Cryogenic electrical property of cyanate ester/epoxy insulation material for fusion superconducting magnet

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Background

- ✓In order to maintain fusion for long periods of time, high magnetic field is required in ITER to control the high temperature plasma, and it is crucial for superconducting magnets operating in cryogenic environment to maintain its superconductivity
- ✓the insulation of the superconducting coils is affected by a combination of low temperature, irradiation and high voltage as well as by mechanical stresses at the magnet location.
- ✓most of the electrical properties of insulation materials used in high field fusion magnets are based on transposing the existing data available of unirradiated ones at low temperature.

Sample preparation

- ✓The cyanate ester/epoxy insulation material used in this experiment consists of 40% cyanate ester and 60% epoxy, This material was fabricated using the vacuum pressure impregnation(VPI) technique.
- ✓60Co γ–ray is used to irradiate the specimens in air at ambient temperature with a dose rate of 300 Gy/min. The total doses were 1 MGy, 5 MGy and 10 MGy, respectively

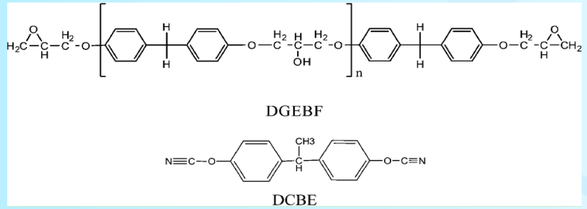

Figure 1. Chemical structure of DGEBF and DCBE

Experimental Apparatus

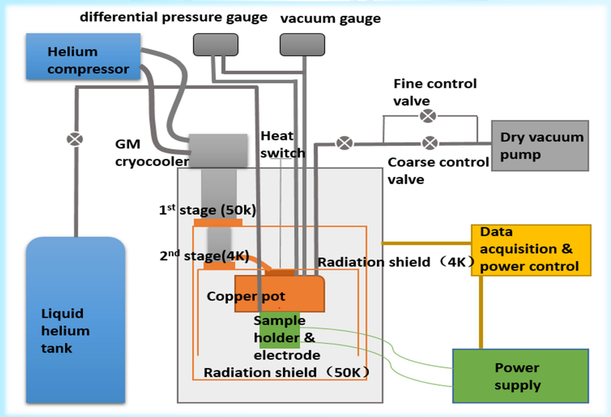

Figure 2. Sketch of cryostat with a GM cryocooler

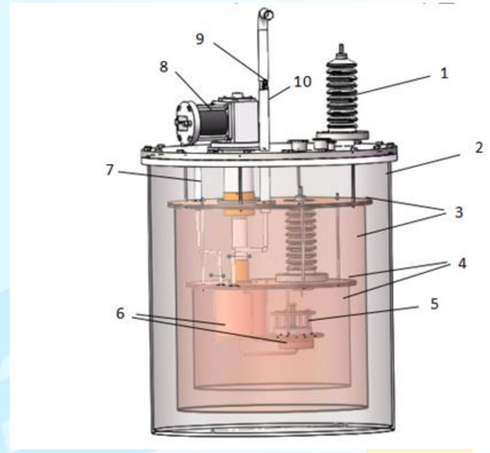

Figure 3. Schematic drawing of cryogenic electrical properties testing system

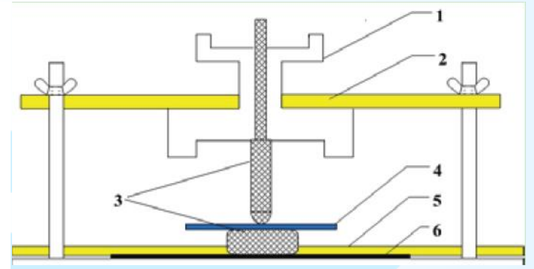

Figure 4. Structure of electrode system for electrical breakdown strength

This system consists of three parts： a G-M cryocooler and a cryogenic liquid tank which are applied to cool down the whole system. An electrode system which is used to measure the breakdown strength of samples, and finally a thermal insulation system to maintain a cryogenic environment.

Experimental Procedure

- ✓The first step is sandwiching the sample between the top electrode and the bottom electrode, the top electrode and the bottom electrode is connected to the high voltage and ground, and then compressing the sample by insulation bushing.
- ✓The second step is exhausting the air from the vessel to create a vacuum pressure environment, and then turning on the cryocooler until the temperature of the sample reach up to 6 K, finally, injecting liquid helium and switching on a heater to keep the temperature.
- ✓The last step is turning on the high voltage DC power supply and ramping up the voltage with a rate of 1 kV/s. When a breakdown occurred, recording the result and taking the average value of 5 samples.

Result

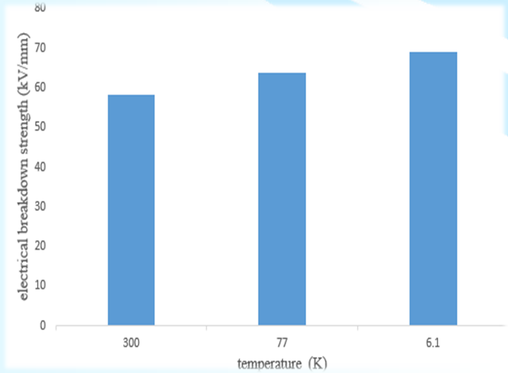

Figure 5. Electrical breakdown strength of the composition in different temperature

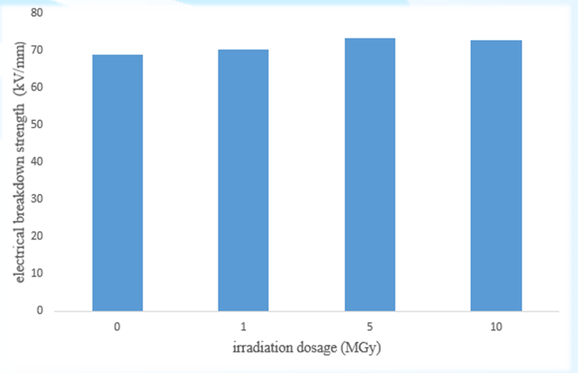

Figure 6. Electrical breakdown strength of the composition before and after irradiation at 6.1 K

- ✓the breakdown strength at 6.1 K is about 18% higher than that at 300 K.
- ✓the breakdown strength at 6.1 K is about 8% higher than that at 77 K.
- ✓The electrical breakdown strength after absorbing 1 MGy is about 1.8% higher than that of unirradiated ones.
- ✓The electrical breakdown strength after absorbing 5 MGy is about 6.4% higher than that of unirradiated ones.
- ✓The electrical breakdown strength after absorbing 10 MGy is about 5.7% higher than that of unirradiated ones.

Conclusion

- ➢Cryogenic temperature has a positive effect on electrical resistance of cyanate ester/epoxy insulation material.
- ➢The effect of irradiation of ^{60}Co γ–ray on cyanate ester/epoxy insulation material at 6.1 K is not obvious.

Future

- ✓Study the action mechanism of cryogenic temperature and irradiation on electrical breakdown strength.
- ✓Improve the equipment to reach the superfluid helium temperature.
- ✓Test more kinds of electrical properties of cyanate ester/epoxy insulation material

Acknowledgment

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