§3. Establishment of Partial Discharge Protection Technology for Reliability Improvement of Electrical Insulation of LHD

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The world's largest class superconducting coil is used in the "Large-scale Helical Device" in NIFS. Its electrical insulation system is exposed to considerably severe multiple stresses including cryogenic temperature, large mechanical stresses and strong magnetic fields. It is therefore very important to study its electrical insulation performance under these severe conditions in order to establish the reliability of the coil. If a superconductor quenches from superconducting state to normal state, the liquid coolant vaporizes very easily and turns into high-density gas at cryogenic temperature. In these bubbles, partial discharge (PD) easily occurs and would lead to the breakdown. So it is required to clarify the influence of the PD on the electrical insulation performances.

Figure 1 shows the electrode configuration and the experimental setup. The polymer employed was a polyimide film of about 0.125 mm in thickness. A copper tape, the edge of which was cut to an equilateral triangle shape, was installed on one side of the film. The groove of about 0.025 mm in deepness was also installed using a cutter along the extension line from a top of the equilateral triangle. On other side of the film, a back electrode was formed by a copper tape. The electrode system can restrict occurrence position of the PD into the groove by the configuration of the groove and the back electrode. Experiments were carried out with the electrode system in liquid nitrogen (LN_2) at 77 K and that in gaseous nitrogen (GN_2) at cryogenic temperatures. The 1000 waveforms of the PD current were measured by a digital oscilloscope under application of AC voltage of 3-14 kV_{pp} with frequency of 50 Hz. In order to obtain the waveform feature of PD current, the background noise was filtered out with using digital low-pass filter with a cutoff frequency at -50 dB of the power spectrum.

Figure 2 shows the PD current in LN_2 as typical waveforms. In comparison of PD current waveforms under each voltage applied, both of short pulse-width and long one were observed. By processing the PD current waveforms, half width of the PD current, which was the pulse duration at the 50 % of the current peak, was obtained.

Figure 3 shows the cumulative distribution of the half width of PD current in LN_2 and GN_2. The occurrence probability of PD with long half-width of its current in LN_2 was increased with the increase of voltage applied although the very few of PD with long half-width, e.g. more than 4 ns, under the 6 kV_{pp} application. It is considered that PD in gas bubbles of N_2, which are caused by a regional concentration of PD energy in LN_2, occurs more frequently by increasing voltage applied. On the other hand, the occurrence probability of PD with long half-width in GN_2 was almost the same as that in LN_2 under application of 10, 14 kV_{pp}. It is suggested that PD in LN_2 and in gas bubbles of N_2 are possible to be distinguished by comparing their half width of the PD current waveforms.

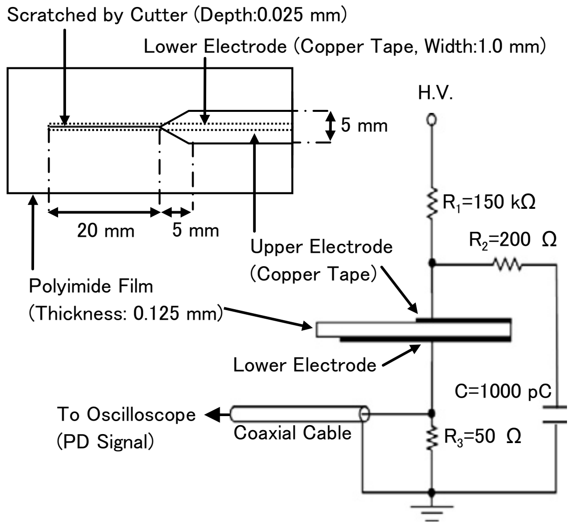
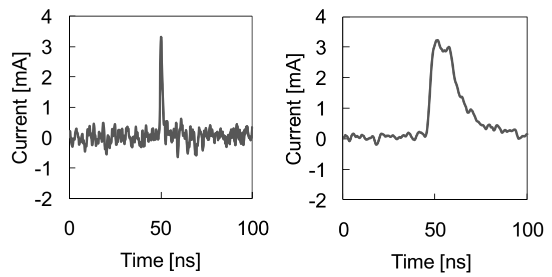


Fig.1 Electrode configuration and experimental setup.



(a) Short pulse-width (b) Long pulse-width

Fig.2 Typical waveforms of PD current in LN_2.

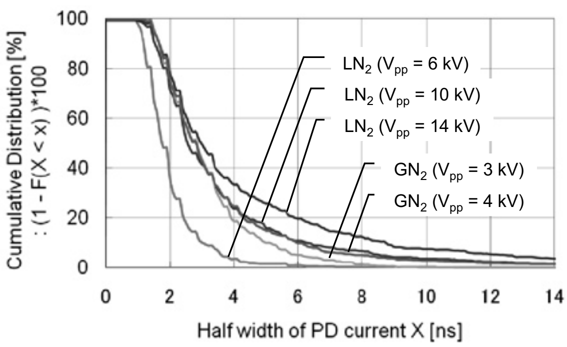


Fig.3 Cumulative distribution of half width of PD current.