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A Study on the Dielectric Design of High Voltage Platform for developing 28 GHz ECRIS at KBSI

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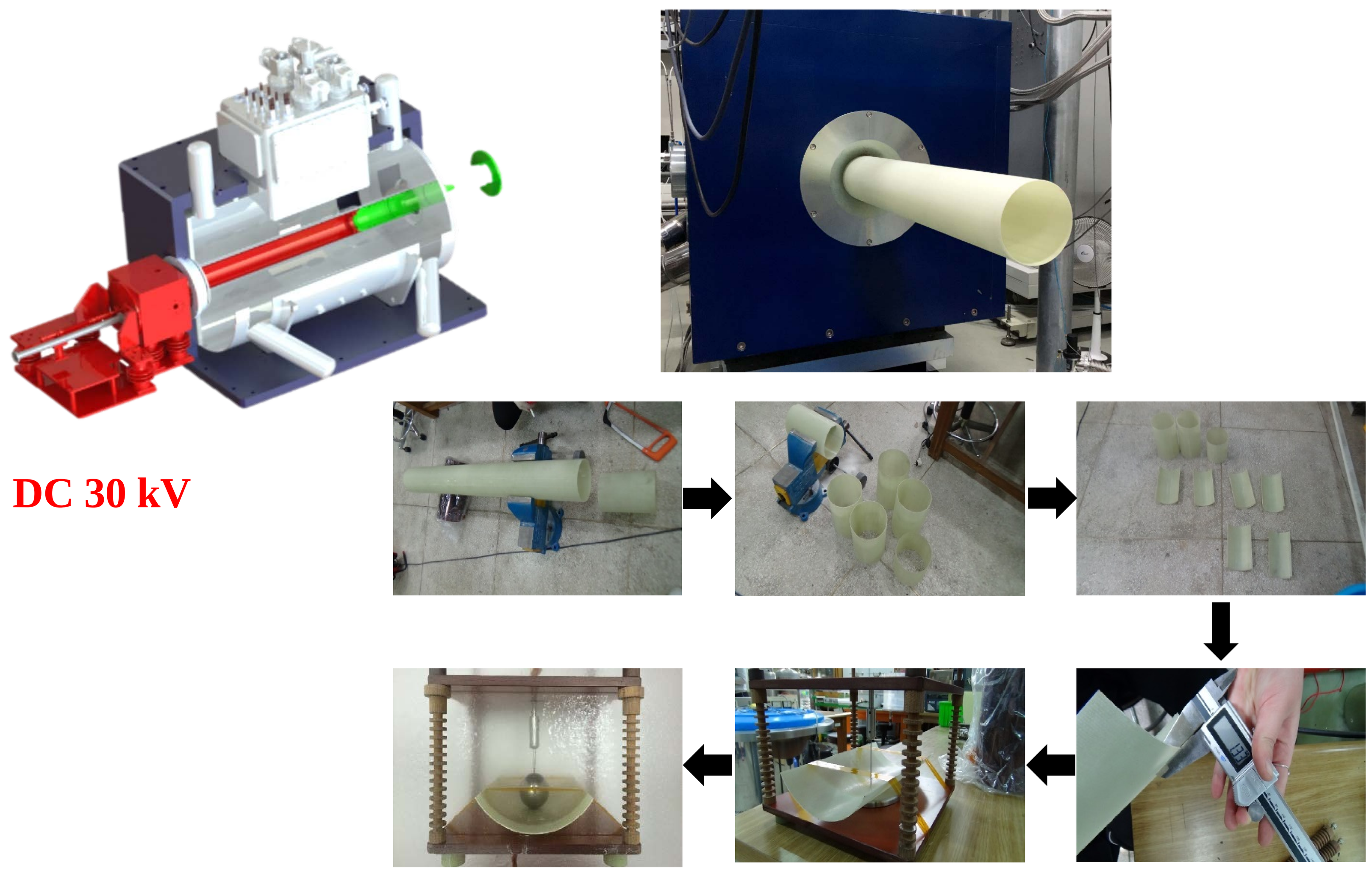
Abstract

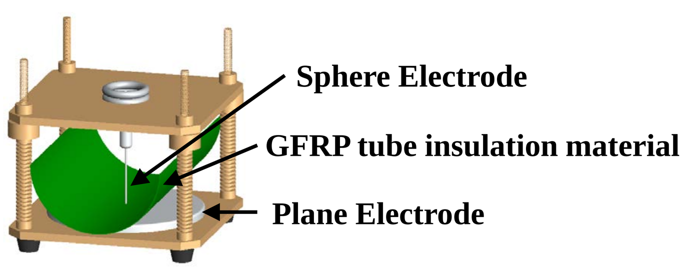
Currently, the 28 GHz electron cyclotron resonance ion source (ECRIS) has been developed to produce a high current heavy ion at korea basic science institute (KBSI). The high voltage platform of 28 GHz ECRIS is essential to deliver an ion beam to the next acceleration stage. In order to ensure the electrical safety, the high voltage platform has been designed considering dielectric characteristics. In this paper, a study on the dielectric characteristics of glass fiber reinforced plastic (GFRP) is performed to determine the thickness of GFRP tube located between plasma chamber and inner bore of cryostat. The dielectric experiments on GFRP tube are conducted under DC voltage. Sphere-to-plane electrode systems are used to examine the dielectric characteristics. Also, the relationship between the dielectric characteristics of GFRP tube and the distribution of electric field intensity is calculated and analyzed by the finite elements method (FEM).

Experimental Set-up

- In this paper, experiments on the sparkover breakdown voltage are conducted to verify the dielectric characteristics of GFRP tube insulation material.
- Fig. 1. show the schematic drawing of the experimental set-up.



Electrode material	Aluminum
Sphere Electrode	100 umm, 1mm, 2mm, 6mm, 10mm, 20mm, 50mm
Plane Electrode	Diameter 80mm, thickness 10mm, radius of curvature 5mm at edge
Thickness of GFRP	1 mm



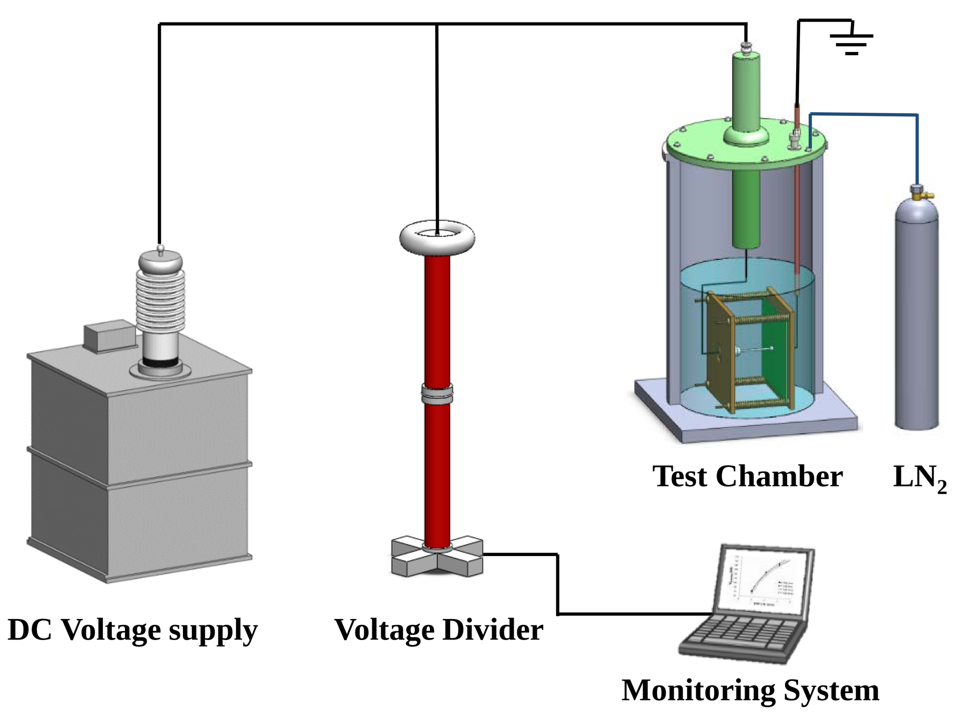


Fig. 1. The schematic drawing of the experimental set-up.

Experimental Results

- The experimental results on GFRP tube insulation material under DC voltage are shown in Fig. 2.

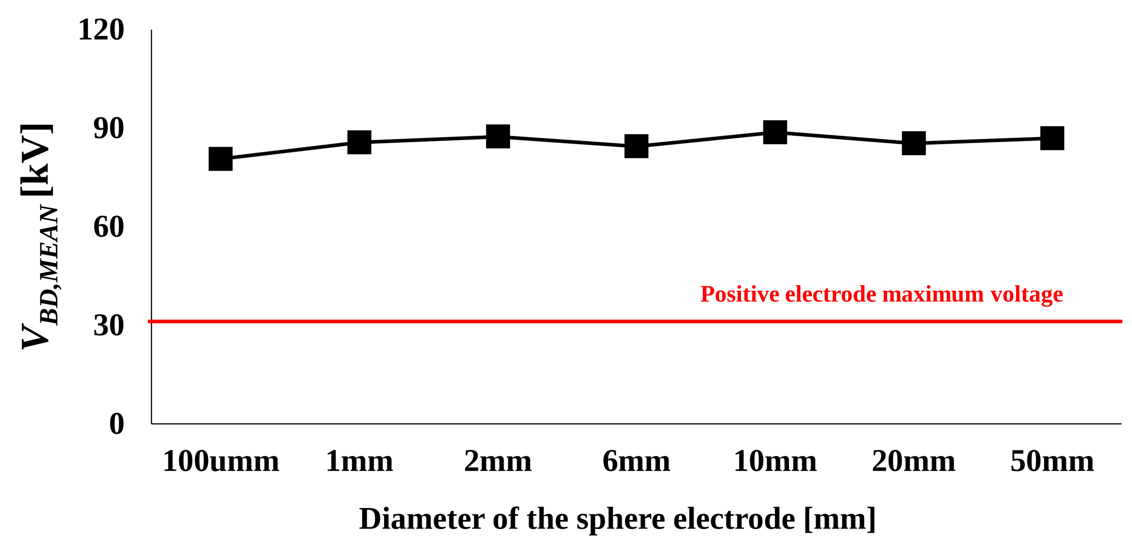


Fig. 2. The $V_{BD,MEAN}$ of GFRP tube insulation material according to various diameter of the sphere electrode.

- These results shows that the electrical breakdown voltage with penetration is not affected by the diameter of the sphere electrode.
- It is thought that this result is mainly caused by the relatively little momentum of the lattice. The velocity of emitted electrons from an electrode could not accelerate easily due to the densely arranged lattice.
- The maximum E at sparkover ($E_{BD,MAX}$) is calculated by multiplying $V_{BD,MEAN}$ by the analytic maximum E ($E_{1kV,MAX}$), which is calculated by inputting 1 kV into an FEM analysis. The relation among $E_{BD,MAX}$ (or $E_{BD,MEAN}$), $E_{1kV,MAX}$ (or $E_{1kV,MEAN}$) and $V_{BD,MEAN}$ can be represented as follows:

$$E_{BD,MAX} = E_{1kV,MAX} \times V_{BD,MEAN} \dots (1)$$

$$E_{BD,MEAN} = E_{1kV,MEAN} \times V_{BD,MEAN} \dots (2)$$

- $E_{BD,MAX}$ indicates the maximum E at sparkover, and $E_{BD,MEAN}$ denotes the mean E at sparkover, respectively. As a result, the relation between $E_{BD,MAX}$ (or $E_{BD,MEAN}$) and ξ can be calculated by (1) or (2). The value of ξ can be calculated by simulating the electrode structure at sparkover. $V_{BE,MEAN}$ of GFRP tube insulation material is converted into $E_{BD,MAX}$ and $E_{BD,MEAN}$ to verify the relation between E and ξ.
- The dielectric characteristics of GFRP tube insulation material, $E_{BD,MEAN}$, remains constant value, and $E_{BD,MAX}$ has an exponential relation to ξ, as shown in Fig. 3.

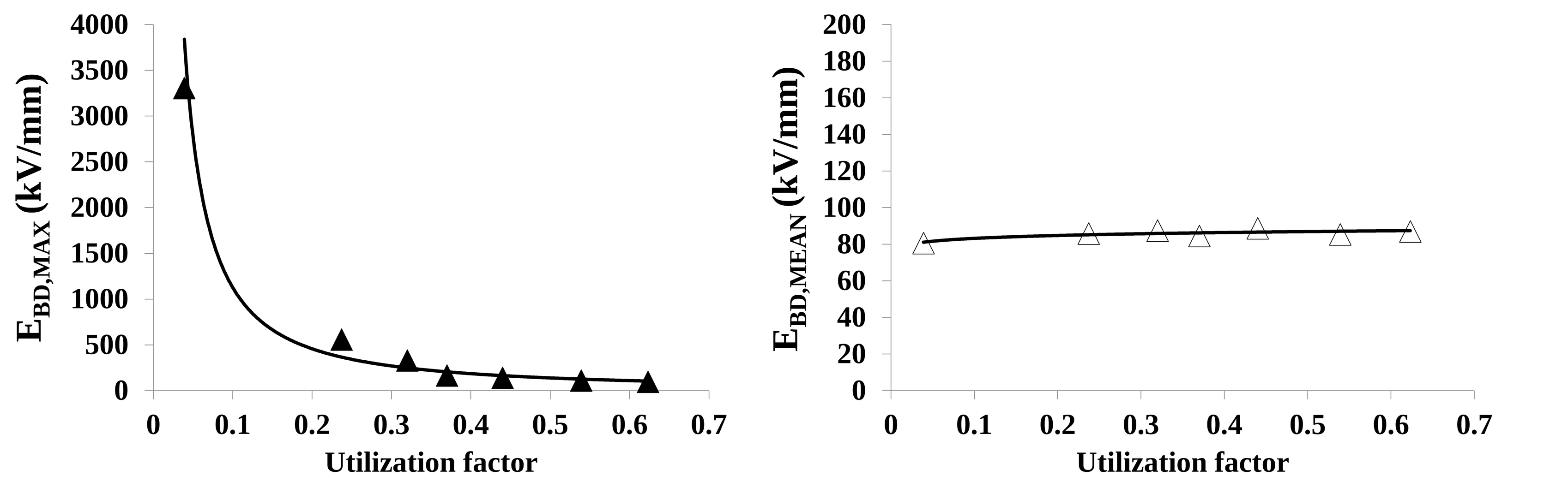


Fig. 3. $E_{BD,MAX}$ and $E_{BD,MEAN}$ at sparkover of GFRP tube insulation material according to ξ.

- Also, It is expressed that the functional relation between the dielectric characteristics of GFRP tube insulation material and ξ in Table 1.

Table 1. $E_{BD,MAX}$ and $E_{BD,MEAN}$ of GFRP tube insulation material.

E	$E_{BD,MAX}$	$E_{BD,MEAN}$
Voltage	56.2 $\xi^{0.0272}$ kV	88 kV

Conclusion

- Experimental results on GFRP tube insulation material were analyzed by FEM simulation.
- The functional relations between electric field intensity and ξ were expressed as exponential equations.
- As a results, it was found that the dielectric characteristics of GFRP tube insulation material (thickness 1 mm) could be explained by not only $E_{BD,MAX}$ but also $E_{BD,MEAN}$.
- Finally, the dielectric design of high voltage platform for developing 28 GHz ECRIS can be conducted by applying the deduced empirical formulae.
- We also plan to analyze various dielectric material of the high voltage platform.