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Surface Dielectric Characteristics of GFRP and PTFE in Cryogenic Environment under the Switching Impulse Superimposed on DC Voltage

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Background

- Insulation of the DC circuit breaker combined with the superconducting current-limiting module may cause a big problem when DC and SI superimposed due to the generation of a switching impulse waveform.
- When voltage sources of different polarities are superimposed, the fault voltage can be reduced, but when voltages of the same polarity are superimposed, it causes more serious stress in the system.
- Therefore, for the insulation design of the DC circuit breaker combined with the superconducting current-limiting module, it is essential to analyze the surface insulation characteristics according to the superimposing switching impulse waveform during DC operation of solid insulators.

Aim of work

- In order to obtain the surface insulation properties of the solid insulator of the DC circuit breaker combined with the superconducting current-limiting module, GFRP and PTFE were selected as insulation materials.
- For the insulation problem of DC circuit breaker combined with superconducting current-limiting module and compactness of the product, DC+SI superimposing surface dielectric breakdown experiment of GFRP and PTFE was performed.

Experiment Set-up

- In order to measure surface dielectric breakdown of DC and SI superimposed voltages of solid insulators according to the gap distance, the specimens were made of 50x50x15 mm GFRP and PTFE as shown in the fig.1
- As shown in Fig. 2, a jig was manufactured so that the solid insulator could be placed in the jig and adhered to the electrode. For the electrode used in the experiment, the edge of the electrode was rounded with R10 to prevent electric field concentration due to the corona phenomenon at the edge of the electrode, and the rod-shaped electrode was cut at 180 degrees to adhere to the specimen.
- In order to check the surface insulation properties of GFRP and PTFE according to the gap distance, the gap distance was selected as 5, 10, 15, 20 [mm].
- The surface breakdown was configured as shown in Fig. 3, and liquid nitrogen was filled in the cryostat so that the experimental jig could be sufficiently submerged.
- In order to prevent the formation of bubbles in liquid nitrogen, the experiment was conducted after maintaining a pressure of 3 bar by pressurizing with gaseous nitrogen.

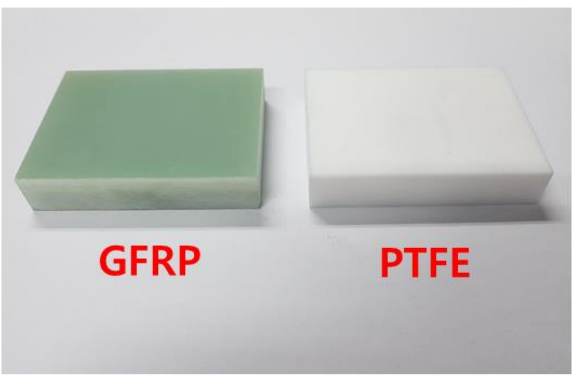


Fig. 1 Prepare two kind of specimens

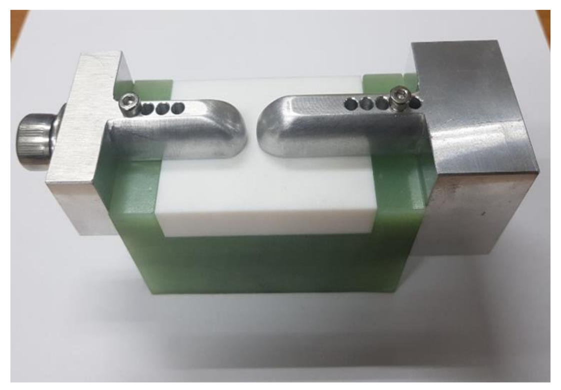


Fig. 2 Configuration of test jig

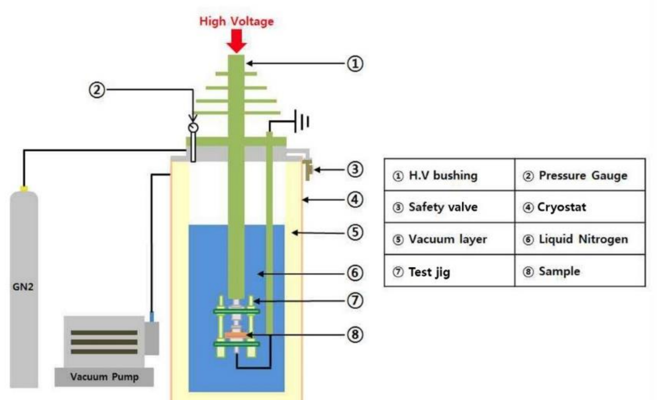


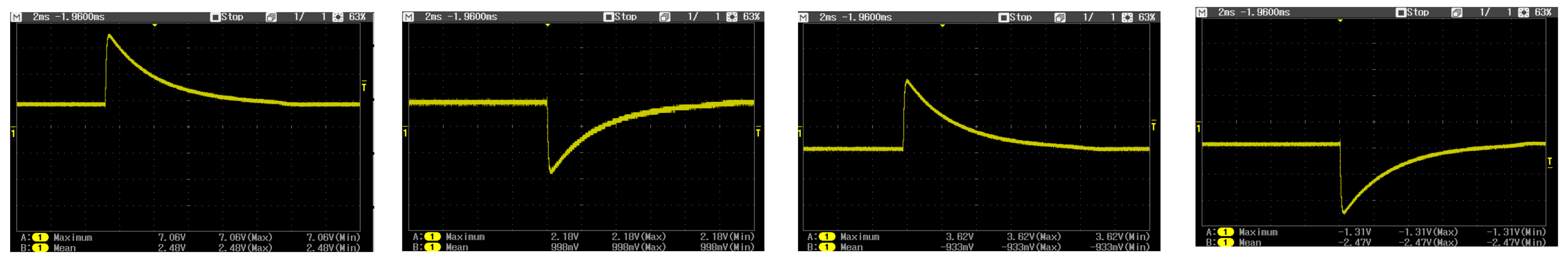
Fig. 3 surface breakdown test set-up

Conclusion

- As a result of comparing the surface dielectric strength of GFRP and PTFE, GFRP is superior to PTFE, but the difference in surface dielectric breakdown voltage decreases as the gap distance increases.
- The surface dielectric strength of GFRP and PTFE is the weakest when voltages of the same polarity are superimposed.
- It will be helpful in estimating the separation distance of solid insulation using the experiment result of superimposed DC + SI surface dielectric breakdown according to the gap distance.

DC+SI superimposition system

- A DC+SI superimposition system was constructed using a switching impulse generator, a DC generator, and a superposition facility, as shown in Fig. 4. The switching impulse generator and blocking capacitor were connected in series, and the DC generator was also connected in series with the protection resistor. The blocking capacitor and the protective resistor were connected in series to the superimposing equipment and the experiment was performed.
- DC positive and DC negative voltages of less than 3% ripple and switching impulse of 215 us/2390 us were used. The superimposed DC+SI voltage was checked through an oscilloscope, as shown in Fig. 5.



(a) +DC +SI superimpose (b) +DC -SI superimpose (c) -DC +SI superimpose (d) -DC -SI superimpose

Fig. 5 Superimposed DC+SI voltage wave

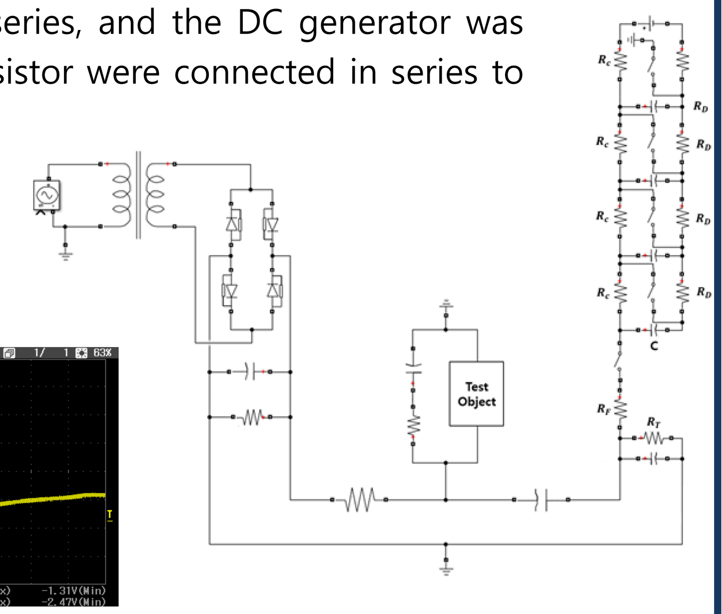


Fig. 4 DC+SI superimposition system

Experiment result and discussion

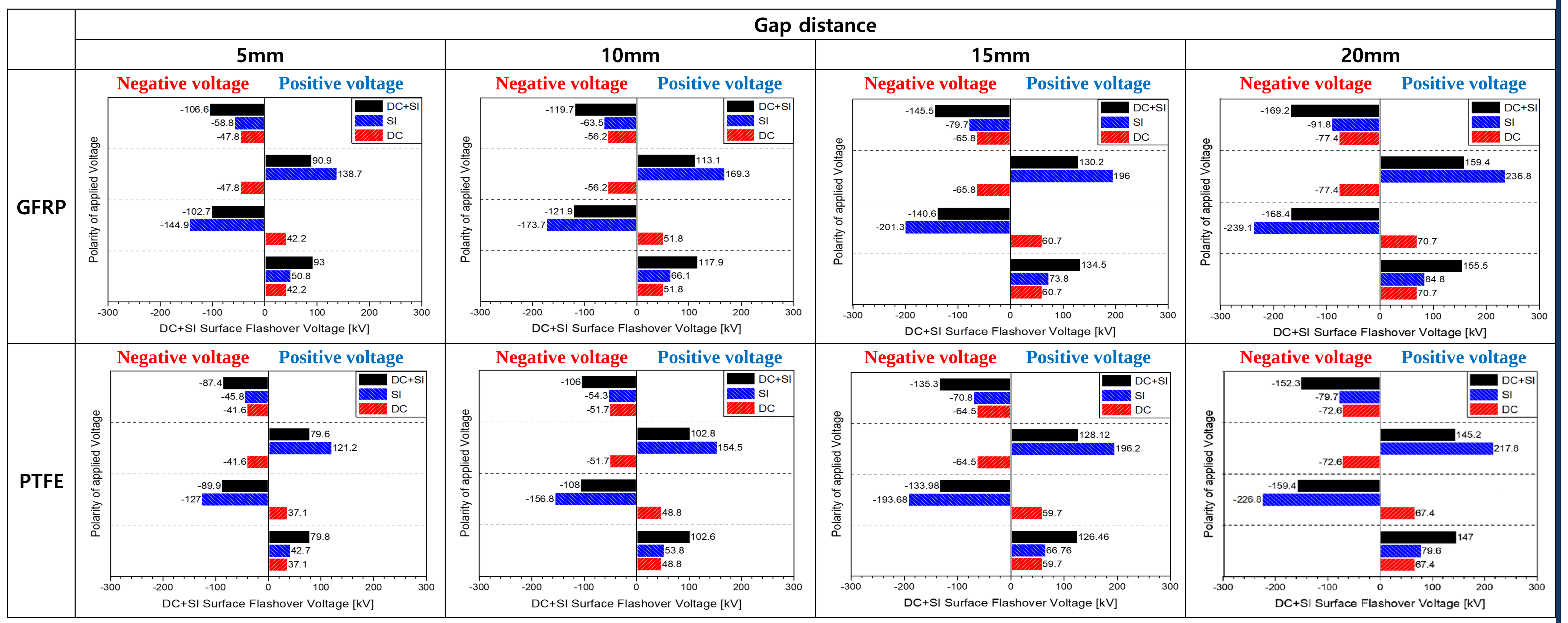


Fig. 6 surface breakdown voltage of GFRP and PTFE under DC+SI superimposed voltage

- In order to evaluate the DC+SI surface dielectric breakdown characteristics of GFRP and PTFE, the polarity of the applied voltage and the gap distance were selected and the experiment was performed.
- As the gap distance increased, both the SI and DC applied voltages rise regardless of the polarity and insulating material, so the superimposed SI+DC surface breakdown voltage increased.
- the surface breakdown voltage of GFRP was measured to be higher than that of PTFE, but as the gap distance increased, the difference in surface breakdown voltage according to the insulating material decreased.
- GFRP had a higher surface breakdown voltage when the polarities were the same, and PTFE had a high surface breakdown voltage when the polarities were different, but the difference according to polarity was insignificant.
- When only SI and DC applied voltages are considered, surface dielectric strength is the weakest when voltages of the same polarity are superimposed.