# DIELETRIC STRENGEH AND INSULATING PROPERTY ON SURFACE OF SPACER FOR PARTICLE CONTANMINNATION UNDER $SF_6/N_2$ MIXTURE

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**Abstract**: Sulfur hexafluoride is the most commonly used insulation gas in electrical systems. Gas insulated systems are widely used in the electric power industry for transmission and distribution of electrical energy. When $SF_6$ was first discovered, the potential application was only considered for insulation because of good dielectric properties. But the widespread use of $SF_6$ gas by electric power and other industries has led to increased concentrations of $SF_6$ gas in the atmosphere. This causes concern as to possible effects on global warming because $SF_6$ is a potent greenhouse gas. Due to this reason, first we studied uniform and non-uniform field property by mixing $SF_6$ and $N_2$ gas. This paper presents the dielectric strength and insulating property on the surface of spacer for particle contamination under $SF_6/N_2$ mixture. Two types of mixed gases (50%$SF_6$_50%$N_2$, 20%$SF_6$_80%$N_2$) were applied. We performed tests for the length and shape of particle. Test gas pressure is from 0.3 to 0.7 MPa. Particle position on surface of spacer is divided into nine parts and review. The results of analysis on the central conductor 31mm concave point has been identified as critical point. We anticipated that the breakdown voltage through analysis and testing were conducted. To find the 50% Breakdown voltage, the number of breakdown was performed 10 times and all test results were applied to analyze the normal distribution. The study was conducted to develop environment-friendly insulating material for GIS that can reduce SF6 gas and make a design Criteria for mixtures.

## 1 INTRODUCTION

Sulfur hexafluoride (SF6) is widely used in the electrical equipments such as gas insulated switchgear (GIS) and gas circuit breaker (GCB), due to its excellent insulation and arc extinguishing characteristics and thermal stability. Despite its important advantages, SF6 gas became the focus of environmental influence, because SF6 gas causes the serious green house effect by its emission in the atmosphere. Due to this problem, $SF_6$ gas was classified as regulated gas on Kyoto Protocol(1997) and many countries are studying it for reduction of $SF_6$ gas.

Reduction of using $SF_6$ gas in electrical equipments has been going in various methods. Japanese makers developed 72/84kV $SF_6$ gas-free switchgear using dry air and solid insulation. [4] Korean makers are also developing the product using them. And studying about gas insulated line (GIL) using $SF_6/N_2$ gas mixture rated 20:80 are active by the manufacturer. It is already developed up to 550kV GIL. LS cable corporation are testing the long-term overvoltage test after developing 362kV GIL in Korea.[1]

A study of insulation materials which have isolation and arc extinguishing capability is used in variety of medium voltage class commercial products, however, the basic research that can substitute for $SF_6$ in high voltage class is not in advanced level yet. So we were conducted to develop environment-friendly insulating material for GIS that can reduce $SF_6$ gas and make design criteria under $SF_6/N_2$ mixture.

This paper presents the dielectric strength and insulating property on the surface of spacer for particle contamination under $SF_6/N_2$ gas mixtures.

## 2 EXPERIMENTAL SETUP AND PROCEDURES

### 2.1 Test chamber

A lightning impulse voltage with a waveform of 1.2/50μs was applied to the surface of spacer with particle. All tests were carried out in a pressure vessel. The chamber was designed for the maximum pressure of 1.0Mpa. The high-voltage connection to the vessel was through a composite bushing.

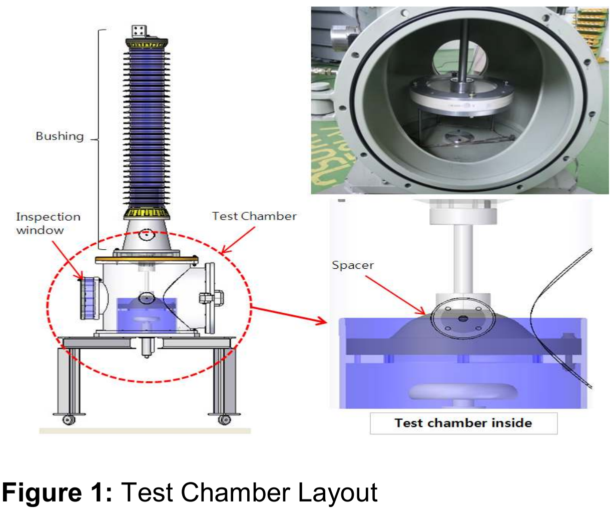


**Figure 1:** Test Chamber Layout

Figure 1 is the test chamber layout. The upper conduct and spacer's central conductor was assembled. The outer surface of the spacer applied flanges in order to implement the same conditions for GIS. The pure $SF_6$ gas with the pressure of 0.6Mpa was injected into the bushing section. Mixtures were injected into the test section.

**Table 1:** Test Information

| | Test Information | |
|---|---|---|
| Particle | Material type | AL |
| | Length[mm] | 5,10,20,30,40 |
| | Thickness | 0.2,0.3,0.4,0.45 |
| | Attaching Position | Spacer (maximum field) |
| Test condition | Test Method | LI/AC |
| | Pressure[Mpa] | 0.3,0.4,0.5,0.6,0.7 |
| | Mixing ratio[%] | 20,50,100 (SF6 gas ratio) |

Table 1 presents the test information. Particles were used to create a material after processing tanks in the factory.

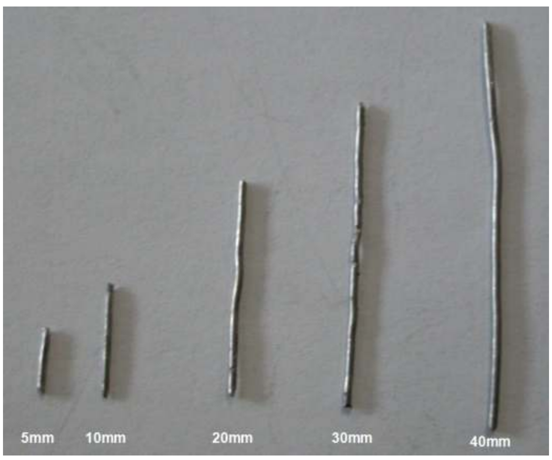


**Figure 2:** Particle shape

Figure 2 presents particle's shape. Each length is from 5mm to 40mm.

## 2.2 Analysis

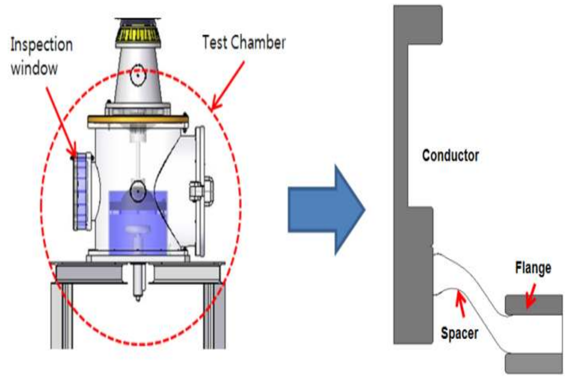


**Figure 3:** Analysis Model

Figure 3 shows the test chamber is a 2D shape model for analysis. Firstly the analysis was conducted on insulator without particle.

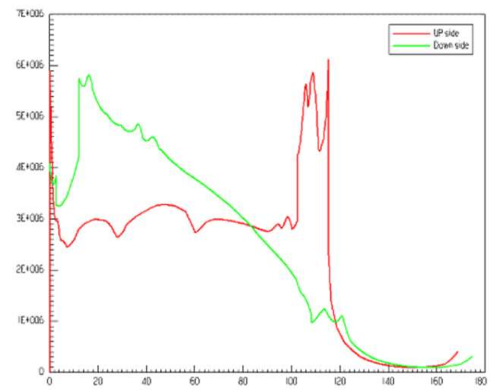


**Figure 4:** Analysis result without particles

Figure 4 is the result of insulation surface from the central conductor to flanges. The Convex and concave surface were almost identical to the value of the maximum electric field without particle. But the convex surface maximum electric field location was close to the central conductor and the triple point of the concave surface maximum electric field was located.

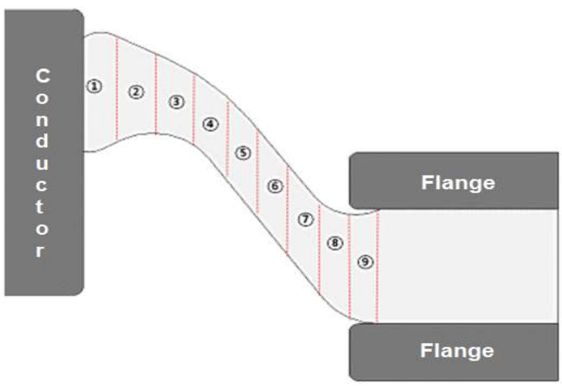


**Figure 5:** Spacer's surface attachment site for a particle

Figure 5 is the spacer's surface attachment site for a particle. A particle position on the surface of spacer is divided into nine parts and reviewed. Analysis results by each location of a particle are shown in the Figure 6 graph.

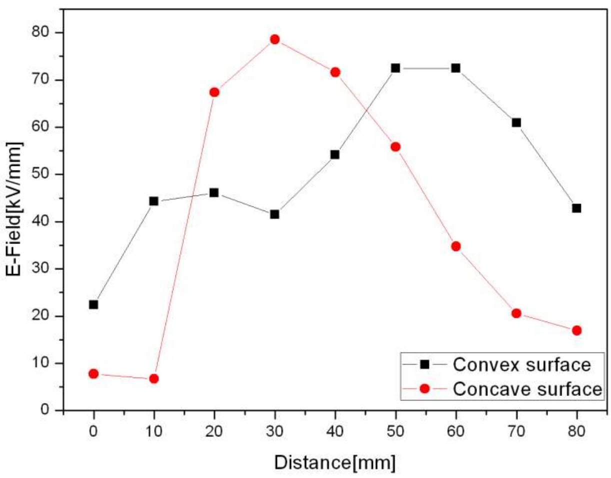


**Figure 6:** Analysis result for attachment site of spacer' surface for a particle(particle length 10mm)

In the initial attachment site, we conducted the analysis for spacer on the surface with the particle's length to 10~50mm in 10mm gap. As particle's length becomes longer, the maximum E-filed increase and the breakdown voltage can be expected to become lower. The results of analysis on the central conductor 31mm concave point has been identified as critical point. That is shown in Figure 7.

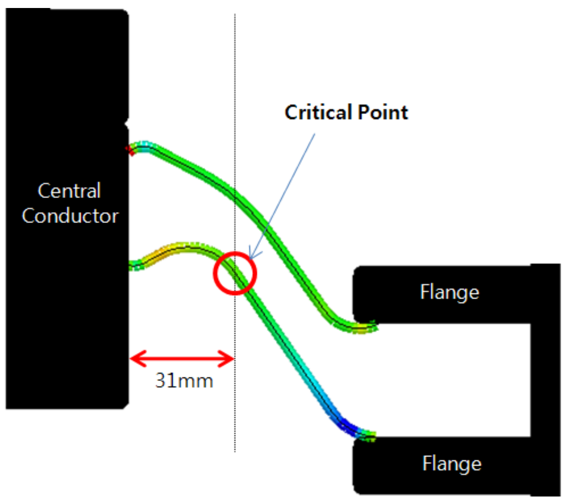


**Figure 7:** Analysis result for critical point of a particle

Based on these results, the initial tests(LI) were conducted. According to the position of spacer's the convex and concave surface, the dielectric break down test was carried out. Figure 8 present breakdown picture of spacer for initial tests. [2]

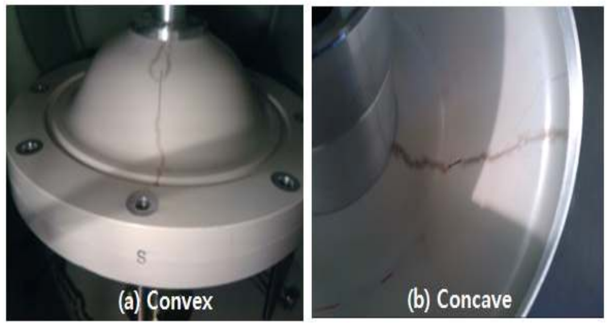


**Figure 8:** Breakdown picture of spacer for initial Tests
(a) convex of spacer, (b) concave of spacer

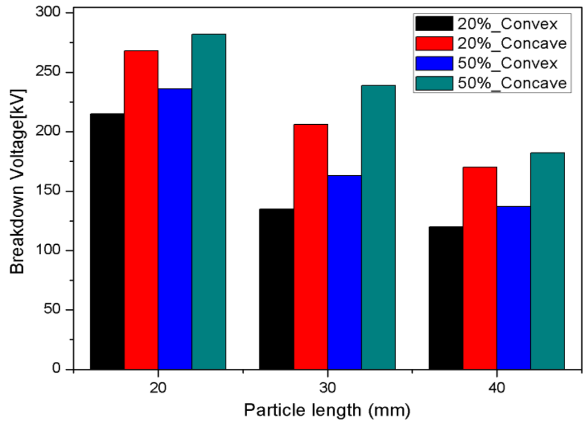


**Figure 9:** **I**nitial Test results for breakdown voltage

## 2.3 Test and Results

The test results based on the particle's length was estimated according to the breakdown voltage. During the test, the voltage increased by 5kV until the breakdown were performed. To find the 50% Breakdown voltage, the breakdown was performed 10 times and all test results were applied to analyze the normal distribution. [3]

**Figure 10:** LI and AC Test layout

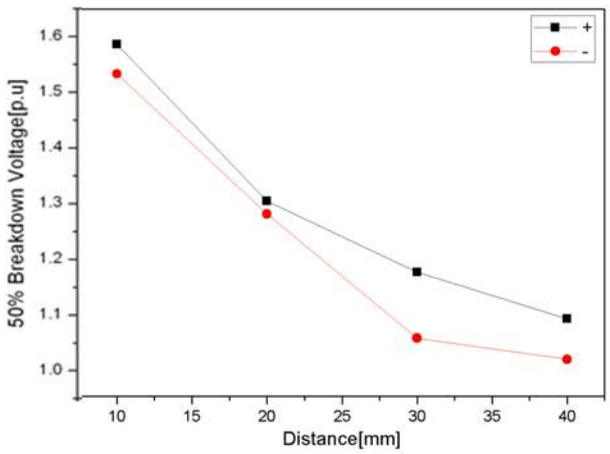


**Figure 11:** LI Test result for Polarity in 20%SF6 80%N2 gas

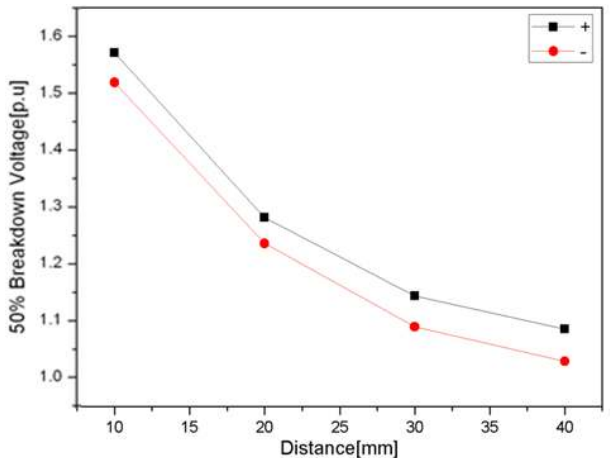


**Figure 12:** LI Test result for Polarity in 50%SF6 50%N2 gas

Figure 11 and 12 shows polarity test results for the mixed gas 20% and 50%. Convex to concave surface was compared to the high breakdown voltage. Breakdown voltage level was higher the positive than the negative polarity. This shows the weak performance of the negative isolation.

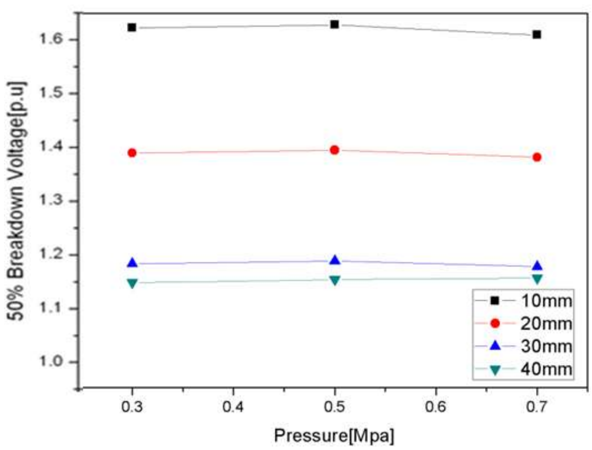


**Figure 13:** LI Test result for Pressure in 20%SF6 80%N2 gas

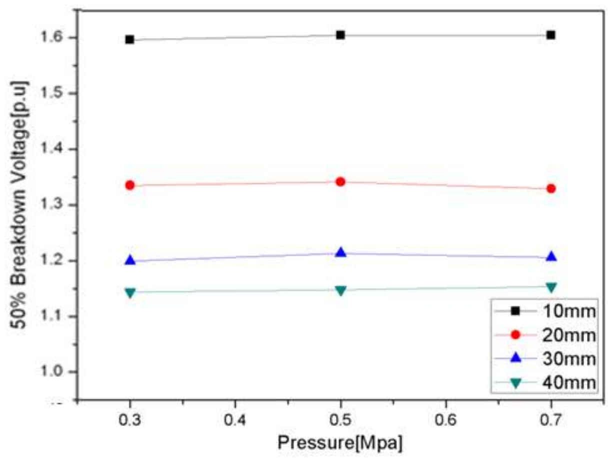


**Figure 14:** LI Test result for Pressure in 50%SF6 50%N2 gas

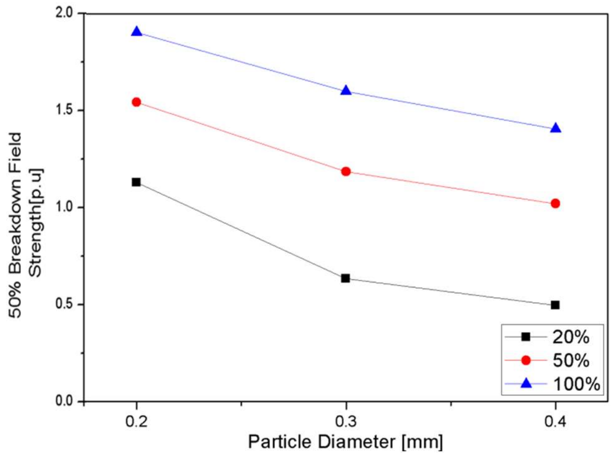


**Figure 15:** LI Test result for Particle Diameter in gas mixture ratio

Figure 13 and 14 shows the results in the breakdown of the gas pressure for mixture gas. With increasing gas pressure in same conditions, small change was shown in the breakdown voltage. With increasing gas mixture ratio of dielectric breakdown, the voltage rises slightly. The larger the diameter of particle breakdown the voltage decreases. Figure 15 shows the test results of each particle diameter in the same length. As the mixture ratio is in the higher percentage (100%>50%>20%), the order of breakdown voltage is also higher. Figure 16 shows the results for particle length in gas mixture ratio. Smaller the length of particle, the breakdown voltage is increased. Mixture ratio 50%>20%>100% of the breakdown voltage is higher order. This is the corona stabilization effect. After the initial corona was occurred, rise of ion voltage becomes slow prior to the minimum leader inception voltage and it is out of the corona region. Therefore, the space charge generated by corona discharge and it appears to mitigate the electric field effect. [4]

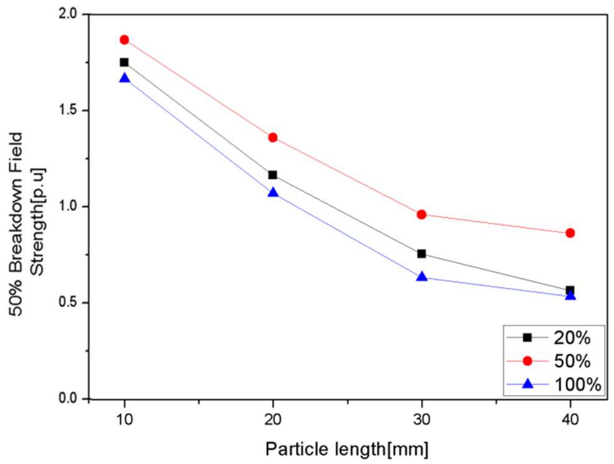


**Figure 16:** AC Test result for Particle length in gas mixture ratio

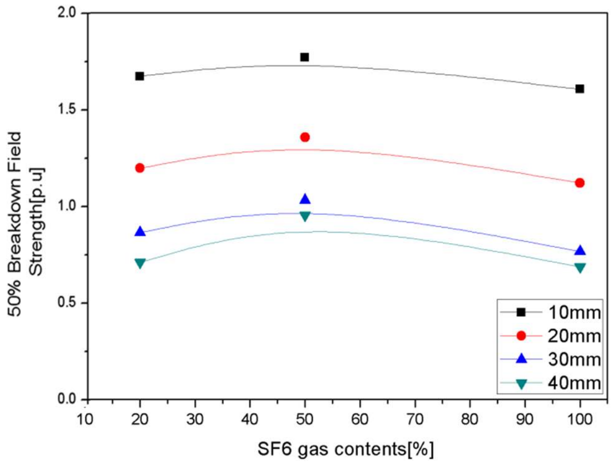


**Figure 17:** AC Test result for mixture ratio and particle length in same diameter's particle

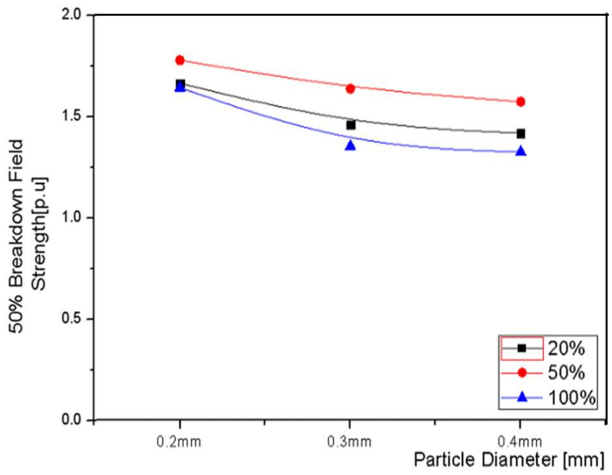


**Figure 18:** AC Test result for mixture ratio and particle diameter in same length

Figure 17 and 18 shows the results in the breakdown for mixture ratio. With increasing gas pressure in same conditions, the breakdown voltage changes small amount. With increasing gas mixture ratio of the dielectric breakdown voltage rises slightly. The larger the diameter of particle, breakdown voltage decreases.

## 3 CONCLUSION

This study is performed to make the insulation design criteria about the surface of spacer for particle contamination under $SF_6/N_2$ gas mixtures, as the fundamental step to develop the environmental friendly product of HV class level.

1. The dielectric strength of 50% $SF_6$ gas mixture is about 8~12% higher than 20% SF6 gas mixture.

2. The metal particle on Spacer's surface by the attractive force is easy to attach

3. Particle's breakdown is determined by the electric field strength of spacer's surface direction.

4. Under AC Test, because of the corona stabilization effect, the breakdown voltage values by $SF_6$ gas ratio are 50%>20%>100%.

5. Under the same particle, there is small change in breakdown voltage by the gas pressure.

Through this study, we established the process about the insulation design criteria in the surface of spacer for particle contamination using test chamber. And we also performed the electric test about uniform and non-uniform field and the temperature rising test for the application of products using this design criteria. Now, we are reviewing the results. Finally, we think the results will be used as the basic data of $SF_6$-$N_2$ gas mixtures to develop the environmental friendly power equipments.

## 4 REFERENCES

[1] D. H. Jeong et al., "Insulation characteristic of HV switchgear applied dry air", Trans. KIEE, Vol. 57, No. 10, 2008

[2] Tokio Yamagiwa et al., "Particle-Initiated breakdown Characteristics on A Ribbed Spacer surface for $SF_6$ Gas Insulated Switchgear", Trans. of IEEE, Volume 3, No3, 1998.

[3] M. Hinow, W. Hauschild, E.Gockenbach: "Lightning Impulse Voltage and Overshoot Evaluation Proposed in Drafts of IEC 60060-1 and Future UHV Testing", IEEE TDEI, Vol. 17, No. 5, pp. 1628- 1634, 2010

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