Electrical Strength of the Insulating Materials for High-Tc Superconducting Devices

Duck Kweon Bae, Chung-Hyeok Kim*, Yong Cheul Oh*, Jin Sa Kim*, Cheol Gee Shin*, Min Jong Song**, Joon Ung Lee*

KIMM, Kwangwoon University*, Kwangju Health Colle**

Abstract : According to the trend for electric power equipment of high capacity and reduction of its size, the needs for the new high performance electric equipments become more and more important. On of the possible solution is high temperature superconducting (HTS) power application. Following the successful development of practical HTS wires, there have been renewed activities in developing superconducting power equipment. HTS equipments have to be operated in a coolant such as liquid nitrogen (LN_2) or cooled by conduction-cooling method such as using Gifford-McMahon (G-M) cryocooler to maintain the temperature below critical level. In this paper, the dielectric strength of unfilled epoxy and filled epoxy in LN_2 was analyzed. The filled epoxy composite not only compensates for this fragile property but enhances its dielectric strength

Key Words : Superconducting magnet, cryogenic insulation, surface flashover, dielectric strengt

1. Introduction

The existing commercialized superconducting magnetic resonance imaging (MRI) and nuclear magnetic resonance (NMR) actualize the high and uniformity magnetic field by using Low-Tc superconducting (LTS) magnet. The development of HTS power equipments have been actively progressing since Bi-2223 wire, the successfully commercialized HTS wire, appeared and was used [1]. For the purpose of their successful development, the development of the cryogenic temperature insulation system has to be carried out side by side [2]. The skills of companies with the insulation system under room temperature have been developed well but the study on cryogenic temperature insulation material is still under-developed. The study on the materials should be actively implemented to promote successful development for HTS power equipments. This paper is about the study of the insulation system for HTS power equipments, such as HTS magnets, HTS current leads, HTS power cables, and so on.

2. Preparation of Specimens and Experimental Setup

2.1 Preparation of Specimens

The specimens were made of two kinds of epoxy composites, which are unfilled epoxy made of Stycast 1266 part A and part B and filled epoxy made of Stycast 2850FT and Catalyst 23LV. The thicknesses of the specimens, as shown in Fig. 1, were 100, 150 and 200 μm, respectively. Fig. 1 shows the structure of specimen. As room temperature curing hardener was used in the manufacturing, all specimens were cured at room temperature in a drying oven. The cured each specimen was separated from molder, cleaned and dried in the drying oven.

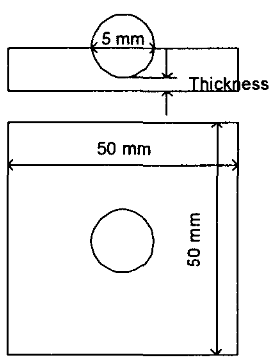

Fig. 1. Preparation of specimen

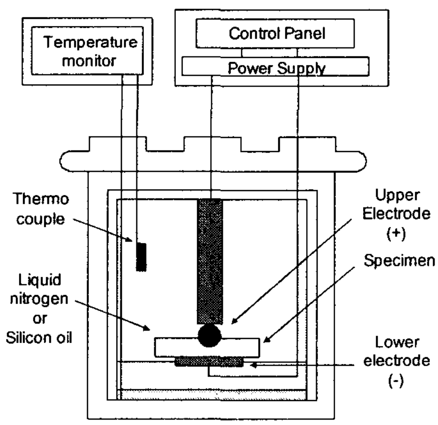

Fig. 2. Experimental setup

2.1 Experimental Setup

Test method was selected according to the short-time test (current setting: 10[mA], rate-of-rise: 500[V/s]) of ASTM D 149-95a (Dielectric breakdown voltage and dielectric strength of solid electrical insulating materials at commercial power frequencies) [3]. Fig. 2 shows the structure of experimental system. The dielectric strength of the each type of specimen was measured both at room temperature and 77K. Before the measurement at 77K, because of the weakness to thermal shock, the each specimen was immersed in the liquid nitrogen vessel very carefully and slowly. The sudden change of the temperature may make the mechanical crack in the specimen. All specimens were immersed in LN_2 vessel for 30 minutes before breakdown test.

3. Results and Discussions

3.1 Breakdown voltage of unfilled epoxy

A stycast 1266A/B was selected as an unfilled epoxy. Fig. 3 show the breakdown voltage of unfilled epoxy specimen. The measured breakdown voltage at room temperature was slightly higher than that at 77K. The dependence of the breakdown voltage measured at 77K in kV was proportional to $d^{0.54}$, and it at room temperature was proportional to $d^{0.53}$. Although each specimen was immersed into LN_2 very carefully and slowly in this measurement, some specimen had very low dielectric strength due to the crack formation caused by the thermal shock. One possible reason is the different thermal expansion between stainless sphere electrode and unfilled epoxy.

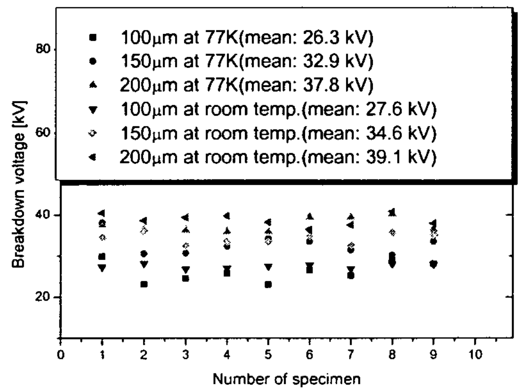

Fig. 3. Breakdown voltage of unfilled epoxy

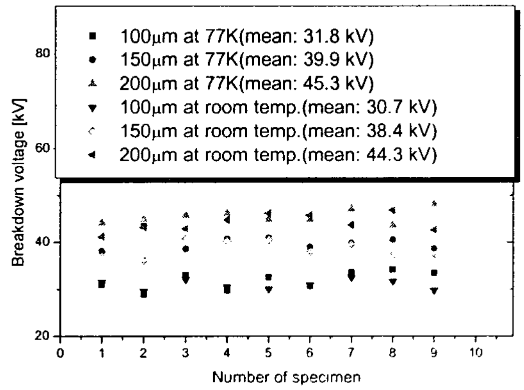

Fig. 4. Breakdown voltage of filled epoxy

3.2 Breakdown voltage of filled epoxy

A stycast 2850FT/23LV, which has a low coefficient of thermal expansion and good electrical insulation properties, was selected as a unfilled epoxy. Fig. 4 shows the breakdown voltage at 77K and room temperature of filled epoxy specimen. The dependence of the breakdown voltage measured at 77K in kV was proportional to $d^{0.52}$, and it at room temperature was proportional to $d^{0.53}$. The dielectric strength of filled epoxy was higher than that of unfilled epoxy. Moreover, there was no evidence of crack formation during all the experiments.

Because of the heat generated by the displacement of dipoles, the AC breakdown voltage is generally lower than DC one. First, it is expected that the breakdown voltage at cryogenic temperature is higher than that at room temperature. But the measured results was some different to the expectation. Although there are some results concerning this phenomenon, they are different to each other [4].

4. Summery

The insulation characteristics of some insulating materials for the insulation of superconducting power devices was investigated in this paper. The dielectric strength of selected unfilled epoxy and filled epoxy at cryogenic temperature (77K) was similar to that at room temperature. The breakdown voltage is also proportional to the root of the variation of material thickness ($d^{0.5}$) at cryogenic temperature. The filled epoxy has both good electrical insulation property and good thermal properties. The measured data can use in the practical design in superconducting power devices.

References

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