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Degradation Processes of Voids in Silicone Rubber under Applied AC Fields

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Introduction

Micro-defects, such as micro-cavities, protrusions and contaminations, play a major role in the failure of power apparatus. Partial discharge occuring in cavities of an insulation system are believed to be one of the most important causes of solid dielectric material degradation under an applied AC voltage.

The results reported in this paper are concerned with an experimental study into the degradation processes that occur when voids in solid dielectric materials experience high applied electric fields.

A method has been developed for manufacturing 2mm thick samples of silicone resin that contain a single void of 1mm diameter. Five Samples are simultaneously electrically stressed under an applied ac sinusoidal voltage of 12kV for 6 hours that is then increased to 15kV until a sample fails. During the stressing period, PD data is regularly acquired. The remaining 4 samples are then inspected for signs of degradation.

The experiment is repeatable and the obtained degraded samples have been analysed using Raman spectroscopy to identify the chemical content of the degraded areas at the void /silicone rubber interface. Initial results indicate that the degradation is a pre-cursor to the development of a bow-tie electrical tree, although further research is required to confirm this.

Preparation of the test samples and samples set up

To prepare the silicone rubber, the mixture ratio between the silicone rubber and its hardener is 10:1.The strength of the silicone rubber can be enhanced using a post curing process, depending on the post cure time duration and the temperature.

10g material is weighed and then placed in a vacuum oven to degas. After degassing, the material is poured into a plastic petri dish to cure. This is first placed in a $60^\circ C$ oven for 10 minutes to the pre-cure.

After the pre-curing process finishes, a syringe is used to inject a single bubble into the material. It is then replaced in the oven for half an hour at $60^\circ C$ for post cure. Finally, the sample is cut to a suitable size for the PD measurement. The thickness, h, of Each sample is 2mm and the diameter, d, of the void is around 1mm.

Five samples are stressed simultaneously using five electrodes. Figure 1 shows the schematic diagram of a single sample.

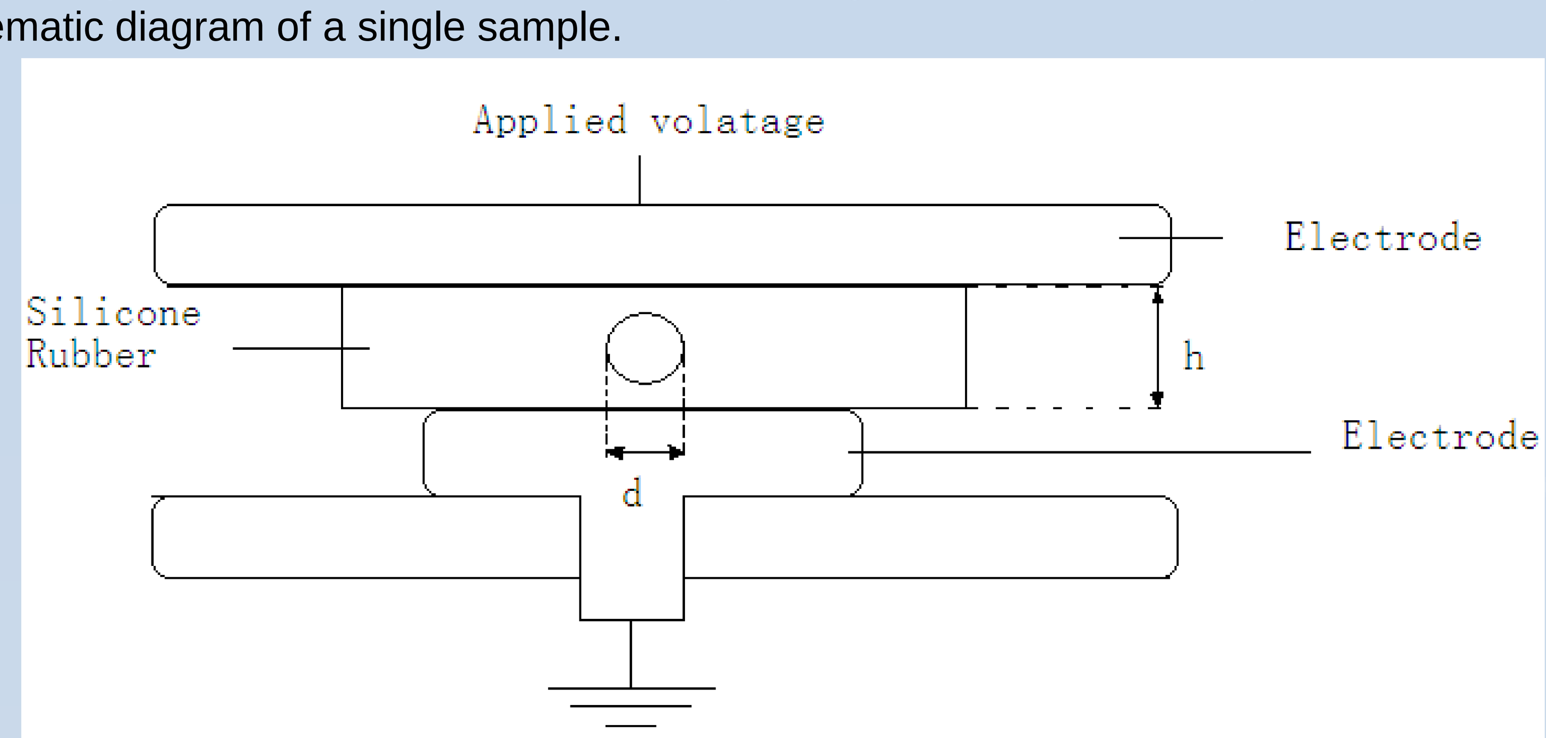

Figure 1. The schematic diagram of a sample

Experimental set up

The equipment used for the PD degradation experiment is the Mtronix MPD 600 system, which is manufactured by OMICRON. The Mtronix MPD 600 system is a fully digital system which is suitable for laboratory and on-site measurement of PD activity in high voltage equipment.

Figure 2 shows the schematic diagram of the experiment that has been used to measure PD activity. The experiment consists of a high voltage supply, a high voltage filter, a coupling capacitor, Ck, a test object, a coupling device, a PD detector and a USB controller which is connected to a personal computer (PC) via fiber optic cables. The operating frequency range for the overall setup is 0.1 Hz to 2.5 kHz. The system captures any detected PD signal of center frequency in the range of 0 Hz to 32 MHz with bandwidth range of 9 kHz to 3 MHz. The system noise is less than 15 fC. The PD event time resolution is less than 2 ns, which makes the phase angle of the detected pulse very precise.

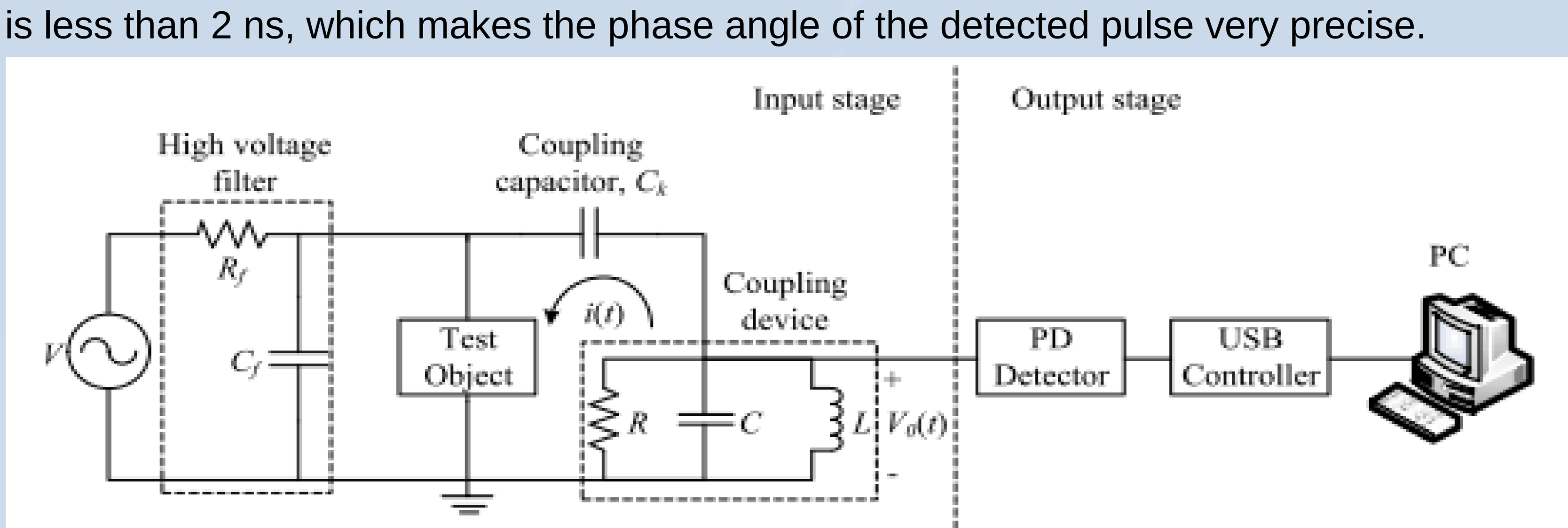

Figure 2. The schematic diagram of PD degradation experiment

Results and Discussions

The five degraded samples are obtained from repeatable degradation experiments. Figure 3 shows five degraded samples which experienced applied AC fields.

➢Images of degraded samples

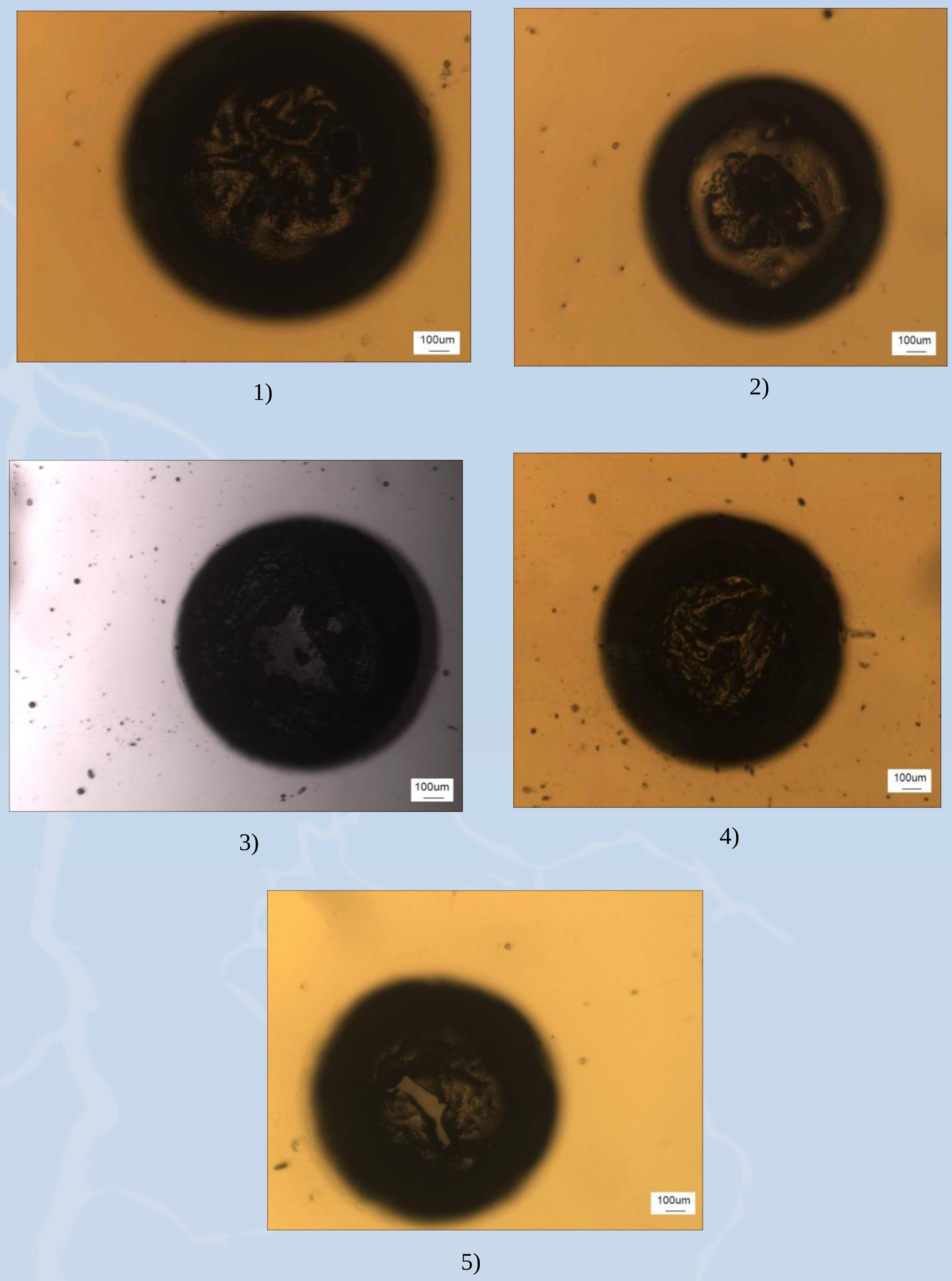

Figure 3. Indications of degradation to the surfaces of voids that are in line with the applied field

From the five images, the void /silicone rubber interface is obviously degraded compared with a sample that has not been stressed.

However, from the images, the chemical content of degraded area cannot be identified. Therefore, Raman microprobe analysis has been used to analyse the chemical content of the five samples.

Currently, the PD data obtained from the degradation experiment is being analysed to understand the changes in PD signature that occur during the degradation process.

In addition, Five samples perhaps containing trees or pits will be cut open using an RMC MT-7 ultra-microtome equipped with a CR-21 cryo-system set at -110$^\circ C$ in order to provide a surface containing open segments of trees or pits. Then, Raman spectroscopy will be used to analyse the chemical content of the microtomed surface of samples.

Conclusions

➢Initial results indicate that the observed degradation is a pre-cursor to the development of a bow-tie electrical tree, although further research is required to confirm this.

➢Consistent PD data which is obtained from the experiment will be used to analyse the degradation process.

➢Raman microprobe analysis on the microtomed surfaces of the samples will be used to analyse the changes in chemical content of the degraded samples.

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