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ELECTRICAL CHARACTERISTICS OF THE BLENDS OF SILICON AND EPDM OUTDOOR INSULATORS

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ABSTRACT
Polymeric insulators are widely used as outdoor H.V insulators due to their superior service properties in the presence of heavy polluted and wet condition, resistance to vandalism and high dielectric strength voltage. Polymer insulators particularly those made of ethylene propylene diene monomer and silicone rubber are increasingly being used today and blending of two polymers is an attractive way to develop a new material combines the best properties of these two materials. In 1986 the first alloy of SiR/EPDM was prepared. Today the most widely used insulator weather shed materials are SiR/EPDM blends. This paper aims to improve SiR/EPDM blends electrical properties (dielectric strength) for high voltage insulators. Blends of SiR with EPDM were prepared with 0%, 25%, 50%, 75% and 100% by weight percentages concentration. The dielectric strength of the blends was tested in several conditions such as (dry, wet, low and high salinity of water and ultra violet). Also dielectric strength of blends was tested after being exposed to thermal aging for 24 hours(hrs) in high temperatures (60, 100 and 130ºC).
KEYWORDS: Polymeric materials; Blends; High voltage insulators; Dielectric strength.

INTRODUCTION
Overhead transmission and distribution systems operating at wide range of voltages are the most economical method of supplying power to industry worldwide therefore the outdoor insulators play a very important role in the power system reliability and their performance influences the whole system [1].Outdoor insulations are subjected to a variety of stresses including electrical and environmental. Depending on the design, application and location of the insulators, the nature and magnitude of such stresses can be very different [2].
From the electrical point of view, there is the steady state stress imposed by the operating voltage and transient stresses due to lightning and switching operation [3]. Finally outdoor environmental conditions, which include temperature variations, ultra violet radiation from sunlight, altitude, moisture and contamination.
Polymeric insulators are being accepted increasingly for use in outdoor applications. The tremendous growth is due to their advantages over the traditional ceramic and glass insulators. It includes lightweight, higher mechanical strength to weight ratio, resistance to vandalism, better performance in the presence of heavy pollution in wet condition, and better withstand voltage than porcelain insulators. However, because polymeric insulators are relatively new, the expected lifetime and their long-term reliability are not known, and therefore are of concern to users [4-5].
Blending of Silicone rubber with EPDM in a composition of 50: 50 by weight was done in a laboratory model, two roll mill for 5 minutes at room temperature. A curing agent of DCP (3phr) and various percentages of silica filler were added during the mill mixing.
The blended compounds were vulcanized in a hydraulically operated press at (443 K) and 10 minutes as per the usual procedure. Then the vulcanizates were postcured for 2 hours at (423 K) in an air circulated oven. Sheets of 3mm thickness were prepared by the above procedure and test samples were punched out from the sheets [6].Several studies aimed to improve electrical performance of SiR/EPDM blends high voltage insulators [7-10]
.This paper aims to improve SiR/EPDM electrical properties. It focuses on trying to find an appropriate weight percentage composition of such blend in order to enhance the dielectric strength of the insulation in different conditions. Soft program(Curve fitting) was used to interpreted the equation between different conditions.

EXPERIMENTAL AND PROCEDURES

Sample Preparation and Dimensions

Five blend percentages have been prepared: 100% EPDM, 100% SiR, 25%EPDM with 75% SiR, 50% EPDM with 50% SiR, and 75%EPDM with 25% SiR. Table 1 shows the mixing formulation. The blends were carried out in a laboratory model two roll mill (470 mm diameter and 300 mm working distance). The gap between two rolls changed from 1mm to 3mm according to the mixing conditions. The speed of the slow roll is 24 rpm with a gear ratio 1:1.4. At first both rubber were masticated and then dicumyl peroxide was added. The blends were left overnight before vulcanization.

Table 1. Mixing formulation

Sample Symbol	SiR (%)	EPDM (%)
A	0	100
B	25	75
C	50	50
D	75	25
E	100	0

Dielectric Breakdown Strength Test

Dielectric strength of an insulating material is the maximum electric field strength that it can withstand intrinsically without breaking down, without experiencing failure of its insulating properties. It is expressed in voltage gradient items, such as voltage per thickness (kV/mm). It is one of the major electrical properties for insulation.

The failure is characterized by an excessive flow of current (arc) and by partial destruction of the material. Dielectric strength is measured through the thickness of the specimen which is equal 1 mm, and is expressed in volts per unit of thickness. Samples are in the form of disc with diameter 5 cm and thickness 1 mm. For each test, the average result of 5 samples has been taken to minimize the error. Figure 1 shows dielectric breakdown strength test.

The relation (equation) between different conditions by the MATLAB.

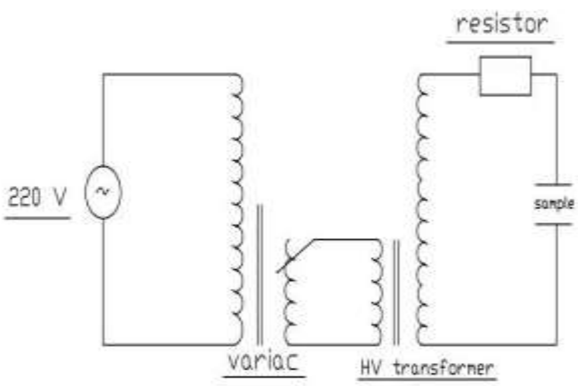

Figure 1. Dielectric breakdown strength test.

RESULTS AND DISSCUSION

Dielectric Strength Test

The dielectric strength for SiR/ EPDM blends studied with different conditions (dry, wet, low salinity and high salinity) in different percentages of SiR (0%, 25%, 50%, 75% and 100%). Figure 2 shows the comparison between dielectric strength test for silicone rubber/EPDM blends and all conditions (dry, wet, and low and high salinity of water).

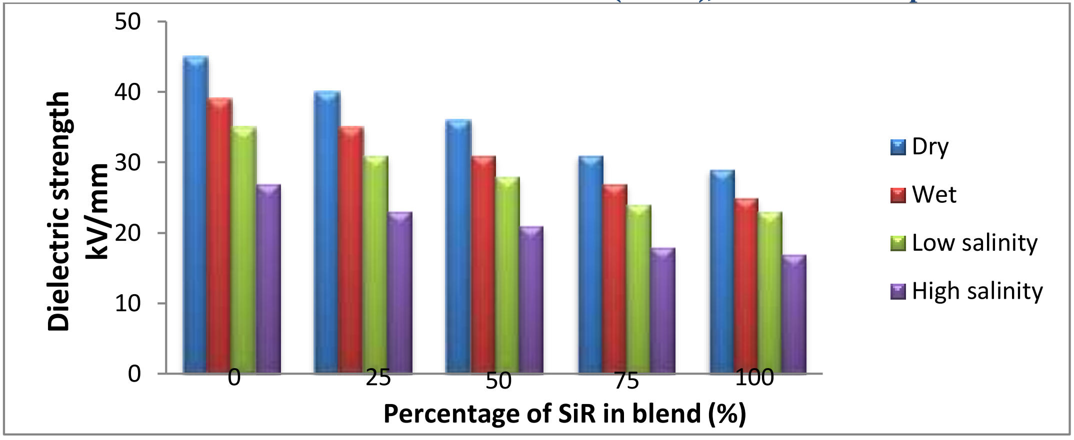

Figure 2. Dielectric strength (kV/mm) of blend samples under different conditions.

Also it can be concluded that, the dielectric strength of the blend samples decreases from 45 kV/mm for sample A in dry condition to 39kV/mm for sample A in wet condition to 35 kV/mm for sample A in salty wet condition to 27 kV/mm for sample A in very salty wet condition, and the dielectric strength of the blend samples decreases from 29 kV/mm for sample E in dry condition to 25 kV/mm for sample E in wet condition to 23 kV/mm for sample E in salty wet condition to 17 kV/mm for sample E in very salty wet condition.

It can be observed that, the dielectric strength decreases from dry condition to wet condition to salty wet condition to very salty wet condition. This is because of the shortage of water and salinity caused leakage current that reason circuit connected.

Furthermore, the dielectric strength test was carried out after the blends exposed to thermal aging for 24 hrs in several high temperatures (60, 100 and 130ºC). Fig. 3 shows the comparison between dielectric strength test for silicone rubber/EPDM blends and thermal aging for 24 hrs.

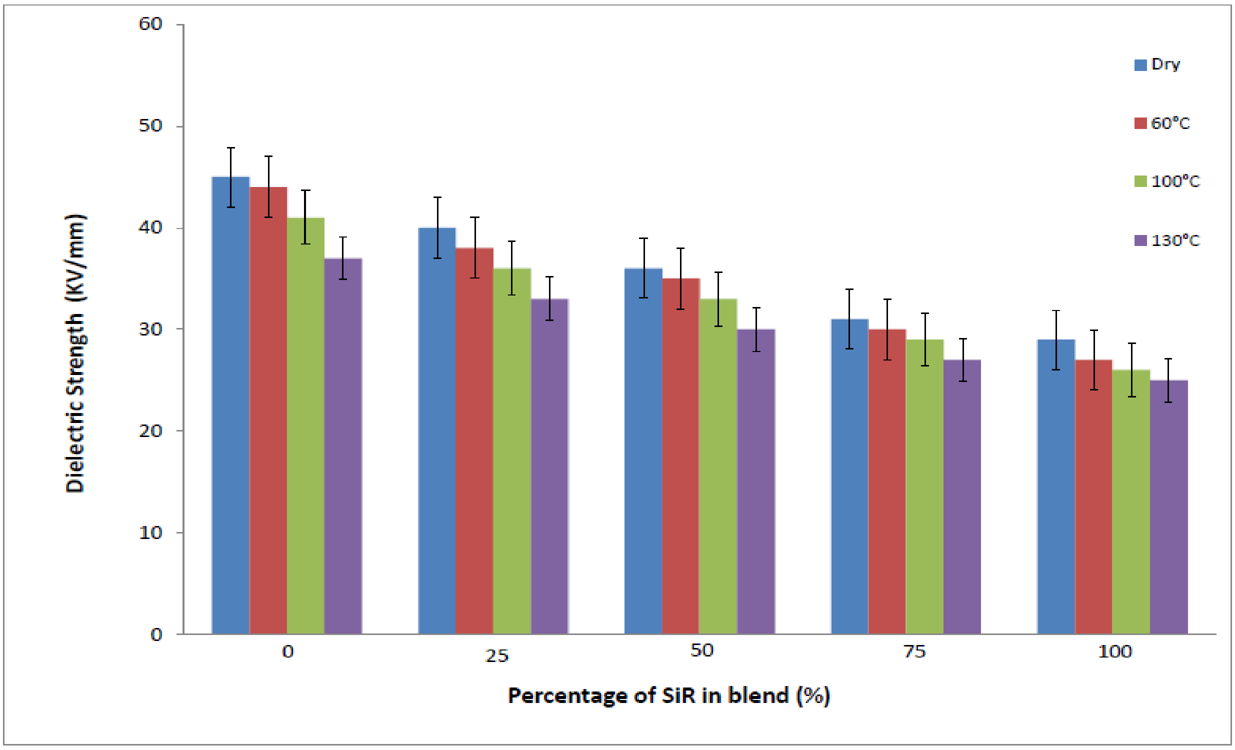

Figure 3. Dielectric strength of blends after thermal aging for 24 hrs in several temperatures.

Also it can be concluded that, the dielectric strength of the blend samples decreases from 45 kV/mm for sample A in dry condition to 44kV/mm for sample A at 60ºC to 41 kV/mm for sample A at 100ºC to 37 kV/mm for sample A at 130ºC, and the dielectric strength of the blend samples decreases from 29 kV/mm for sample E in dry condition to 27 kV/mm for sample E at 60ºC to 26 kV/mm for sample E at 100ºC to 25 kV/mm for sample E at 130ºC .
It can be observed that, the dielectric strength decreases at high temperatures.
Furthermore, the dielectric strength test was carried out after the blends exposed to ultra violet at (1000, 2000 and 4000 hrs). Fig. 3 shows the comparison between dielectric strength test for silicone rubber/EPDM blends and ultra violet conditions.

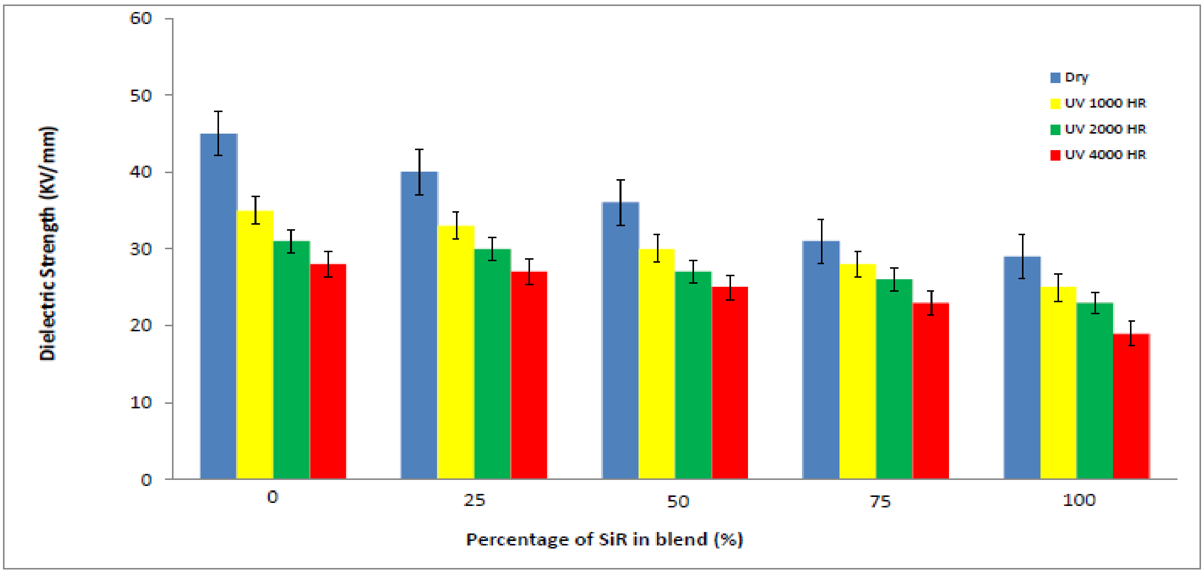

Figure 4. Dielectric strength of blend under ultra violet.

As the amount of SiR increases the breakdown strength decreases in all aged duration (1000 hrs, 2000 hrs and 4000 hrs). The breakdown strength of (sample A) decreases from 45 kV/mm for un-aged case to 35 kV/mm for 1000 hours UV aged duration and to 31 kV/mm for 2000 hours UV aged duration and to 28 kV/mm for 4000 hours UV aged duration. The breakdown strength of (sample E) decreases from 29 kV/mm for un-aged case to 25 kV/mm for 1000 hours UV aged duration and to 23 kV/mm for 2000 hours UV aged duration and to 19 kV/mm for 4000 hours UV aged duration. The dielectric strength loss will increase by increasing aged duration (1000, 2000 and 4000 hrs).

Soft Program (MATLAB) Results in Dielectric Strength Test

By using curve fitting program, the best curve fit for the obtained results from the test is shown in fig 5.

1. Curve fitting for the dielectric strength results for the samples under dry condition.

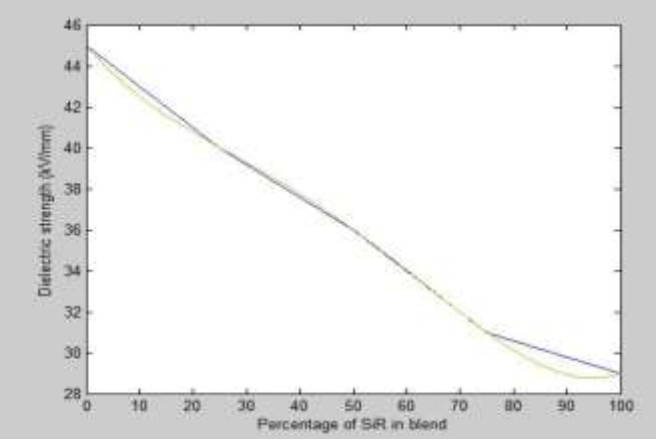

Fig. 5. Curve fitting results for dielectric strength (kV/mm) of blend samples under dry condition.

From the calculation of the program the best curve fitting for the data obtained can be represented by 4th degree polynomial equation as follow:

$Y=AX^4+BX^3+CX^2+DX+E$

Where Y is the dielectric strength under dry condition value and X is the percentage of SiR in blend.

A is a constant = 6.4E-7

B is a constant = -0.00012

C is a constant = 0.0068

D is a constant = -0.31

E is a constant = 45

Curve fitting for the dielectric strength results for the samples under wet condition.

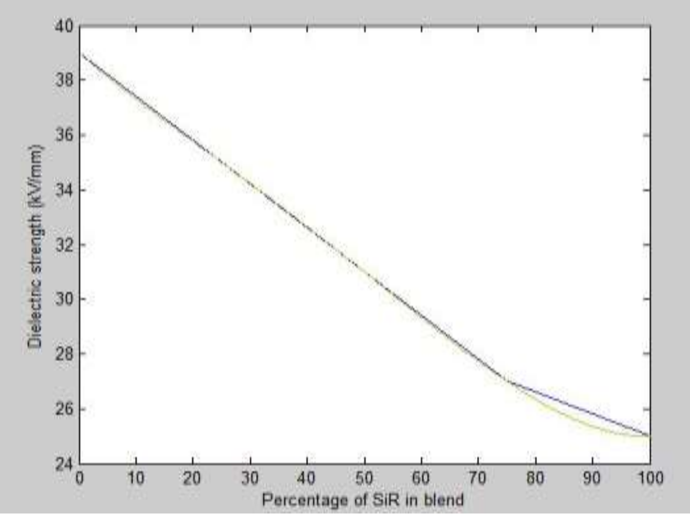

Fig.6. Curve fitting results for dielectric strength (kV/mm) of blend samples under wet condition.

From the calculation of the program the best curve fitting for the data obtained can be represented by 4th degree polynomial equation as follow:

$Y=AX^4+BX^3+CX^2+DX+E$

Where Y is the dielectric strength under dry condition value and X is the percentage of SiR in blend.

A is a constant = 2.1E-7

B is a constant = -3.2E-5

C is a constant = 0.0015

D is a constant = -0.18
E is a constant =39

2. Curve fitting for the dielectric strength results for the samples under low salinity condition.

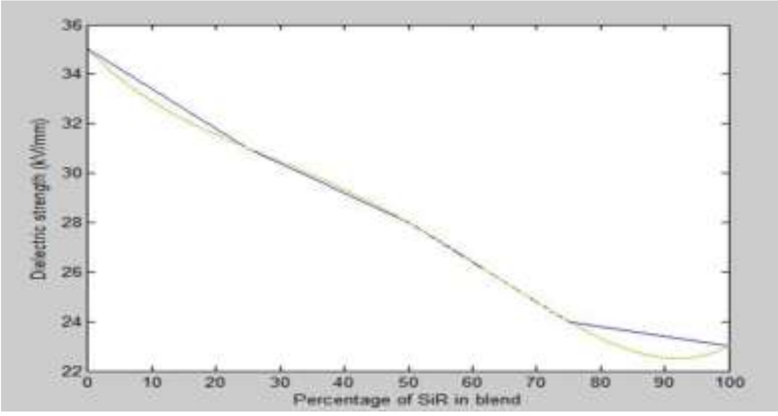

Fig.7. Curve fitting results for dielectric strength (kV/mm) of blend samples under low salinity condition.

From the calculation of the program the best curve fitting for the data obtained can be represented by 4th degree polynomial equationas follow:

$Y=AX^4+BX^3+CX^2+DX+E$

Where Y is the dielectric strength under low salinity condition value, X percentage of SiR in blend
A is a constant = 6.4E-7
B is a constant = -0.00012
C is a constant = 0.0068
D is a constant = -0.27
E is a constant =35

3. Curve fitting for the dielectric strength results for the samples under high salinity condition.

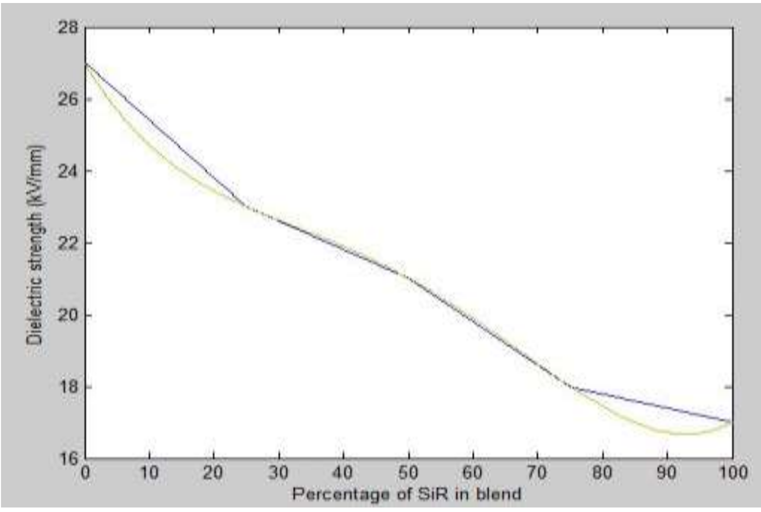

Fig.8. Curve fitting results for dielectric strength (kV/mm) of blend samples under high salinity condition.

From the calculation of the program the best curve fitting for the data obtained can be represented by 4th degree polynomial equation as follow:

$Y=AX^4+BX^3+CX^2+DX+E$

Where Y is the dielectric strength under high salinity condition value, X is the percentage of SiR in blend

A is a constant = 6.4E-7

B is a constant = -0.00013

C is a constant = 0.0084

D is a constant = -0.3

E is a constant = 27

4. Curve fitting for the dielectric strength results for the samples thermally stressed for 24 hrs aging at 60ºC.

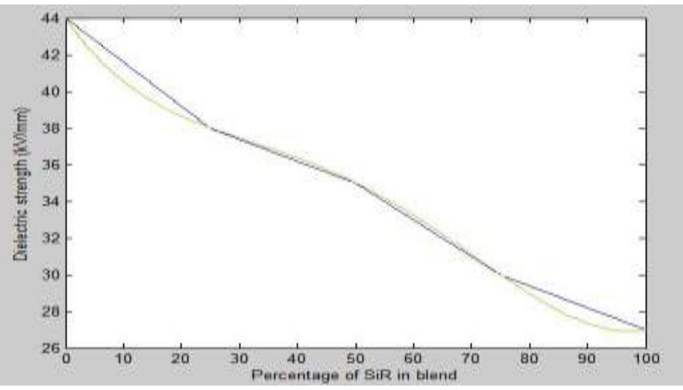

Fig.9. Curve fitting results for the dielectric strength of the blend samples thermally stressed for 24 hrs aging at 60 ^{O}C.

From the calculation of the program the best curve fitting for the data obtained can be represented by 4th degree polynomial equation as follow:

Y=AX^4+BX^3+CX^2+DX+E

Where Y is the dielectric strength under thermally stressed for 24 hrs aging at 60 ^{0}C, X is the percentage of SiR in blend

A is a constant = 9.6E-7

B is a constant = -0.0002

C is a constant = 0.013

D is a constant = -0.46

E is a constant =44

5. Curve fitting for the dielectric strength results for the samples thermally stressed for 24 hrs aging at 100ºC.

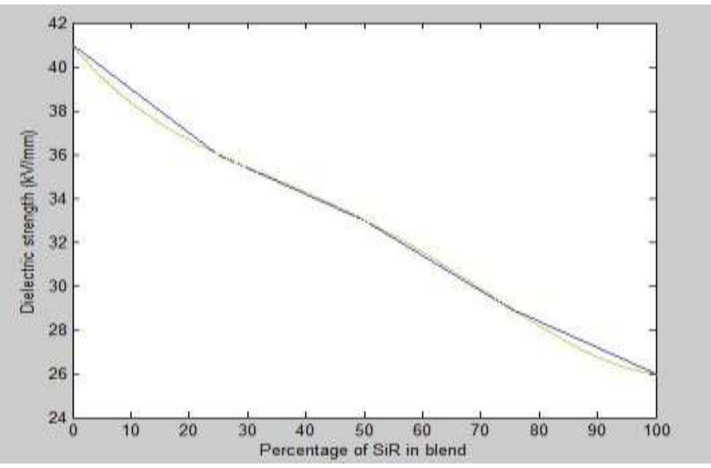

Fig.10. Curve fitting results for the dielectric strength of the blend samples thermally stressed for 24 hrs aging at 100 ^{O}C.

From the calculation of the program the best curve fitting for the data obtained can be represented by 4th degree polynomial equation as follow:

$Y=AX^4+BX^3+CX^2+DX+E$

Where Y is the dielectric strength under thermally stressed for 24 hrs aging at 100 ^{0}C, X percentage of SiR in blend

A is a constant = 5.3E-7

B is a constant = -0.00011

C is a constant = 0.0077

D is a constant = -0.33

E is a constant =41

6. Curve fitting for the dielectric strength results for the samples thermally stressed for 24 hrs aging at 130^{o}C.

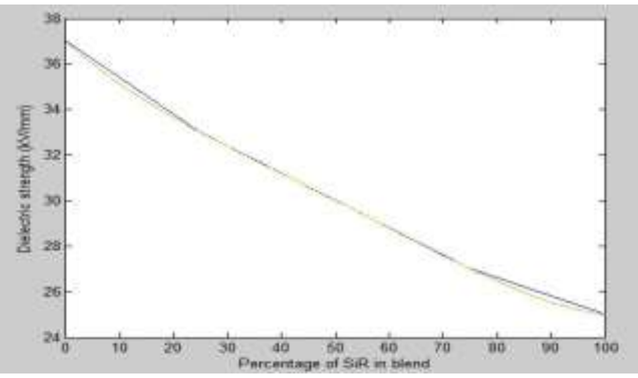

Fig.11. Curve fitting of the dielectric strength of the blend samples thermally stressed for 24 hrs aging at 130 ^{0}C.

From the calculation of the program the best curve fitting for the data obtained can be represented by 4th degree polynomial equation as follow:

$Y=AX^4+BX^3+CX^2+DX+E$

Where Y is the dielectric strength under thermally stressed for 24 hrs aging at 130 ^{0}C, X percentage of SiR in blend

A is a constant = 2.1E-7

B is a constant = -4.3E-5

C is a constant = 0.0031

D is a constant = -0.21

E is a constant = 37

The dielectric strength can be obtained from the equation with SiR varying from 0% to 100%.

The molecules became less interlinked because of the increase of SiR concentrations and this lead to decrease electrical characteristics of EPDM

CONCLUSION

1. The addition of EPDM to silicon rubber enhances the dielectric breakdown strength of the polymer blends.
2. The dielectric strength decreased in wet condition as compared with those in dry conditions.
3. The dielectric strength decreased in high salinity condition as compared with those in low salinity condition.
4. The dielectric strength decreased in thermal aging condition as compared with those in dry condition.
5. The dielectric breakdown strength percentage reduction value of SiR sample is low, if it compared with the corresponding value of EPDM sample at UV radiation.
6. As a result of previous points, the suitable percentage can be used for blend rubber sample is 50% SiR and 50% EPDM (sample C).

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