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Dielectric and Mechanical Properties of High Temperature Vulcanized Silicone Rubber Loaded with Nano Zeolite Filler

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Abstract: Silicone rubber (SiR) insulators have several advantagessuch as high electrical insulation and elasticity, temperature resistance and better contamination resistance so it is widely used in insulators for HVDC transmission lines. This paper is focusing on enhancing the electrical properties of HV SiR insulators with respect to mechanical properties by loading micro and nano Zeolite fillers. Samples were prepared by adding micro Zeolite and nano Zeolite into SiR matrix with concentrations of 0%, 10%, 20%, 30% and 40% by weight and with concentrations of 0%, 1%, 3%, 5% and 7% by weight, respectively. The dielectric breakdown strength test has been used to test the electrical performance of SiR composite insulators under various contaminated conditions like dry, wet, low salinity and high salinity. To check various properties of the samples, the tensile strength and elongation at break tests have been applied.

Keywords: Silicone Rubber, Micro and Nano Fillers, Dielectric Strength, Tensile Strength, Elongation at Break, Zeolite Filler

1. INTRODUCTION

SiR offers stability over a wide temperature range, resistance to harsh environments, and long lasting p erformance exceeding many organic elastomers. SiR insulators are nonconductive because of their chemical nat ure and when compounded with the proper fillers and additives are used to produce rubber for a wide range of el ectrical insulating applications. Simple exposure to adverse environments such as heat, cold, moisture, oil and o zone don't significantly change the electrical properties of SiR [1].

The engineering issue of using outdoor HV SiR insulators is to decrease the surface electrical stress to a level. The fillers are loaded to the SiR to enhance explicit properties and furthermore to decrease costs.

Otherwise, the degree of improvement of the property of the nano-composite depends on the concentrat ion of the filler, the morphology of the filler, as the size and structure of the particles, the degree of dispersion a nd orientation in the matrix, and furthermore the adhesion degree with the polymer chains [2-4].

With the developing enthusiasm for utilizing nano-sized fillers in polymeric materials, the utilization of these fillers could have an excellent influence on the execution of SiR insulators [5].

Nano-composite polymers are outlined as composites during which a little quantity of nano-sized fillers are disseminated in different ways in the polymer by weight percentages (wt%). As defined, the fillers added in the matrix are in very little quantities, which are usually 10% less than the weight. Contrary to traditional compo sites or called micro-composites, the quantity of micro-fillers is therefore high that it will reach 50% of the weig ht of the material's total weight [6].

While conventional micro-composites can change some desired characteristics of composite materials (e.g., thermal and mechanical characteristics), it often comes with the compromises of other negatively affected c haracteristics (e.g., electrical characteristics). The interesting thing is that new nano-composite polymers provide significant improvements in combined electrical, mechanical and thermal properties [7]. These deep effects gen erate great profits for the high voltage insulation industry especially in the improvement of electrical properties.

Many researches have been investigated regarding the electrical, thermal and mechanical properties of polymers as comfortable functional properties, as a result of the presence of various nano fillers [8-13].

The scope of this technical paper is to enhance SiR properties such as electrical and mechanical by addi ng micro and nano Zeolite fillers. The focusing of this work is on trying to find as applicable concentration of co mposite sample so as to improve electrical and mechanical properties of silicone rubber.

2. EXPERIMENTAL ARRANGEMENT

2.1. Methodology

Micro and nano Zeolite are the fillers used in this paper, which are supplied by nanotech, Egypt. The matrix material is a two part addition cure HTV SiR, which is manufactured by Sonax, Germany (A. Faroon Egypt S.A.E).

2.2. Samples Preparation

The samples were made by mixing the micro and nano Zeolite fillers with the base polymer (SiR), the concentrations of the fillers material were obtained as a percentage of the total weight of the SiR polymer. A pure SiR sample without Zeolite filler was considered as reference. Table I shows the mixing formulation. The samples were applied in a laboratory model two roll mill (470mm diameter and 300mm operating distance). The gap between two rolls modified from 1mm to 3mm according to the mixing conditions. The samples were left nightlong before vulcanization. The vulcanization of the samples was applied in a heated plate under pressure about 40kg force/cm^2 and temperature of 150±1^{o}C for about 10 min.

Table 1. The mixing formulation of samples

Type of filler	Sample code	Filler loading (%)
Blank	B	0
Micro Zeolite	Z_{10}	10
	Z_{20}	20
	Z_{30}	30
	Z_{40}	40
Nano Zeolite	Z_1	1
	Z_3	3
	Z_5	5
	Z_7	7

2.3. Dielectric Strength Test

All insulating materials fail at a certain voltage level applied to a given operating condition. The dielectric breakdown strength is expressed in voltage gradient elements, such as voltage per thickness (kV/mm) at the voltage that an insulating material can withstand before dielectric breakdown strength occurs. The dielectric strength is an important electrical property of insulators. The dielectric strength is usually observed as an electrical arc across the electrodes which causes a catastrophic decrease in resistance. The test sample should be in a disc form with a diameter of 5cm and a thickness of 2mm.

2.4. Mechanical Test

Tensile strength and elongation at break are important tests for describing the mechanical performance of the material. A Zwick Roell LTM electro-dynamic testing machine was used to determine the tensile strength and elongation at break of the composite samples. A schematic diagram is illustrated in Fig 1.Test assessed by ASTM D-412.

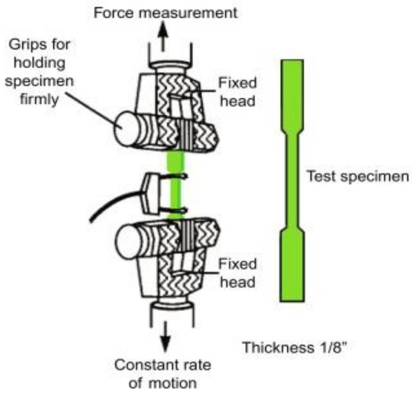

Fig 1. Schematic diagram for measuring the tensile strength of SiR composite samples

3. DISCUSSION

3.1. Dielectric Strength Measurements

3.1.1. Studying the Dielectric Strength for SiR Composite Samples Using Zeolite Filler in Dry Condition

For application of polymer outdoor insulators, SiR samples were prepared by adding micro and nano Zeolite filler for application of polymer outdoor insulators. The dialectic strength test was carried out to evaluate the Zeolite addition effect on its properties.

The relation of dielectric strength and several percentages of micro and nano Zeolite fillers added to SiR when tested under dry condition are shown in Fig 2.

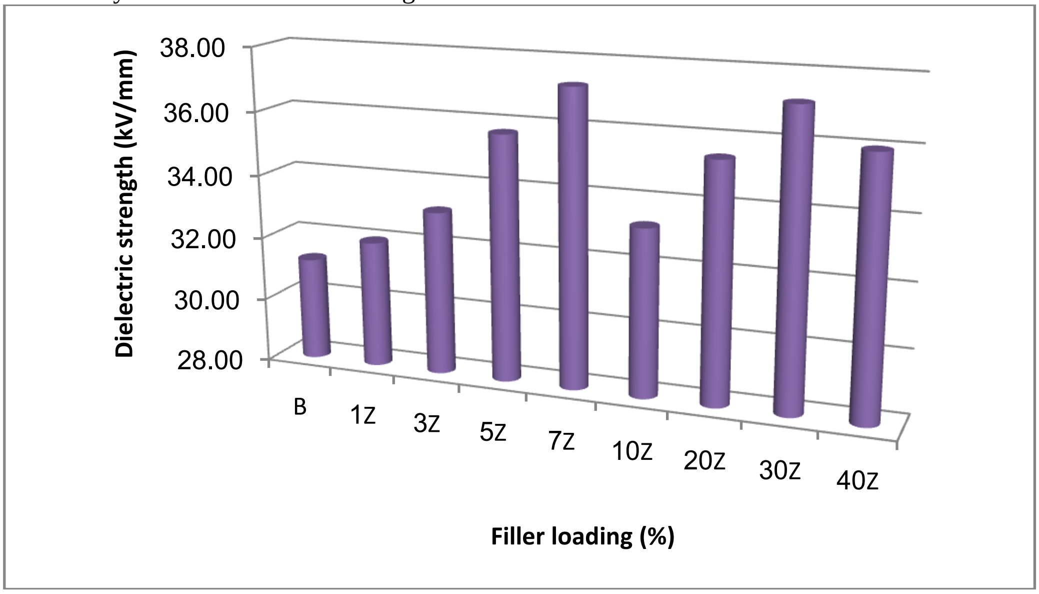

Fig 2. Dielectric strength (kV/mm) of micro and nano Zeolite composite samples under dry condition.

Fig 2 shows the effect of Zeolite micro and nano fillers content on dielectric strength. As a result, it became very clear that dielectric strength performance was better by the addition of Zeolite nano filler under this dry condition. The dielectric strength of nano Zeolite composites increases and reaches the highest value at the percentage of 7%.

From the obtained results it can be stated that 7% by wt nano Zeolite composite electrical performance is almost equivalent to the 30% by wt Zeolite micro composite which is again function of the filler distribution.

3.1.2. Studying the Dielectric Strength for SiR Composite Samples Using Zeolite Filler in Wet Condition

For a simulation of rains and wet weather condition, samples are immersed in distilled water and tested for dielectric strength.

The relation of dielectric strength and several percentages of micro and nano Zeolite fillers added to SiR when tested under wet condition are shown in Fig 3.

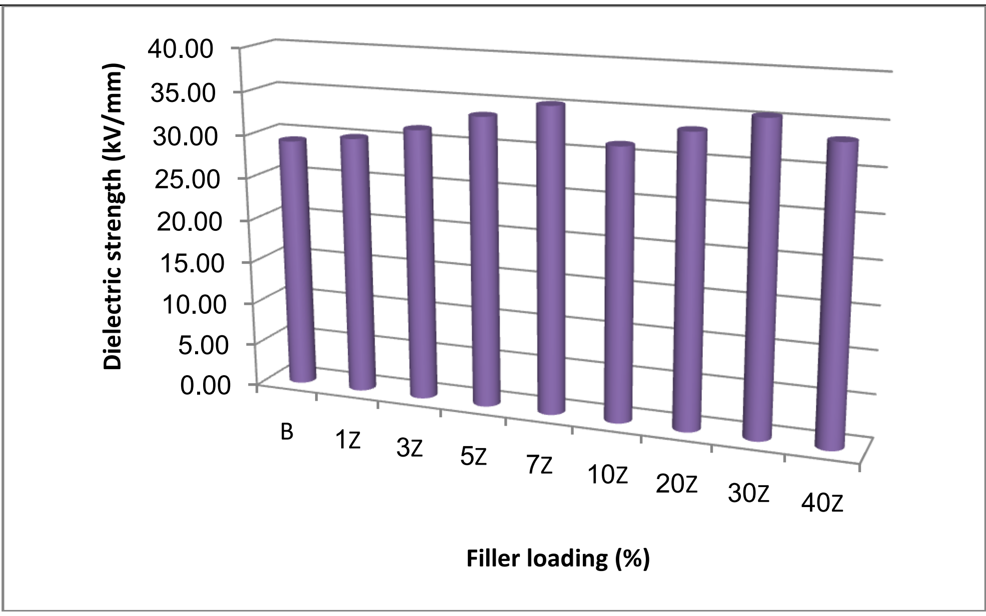

Fig 3. Dielectric strength (kV/mm) of micro and nano Zeolite composite samples under wet condition.

The results showed that after adding Zeolite filler, the dielectric strength of SiR has been improved significantly. It is obviously shown in Fig 3. that with the increase of filler content (from 0% to 7%), the dielectric strength of SiR is increased.

At 30%wt loading, the performance of micro Zeolite composites was better than pure SiR. Compared to nano Zeolite, a much smaller amount of nano Zeolite recorded a similar performance. The dielectric strength of micro Zeolite at 40 wt% was less than that at 30 wt% as shown in Fig 3.

3.1.3. Studying the Dielectric Strength for SiR Composite Samples Using Zeolite Filler in Low Salty Wet Condition

For a simulation of areas near to seas or coastal cities, samples are immersed into a NaCl and tested for dielectric strength.

The relation of dielectric strength and several percentages of micro and nano Zeolite fillers added to SiR when tested under low salty wet condition is shown in Fig 4.

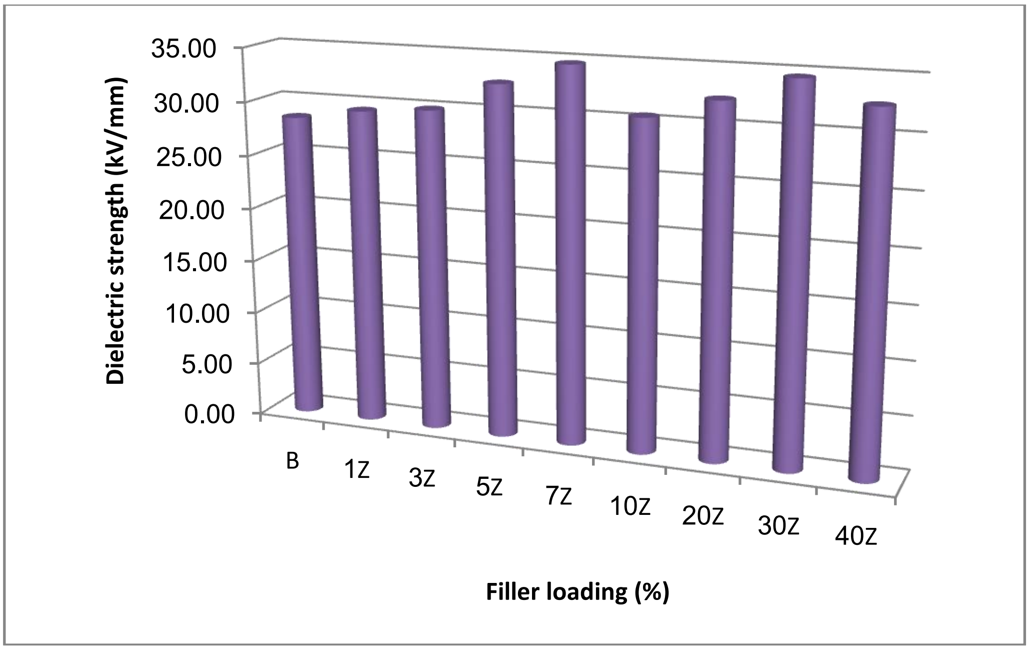

Fig 4. Dielectric strength (kV/mm) of micro and nano Zeolite composite samples in low salty wet condition.

It can be seen from Fig 4 that, the dielectric strength has been enhanced by adding nano scale Zeolite filler because of its larger specific area [14]. Clearly the presence of nano Zeolite filler has offered appreciable dielectric strength in comparison to blank sample. An effective amount of nano scale Zeolite filler for dielectric strength seem to be 7wt%.

The present test has shown that the dielectric strength of the nano composites at lower filler concentrations is comparable with the dielectric strength of the micro composites at higher filler concentrations. With increasing the concentration of micro Zeolite filler up to 30%, the dielectric strength showed an enhanced performance as shown in Fig 4.

3.1.4. Studying the Dielectric Strength for SiR Composite Samples Using Zeolite Filler in High Salty Wet Condition

The relation of dielectric strength and several percentages of micro and nano Zeolite fillers added to SiR when tested under high salty wet condition is shown in Fig 5.

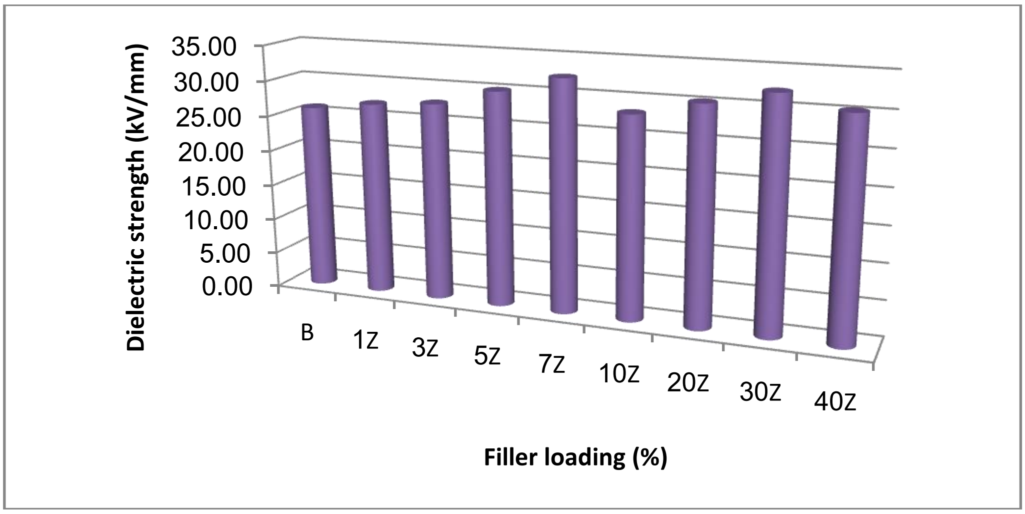

Fig 5. Dielectric strength (kV/mm) of micro and nano Zeolite composite samples under high salty wet condition.

The initial increase with filler concentration as compared to the pure SiR have been showed a trend for dielectric strength. But the performance have been improved with the increase of filler concentration. It is investigated from the test results that, the inclusion of Zeolite nano filler improves the dielectric strength of the base polymer. Nanocomposite with a much smaller concentration of filler performed similar to the highly loading microcomposite Zeolite filler as shown in Fig 5.

3.2. Mechanical Test Results

3.2.1. Studying the Tensile Strength of SiR Composite Samples

Tensile strength is the maximum stress that a material can withstand while being stretched or pulled before necking. Tensile strength is calculated by dividing the load at break by the original minimum cross sectional area. The result is expressed in Mega Pascal (MPa).

Fig 6 displays the tensile strength of micro and nano Zeolite filled SiR composites as a function of filler loading.

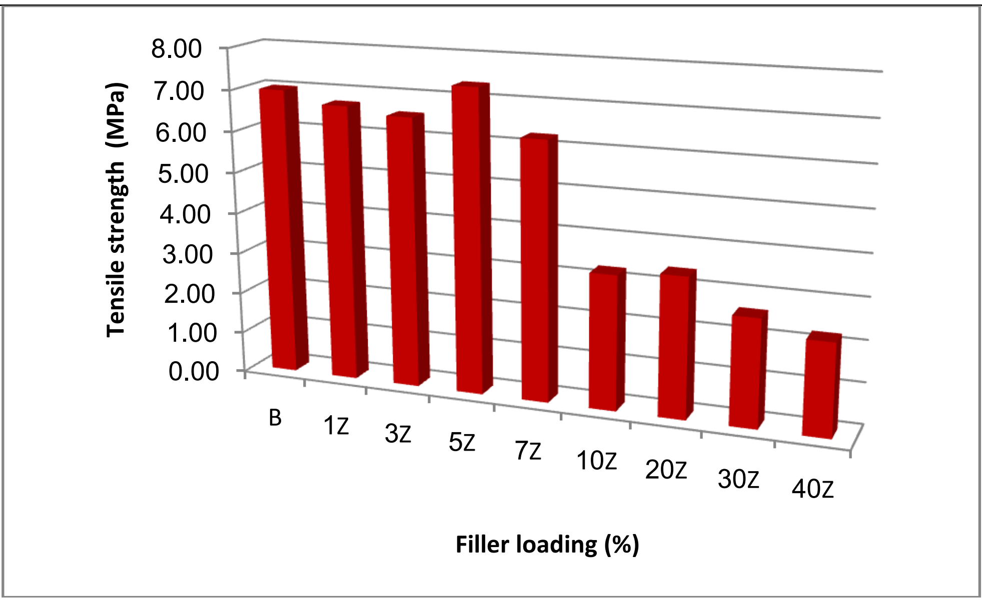

Fig 6. Tensile strength of SiR with nano and micro Zeolite filler percentages.

Zeolite loaded SiR composite improves tensile strength at 5 wt% loading level as shown in Fig 6. All values of tensile strength of SiR composites decrease for increasing amount of micro Zeolite.

From Fig 6 It can be seen that there is marked increase in the tensile strength with increase micro Zeolite concentrations. SiR loaded with 5 wt% nano Zeolite records maximum tensile strength compared with the other concentration for the same filler.

3.2.2. Studying the Elongation at Break of SiR Composite Samples

Elongation at break properties of micro and nano Zeolite loaded SiR composites are shown in Fig 7.

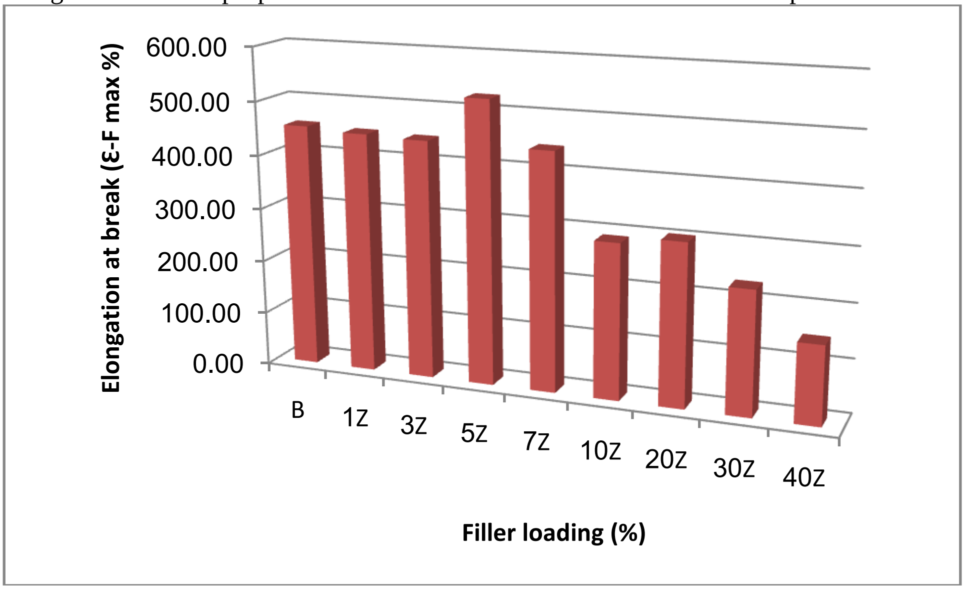

Fig 7. Elongation at break of SiR with nano and micro Zeolite filler percentages.

The values of elongation at break for SiR composite samples decrease with the increase amount of micro Zeolite.

It can be seen from Fig 7 that the addition of nano Zeolite can result in improved elongation at break. When the addition of nano Zeolite is 5 wt%, the composite shows higher elongation at break comparing to pure SiR.

4. CONCLUSION

For applications of polymer outdoor insulators, samples with addition of Zeolite filler having several types of micro and nano sizes were prepared. The dielectric strength test and tensile strength test were carried out to evaluate the Zeolite addition effect on their properties. This paper has shown the effect of adding micro and nano Zeolite to SiR composites. From experimental results, it can be concluded that:

- The dielectric strength has been improved by adding filler to SiR.
- The nano filler improves the electrical properties of SiR composites.
- The optimum concentration of micro or nano Zeolite fillers to improve dielectric strength for SiR composite is 7 wt% nano Zeolite.
- Mechanical properties of SiR decreased by adding micro Zeolite filler.
- The tensile strength and elongation at break properties are improved by increasing the percentage of nano Zeolite filler in the sample up to 5wt%.
- The optimum percentage of nano Zeolite that could be adopted in the SiR samples is in between 5wt% and 7wt%.

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