# Improvement in Interfacial Performances of Silicone Rubber by Oxygen Plasma Treatment

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**Abstract** : The Surface of semi-conductive silicone rubber was treated by oxygen plasma to improve adhesion and electric performance in joints between insulating and semi-conductive silicone materials. Surface characterizations were assessed using contact angle measurement and Fourier transform infrared spectroscope (FTIR). Adhesion level was understood from T-peel tests between plasma treated semi-conductive and insulating material. Electrical breakdown strength was measured to understand the charge of electrical performance. From the results, the oxygen plasma treatment produces a significant increase in function group of containing oxygen which can be mainly ascribed to the creation of carbonyl groups on the silicone surface from the strength were improved. Therefore it is concluded then plasma treatment leads to decrease voids originating form poor adhesive, and the improve the adhesion in silicone interface. So we could obtain higher electrical design level of silicone material used for electrical apparatus using oxygen plasma treatment

**Key Words** : Plasma treatment, Interface, Silicone rubber

## 1. INTRODUCTION

A number of electrical apparatus require light weight, ease handling and manufacturing. So many polymers have been used as insulating material in electrical applications. Especially, silicone rubber has good electrical and mechanical properties. Therefore, it has been used many power applications such as cable joint, bushing and so on. However, because surface of silicone rubber is inherent hydrophobic, adhesion property with other materials is poor. So there is a high chance to be formed voids in the interface, which could lead to and inception point of electrical discharge. For the above problem, the mechanical interlock through roughening the surface and interface agent for adhesion improvement have been used. However, considering of surface roughness and interface, plasma treatment is good to modify the polymer surface[1].

In our work, surface of semi-conductive silicone rubber was treated in and oxygen plasma to improve interface performances such as adhesion and electric performance in joints with insulating and semi-conductive silicone material. The surface characterizations were assessed using FTIR measurement. Adhesion was obtained form T-peel test between plasma treated semi-conductive and insulating material. Weibull test was used to understand the change of electrical performance.

## 2. EXPERIMENT

### 2.1 Samples and plasma treatment

The reference material used in this work is PDMS based silicone rubber. Semi-conductive silicone rubber is a compound with carbon black to obtain conductive properties. Insulating silicone rubber is two components room-temperature-vulcanized type. First, the semi-conductive sample was pressed in hot press under the condition of 170 ℃ and for 10 min. After treating by plasma for a specific minute, insulating silicone rubber compound was poured on semi-conductive specimen and then vulcanized at room temperature.

The samples were treated in a radio frequency plasma generator at a frequency of 13.56 MHz and a power of 50W. Treatments were performed at a pressure of 0.2hPa of pure oxygen and a gas flow rate of 25ml/min. Samples were treated for 1, 5 and 10 min. After treatment, the samples were exposed to the laboratory atmosphere while being transferred to surface analysis.

## 3. RESULTS

### 3.1 Fourier transform infrared spectroscope (FTIR)

Figure 1 displays IR spectrum changes of semiconductive silicone rubber which was differentiated exposure time of oxygen plasma discharge. As shown in the figure, it was increased change of peak value on hydroxyl group (OH) and carbonyl group (C=O) which are polar function group of semiconductive silicone rubber's surface.

These results, by performing treatment oxygen plasma on the semiconductive silicone rubber surface, a large supply of radical reacts on the semiconductive silicone rubber. It is considered that large supply of function group containing oxygen was employed which are Hydroxyl group (OH), Carbonyl group (C=O) onto surface.[2][3].

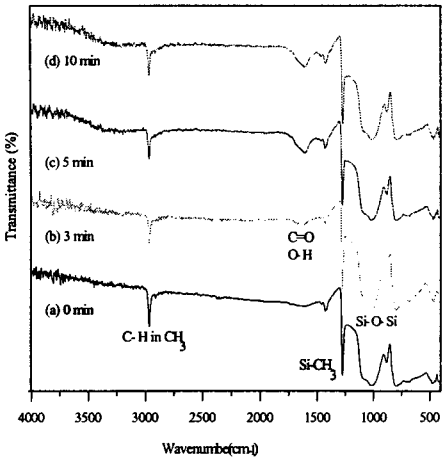


**Fig 1.** ATR-FTIR spectra at plasma discharge treatment of samples

### 3.2 T-peel test

T-peel strength values of untreated and plasma-treated samples are given in Fig. 2. By visual inspection, all untreated samples showed the interfacial breakdown in T-peel test because of a lack of adhesion. The oxygen plasma treatment produces an increase in adhesion strength with increasing treatment duration. However, samples with treatment duration for above 10 min showed decrease in adhesion strength. It is due to the formation of weak oxidized surface layer by excessive treatment. This data wasn't shown in this paper. So, it was found that plasma treatment creates many polar species on utmost surface and facilitates to increase adhesion strength between two materials.

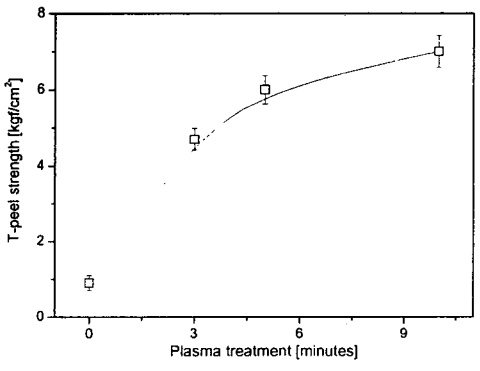


**Fig. 2.** Change of adhesive strength according to the Plasma treatment of samples

### 3.3 Electrical breakdown

The effect of plasma treatment on the breakdown on th breakdown strength of silicone rubber is shown in Table 1. The breakdown strength are analyzed by the Weibull distribution function Eav and $E_{10}$ correspond to the average breakdown strength and the strength at breakdown pro babilities 10% of samples. It is observed that Eav does appear to increase with a longer plasma treatment and breakdown strength with 10% probability is increased with plasma treatment. Therefore, it is concluded that plasma treatment could improve adhesion by increasing th surface energy which could obtain higher insulation level.

Table 1. Effect of plasma treatment on the breakdown strength of insulating samples

| | Eav(kV/mm) | η | $E_{10}$(kV/mm) |
|---|---|---|---|
| Untreated | 76.38 | 72.9 | 52.4 |
| 1 min | 78.58 | 73.1 | 58.1 |
| 5 min | 78.77 | 75.6 | 58.8 |
| 10 min | 82.22 | 79.4 | 59.4 |

## 4. CONCLUSION

We have analyzed the surface of plasma-treated semi-conductive silicone rubber using FTIR. In addition, after plasma treatment, the adhesion and electrical breakdown strength were evaluated in insulating and semi-conductive silicone joints. It is found that plasma treatment leads to the formation of and oxidized layer that increase with longer plasma treatment. From the results of FTIR, it is found that oxygen plasma exposure increase the hydroxyl and carbonyl groups and then improve the adhesive strength, which originates from the generation of oxidized layer. Additionally, it is observed that electrical breakdown strength was increased by above 10%. The oxygen plasma treatment of semi-conductive silicone rubber is a promising method to improve adhesion and electrical strength.

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