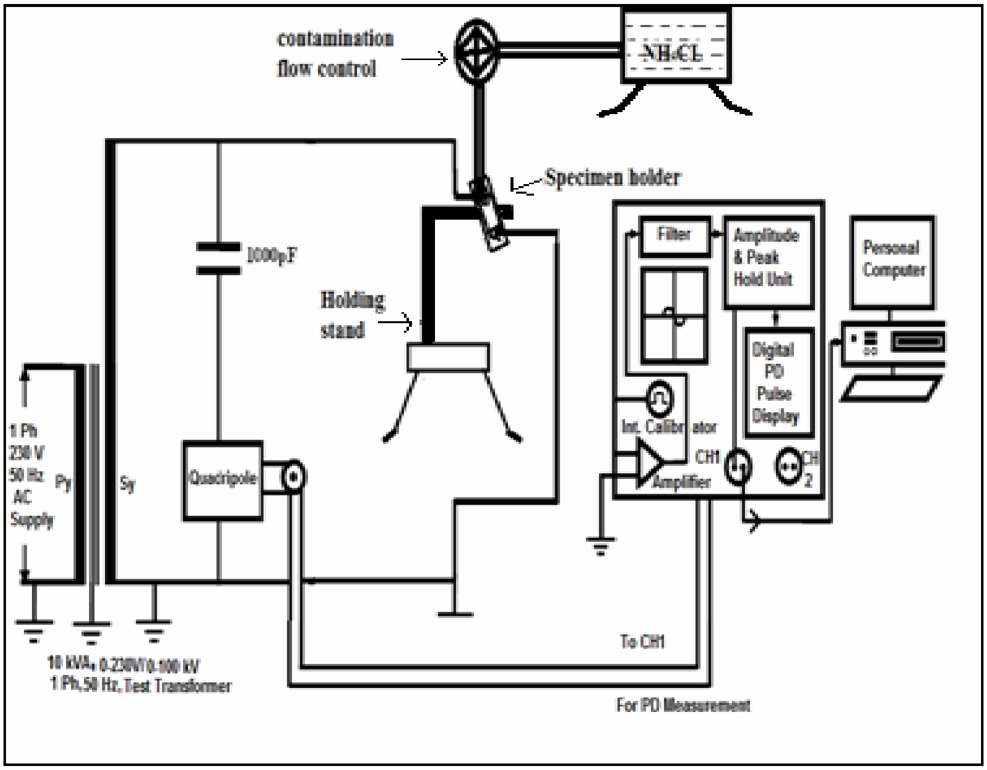
1) Constant voltage tracking method

2) Step-wise voltage tracking method

By using first method loading effect on the test transformer is morehence step wise voltage tracking method is used to carry out the test.

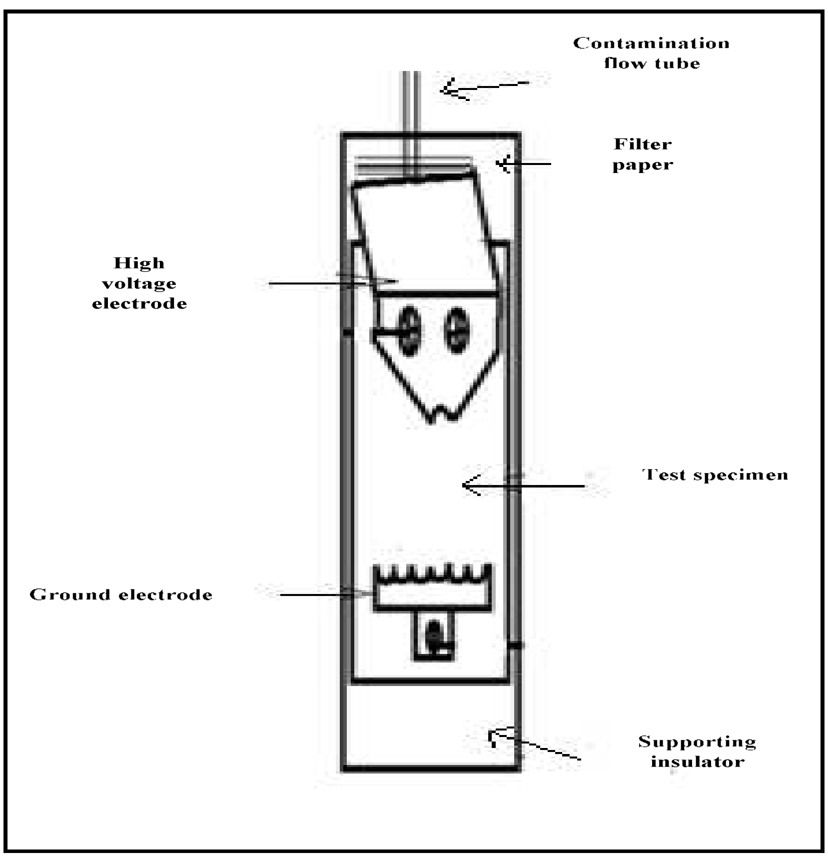
Step-Wise Tracking Method

The prepared test samples are cleaned properly and soaked for about 24 hours in ammonium chloride solution. The specimens are rubbed cleanly and the cleaned specimen is mounted on to test kit carefully to avoid contamination.50 Hz AC power frequency highvoltage up to 6 kV is used to carry out tracking studies using a high voltage test transformer of 100 kV/10 KVA rating. During tracking studies partial discharge measurements are carried out using Digital PD Measurement and Acquisition System(Model No.: DTM-D) comprising a digital storage oscilloscope (TDS 2002B) and a tunable narrow-band filter (Model: DFT-1) at a variable center frequency of range 600 kHz-2400 kHz at 9 kHz bandwidth. The test setup and electrodes configuration arespecially designed according to IEC60587 as shown in figure 2 and figure 3.



(a)

Figure 2. a) Schematic diagram of IPT test.



b) Specimen holder (b)

Figure 3.photograph of IPT test setup and PD measurement system

The contamination used in this study is 0.1% mass ammonium chloride solution (NH_4Cl). Filter paper of 8 layers is placed below a top electrode or high voltage electrode which will act as reservoir for the contaminant. The flow rate of contaminant with respect to applied voltage is as shown in figure 4.

The test specimen is inclined with an angle of 45° in the specimen holder.Initially contaminant flow rate should be checked such that the flow from a top electrode should reach the bottom electrode properly. The initial test voltage is chosen as 3 kV and this voltage is applied to high voltage electrode and the ground electrode has been properly grounded. The test voltage is gradually increased in steps of 0.25 kV until partial discharge is observed. The tracking pattern and duration of tracking has been analyzed for samples with and without nanofillers.

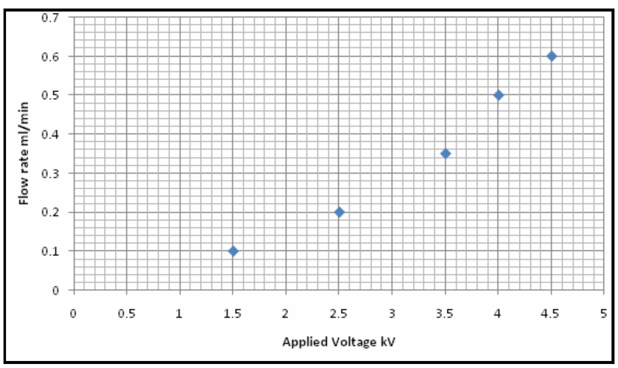


Figure 4.Applied voltage vs. flow rate of contaminant

Test Results

Specimen without nanoparticles

Figure.5 shows the eroded silicone rubber samples prepared without the insertion of nanoparticles. The voltage was gradually increased until partial discharge is observed in PD meter. Voltage was maintained at 4.01 kV and formation of tracking on the sample was observed Table.3 shows the time duration corresponding to various stages of study.

Figure 5.Eroded Silicone rubber with track length of 35mm

Table.3 Tacking studies for silicone rubber without nanoparticles

Applied voltage (kV)	Duration time (min)	Remarks
3.18	0-15	No tracking
3.44	15-30	No tracking
3.70	30-45	Audio corona
3.86	45-75	Initiation of track
4.01	75-100	Formation of dry band
4.01	100-115	Fully carbonized forming a black spot

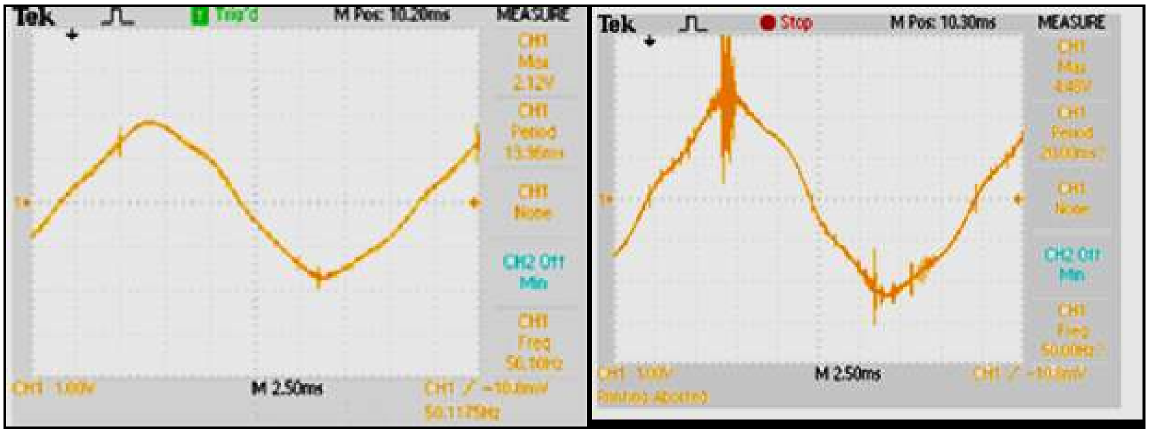


Figure 6.PD patterns at different voltages for silicone rubber

Figure 6 shows the PD patterns recorded during the initiation of tracking and during break down condition. It was observed that PD magnitude was increasing during the tracking process.

Specimens with Zincoxide Nanoparticles

Silicone rubber Nanocomposites prepared with 4 %wt of ZnO nanoparticles are considered for IPT test. The discharge inception voltage (DIV) was found to be greater than DIV for samples without nanoparticles. The tracking time duration was also observed to be greater than tracking time for samples without nanoparticles. Figure.7 shows the eroded portion of the silicone rubber-ZnO Nanocomposites.Table.4 shows the time duration corresponding to various stages of study.

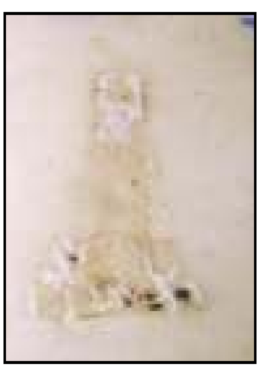


Figure 7. Eroded silicone rubber with ZnO nanoparticles with track length of 30mm

Table.4 Tracking analysis for silicone rubber with ZnO nanoparticles

Applied voltage (kV)	Duration time (min)	Remarks
3.12	0-10	No tracking
3.38	10-20	No tracking
3.89	20-30	No tracking

3.98	30-45	Audio corona
4.28	45-60	Audio corona
4.43	60-75	Initiation of track
4.43	75-90	Tracking grows
4.96	90-105	Forming of dry band
4.96	105-120	full tracking with white carbonized path
4.96	120-135	Forming a lightly black spot and white track is formed

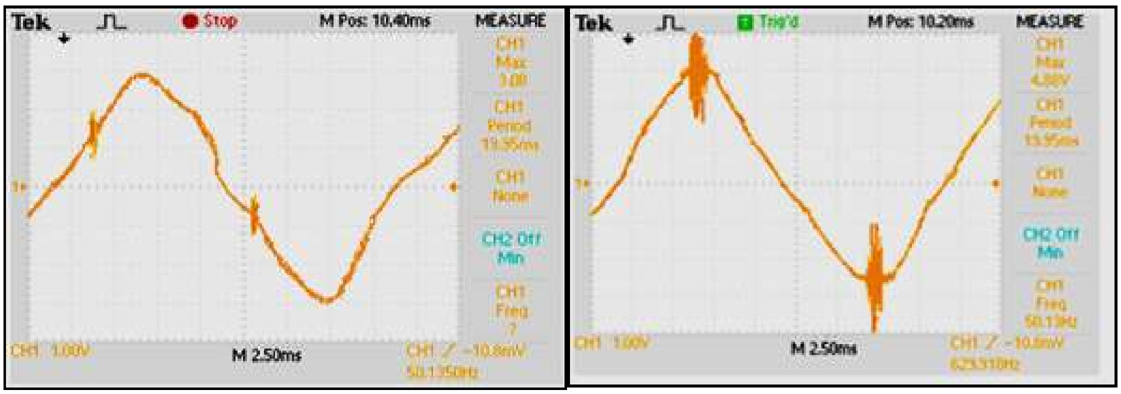


Figure 8. PD pattern at different voltages for silicone rubber with ZnO nanoparticles

The PD pattern shows that the magnitude of PD pulses are comparatively lesser when compared with samples without nanoparticles.

Specimen with Silicone Nanoparticles

Silicone rubber Nano composites prepared with 4 %wt of Silica nanoparticles are considered for IPT test. The discharge inception voltage (DIV) was found to lie in between the DIV for samples without nanoparticles and samples with ZnO. The tracking time duration was also observed to be lesser then the tracking time for samples with ZnO nanoparticles. Figure.9shows the eroded portion of the silicone rubber-silica Nano composites.Table.5 shows the time duration corresponding to various stages of study.

Figure 9. Eroded silicone rubber with silica nanoparticles with track length of 27mm

Table.5 Tracking analysis for silicone rubber with Silica nanoparticles

Applied voltage (kV)	Duration time (min)	Remarks
3.0	0-10	No tracking
3.32	10-20	No tracking
3.89	20-35	No tracking

4.12	35-50	Audio corona
4.28	50-65	Audio corona
4.28	65-85	Initiation of tracking
4.43	85-100	Tracking length increases
4.43	100-110	Forming carbonized path
4.43	110-120	Fully bridged between electrodes with full tracking with white carbonized path

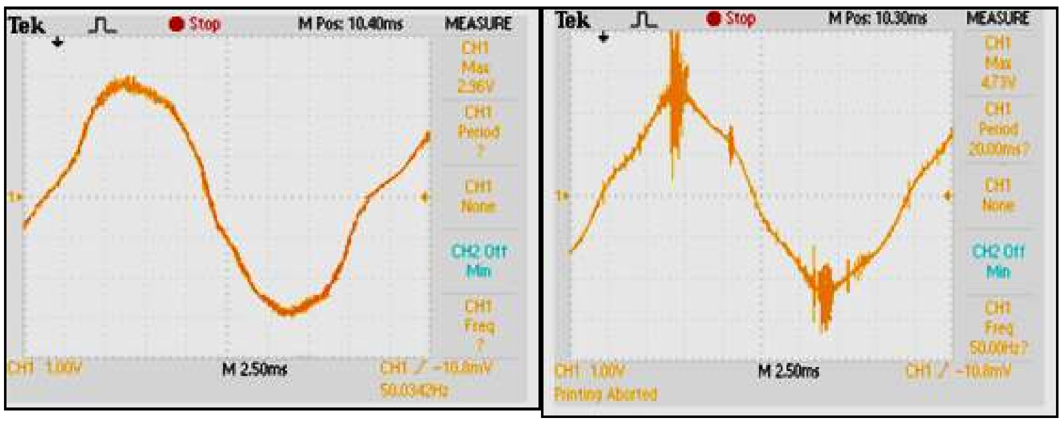


Figure.10 PD pattern analysis at different voltages for silicone rubber with silica nanoparticles

The magnitude of PD pulses is found to be very similar to PD pulses observed during the tracking of ZnO nanocomposites.

Tracking Studies Compression

From the experimental results a detailed comparison is made to study the tracking process happened during IPT test. The tracking initiation voltage found to comparatively high for samples with ZnO nanoparticles. The detailed comparison with regard to time to intial track tracking length are tabulated in table.6

Table.6 Compression between three specimens

	Without nanoparticles	**With ZnO nanoparticles**	**With silica nanoparticles**
Tracking initiation voltage (kV)	4.01	4.43	4.28
Time to initial track (min)	75-80	90-100	85-90
Maximum applied voltage during tracking (kV)	4.01	4.96	4.43
Tracking duration (min)	105-110	130-135	110-115
Track length (mm)	35	30	28

Conclusion

The experimental investigations carried out in this work shows that the initiation of PD and the tracking phenomenon started earlier in the samples without nanoparticles than in the samples in which they were incorporated. The length of the track was also reduced due to the influence of nanoparticles. Nanocomposites with ZnO particles showed higher tracking resistance compared to samples prepared with silica nanoparticles. ZnO nanoparticles play a key role in ageing factor of silicone rubber due to is excellent electrical insulation properties. Silica nanoparticles are highly helpful in improving both mechanical and electrical properties of silicone rubber. Using both ZnO and silica nanoparticles in proper %weight proportions exhibit enhancement in the properties of silicone rubber composites. From the partial discharge measurement it is clear that the magnitude of the discharges during tracking is significantly lesser for Nano composites.

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