# Study on the aging characteristics of silicone rubber materials for composite insulators

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**Abstract.** The electron beam radiation method is emitted by electronic accelerators, which can change the chemical physical properties of radiation. Silicone rubber samples after different irradiation intesities were carried out for the 1000h aging test, and the electronic scanning microscopy (SEM), mechanical tensile and hydrophhy angle of the silicone rubber sample were measured, the test results shows that: after 1000h aging test, the visual apperence of the sample did not changed, the SEM showed that the surface of the silicone rubber became rough and the porosity increased, and the mechanic tension decrease. For moderate Irradiation intensity(60KGy), the aging characteristics of silicon rubber can be improved.

### **1** Introduction

Composite insulator is mainly composed of composite silicone rubber umbrella skirt, epoxy resin core rod and other materials[1-3]. Compared with traditional porcelain and glass insulators, composite insulators have a series of advantages such as light weight, good insulation and anti-pollution performance, so they are widely used in power electric systems. Silicone rubber composite insulator made by high temperature vulcanization is the main material of external insulation of conposite insulator, during the long-term outdoor operation, degradation of mechanical and electrical performance of silicon rubber will shorten the service life of composite insulator, which may even cause flashover of transmission lines. Therefore, in order to improve the economical efficiency, reliability and stability of transmission lines, it is necessary to carry out research on anti-aging technology of silicone rubber.

From the microscopic point of view, in the process of preparing silicone rubber molecules, the chain structure is cross-linked to form a three-dimensional network structure. The silicone rubber for composite insulators is formed by mixing polyorganosiloxane with a variety of chemical additives by heating vulcanization. Due to the uneven dispersion of cross-linking agent in the adhesive during the mechanical mixed curing reaction, the crosslinking degree of surface and internal chemical reaction differ widely, resulting in poor physical properties of silicon rubber and the phenomenon of aging failure is easy to occur in the field use.

The electron beam radiation method irradiates the irradiated material by the electron beam emitted by the electron accelerator, which can change the chemical and physical properties of the irradiated material[4-7]. At present, the method of electronic irradiation modification

has been widely used in cable processing, food disinfection and other fields. However, there is no relevant report on the research of improving the service life of silicone rubber by electronic irradiation[8-10].

Based on the above status, different doses of electron irradiation were carried out for the silicone rubber samples formed by thermal aging in this paper, and 1000h accelerated aging test was carried out for the silicone rubber samples before and after irradiation. Electron tunnel scanning mirror (SEM), mechanical tensile force and hydrophobicity of the silicone rubber samples before and after the test were compared. On the basis of the experimental data, the mechanism of the anti-aging performance of electron irradiation was analyzed, and the optimal anti-aging dose was obtained. The study in this paper provides a new way to improve the anti-aging performance of silicone rubber.

# 2 Electron irradiation and aging test of silicone rubber

#### 2.1. Test specimen

The silicone rubber material, which was traditionally vulcanized by heating, was cut into a 2mm thickness and 20cm\*10cm width flake form (Fig. 1). The material was placed in the Place on radiation production line and the electron irradiation dose of 60KGy and 100KGy was applied to the sample(Fig. 2).

The silicone rubber samples were washed by deionized water ultrasonic for 30min and then placed in the aging box (Fig.3). The silicone rubber aging test was conducted for 1000 hours.

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Fig. 1. silicone rubber sample after electron irradiation



Fig. 2. silicone rubber sample after electron irradiation







Humidity of the climate aging box was maintained at 95%, the temperature is 50 °C. The solar radiation intensity is 550W/m<sup>2</sup>. After aging test, the samples were taken out,

cleaned and dried, and mechanical tensile force, SEM, hydrophobicity were tested.

#### 2.2. Test method

**Surface inspection.** After cleaning the silicone rubber skirt, observe its appearance roughness. At the same time, the microstructure of the surface and cross section was observed under electron tunneling microscope.

**Mechanical tension test.** The dumbbell shape with shear growth degree of 25mm and width of 6mm was used to conduct tensile test of silicone rubber according to Chinese national standard GBT528-2009, and the tensile force of silicone rubber sheets with different irradiation intensity before and after aging was measured.

**Hydrophobicity test.** 3 samples were taken for hydrophobicity test, and the contact Angle of water droplets before and after aging of silicone rubber was measured by instrument, referring to IEC/TS 62073-003.In the test, if the static contact Angle is greater than 90°, the composite silicone rubber is considered to have hydrophobicity, on the contrary, it is not considered to have hydrophobicity.

After aging test, the samples were taken out, cleaned and dried, and mechanical tensile force, SEM, hydrophobicity and other parameters of the silicone rubber material were tested.

#### 3. Test results

#### 3.1 Appearance change

The micrographs of silicone rubber materials with different radiation intensity before and after aging were observed by optical microscope, as shown in Fig. 3 and Fig. 4.



(b) after aging test observed by optical microscope **Fig.4** Micrographs of silicone rubber materials before and after 1000h aging test observed by optical microscope From the perspective of optical electron microscopy, the surface structure of silicone rubber changed little after 1000h of aging. In order to study the changes of microstructures on the surface of silicone rubber after environmental aging, scanning electron microscopy (SEM) was used to observe the surface microstructure of silicone rubber before and after aging, as shown in Fig. 5.

From SEM picture in Fig.4, the surface porosity of silicon rubber surface porosity increased after aging. As the irradiation dose increases, the porosity of the silicone rubber increases, from which it can be indicated that, electron irradiation can relieve the climate aging characteristics of silicone rubber when irradiation dose is 60KGy. As irradiation dose continues to increase, the porosity of silicon rubber re-increases.



(a)ungaged



(b)after 1000h aging, 0KGy



(c)after 1000h aging, 60Kgy



(d)after 1000h aging, 100KGy **Fig.4** SEM graph of different species after 1000h aging test

#### 3.2 Mechanical tension detection

The results of the tensile test results were compared with the different irradiation intensity, as shown in table 1 and Fig.5. According to the experimental results, the stress changes were the minimum and the stress of the mechanical resistance was the most strong.



Fig.5. Silicone rubber tensile test

 Table 1. The stress of silicone rubber before and after aging

	Before aging	After aging
0 KGy	510kN	484kN
60 KGy	595kN	538kN
100 KGy	580kN	525kN

#### 3.3 Appearance change

Hydrophobic angle of different test species were measured (average value of 20 species under each condition). The test results are shown in Fig.5 and Table.2.



(a)unaged, 0KGy



(b)unaged, 60KGy



(c)unaged, 100KGy



(d)1000h aged, 0KGy



(e)1000h aged, 60KGy



(f)1000h aged, 100KGy **Fig.6.** Hydrophobic angle of different test species

**Table 2.** Hydrophobic angle of silicone rubber before and after aging

	Before aging	After aging
0 KGy	115.39°	112.46°
60 KGy	116.11°	112.82°
100 KGy	115.91°	110.47°

Before aging, with the increase of irradiation dose, hydrophobic angle increases first and then decrease.

After aging test. Hydrophobic angle of eah species decreases. As the irradiation intensity increases, the hydrophobic first increases and then increases. From which it can be indicated that, moderate irradiation intensity can increase the mechanic and electric characterstics of silicon rubber.

## 4. Conclusion

This paper studies the influence of irradiation intensity on the electric and mechanic characteristics of silicon rubber. According to the test results, following conclusions can be made:

1. After 1000h aging test, the visual appearance of the sample did not change. SEM shows that the surface of silicone rubber became rough after aging and the porosity increased.

2.As the irradiation intensity increases, the mechanical tension and hydrophobic angle of silicon rubbber increases firstly and then decreases.

3. Moderate irradiation intensity can effectively inprove the aging characteristics of silicon rubber.

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