§9. Degradation Mechanism of Electrical Insulation System in Pool Cooled Superconducting Coils

Hara, M., Suehiro, J. (Kyushu Univ.), Satow, T.

1. Introduction

The most severe electrical insulation environment in pool-cooled superconducting coils appears at quench of the superconductor. The major electrical insulation degradations in them are due to particle contamination and partial discharges (PD's) within the solid insulator at cryogenic temperature. The kind of foreign particles intruding from the outside of the cryogenic vessel after construction of the coil are carbon particles from the filter that settled at the liquid helium inlet and insulator particles that are produced from movement of the coil wire during coil excitation.

From these points of view, the effect of thermal bubble at simulated quench condition of coil and of particles on prebreakdown phenomena in LN_2 were investigated experimentally [1-2]. Moreover, the relationship between the life time of the solid insulator and cool-down rate of coils was studied on the basis of the research on PD in artificial air-filled voids within the solid insulators [3].

2. Effects of metallic and carbon particulates on the breakdown characteristics in LN_2 [1]

The experiments were conducted using copper powder by sieve opening of 175 μm and carbon powder of nominal diameter of 10μm. The particles were placed in a gap space with FRP spacer between parallel plane electrodes of 2mm gap length. The results showed that the breakdown voltage under metallic particle contamination decreased gradually with the number of particles in the tested gap space and suddenly dropped down to zero at a critical number of particles which was around three times the ratio of gap length to particle diameter. In contrast, no sudden fall in the breakdown voltage was recognized with carbon particles even at larger number than the critical one for metallic particle. This suggests that the carbon particles leaking from the filter is not a fatal defect for the electrical insulation if they are not concentrated within a limited region.

3. Thermal bubble behavior and bubble-triggered breakdown in a simulated superconducting coil [2]

The tested electrode system is composed of LN_2 (cooling channel) and FRP between high voltage outer cylinder and grounded inner coil electrodes. The thermal bubbles were produced on the tubular coil electrode by heating a resistance mounted inside it. In this electrode system, stable partial breakdown (PBD) defined as breakdown which appears only in cooling channel are recognized before complete breakdown (BD) between electrodes. The results can be summarized as follows. 1) There are two types of breakdown mechanism: BD preceded by a stable PBD (see Fig.1(a)) ; puncture BD (see Fig.1(b)) without stable PBD. 2) Breakdown voltage depends on the rising rate of applied voltage due to the degradation of the solid insulator attributed to the PBD, and is extremely reduced and approached to the PBD onset voltage at rising rate of 0.1V/s. 3) The smooth exhaust of thermal bubbles from the insulation space or the suppression of bubble generation may be important to minimize the degradation of electrical insulation at quenching state of superconducting devices.

4. Shorten of insulation life time by PD [3]

Degradation process of void surface by PD was observed under different cooling conditions of solid insulator having an artificial void. According to the experiments, the higher cooling rate than 5K/min creates many crazy cracks on the void surface and PDs appeared almost always near the crack. The PD hits repeatedly the initial location of PD, forms a small hole in the solid insulator on the higher stressed electrode and eventually initiates a complete breakdown. Therefore, it is important that any solid insulator in superconducting devices is cooled slowly to avoid the formation of crazy cracks in it.

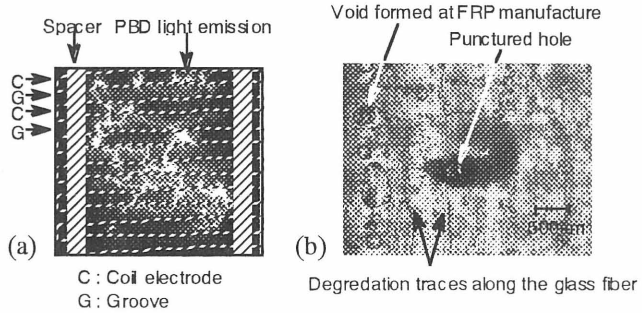

Fig.1 Light emitted from PBD (a) and punctured hole on FRP by BD (b). LN_2, 77K, 0.15MPa

Publications

[1] M.Hara et al., Proc. of 13th ICDL, Nara, JAPAN, pp.466-469 (1999)

[2] B.Y.Seok, et al., IEEE Trans. on DEI, Vol.6, No.1, pp.109-116 (1999)

[3] T.Tsuru, et al., IEEE Trans. on DEI, Vol.6, No.1, pp.43-50 (1999)