Fundamental Study of Electrical Treeing Assessment in Silicone Gel based on Waveform Analysis of Partial Discharge

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Introduction

The resin used to encapsulate power semiconductor devices protects the devices from external mechanical and chemical stress. Since SiC devices operate at higher electric fields compared to current Si devices, the electrical treeing phenomena with partial discharge (PD) inside silicone gel is significantly essential. In this study, we investigated the relationship between the morphology of electrical treeing and the characteristics of PD waveforms in silicone gel.

Experimental Procedures

A needle electrode (diameter 1 mm, tip curvature 5 μm) and an aluminum plane electrode were placed opposite each other with a gap distance of approximately 3 mm. A silicone gel was injected into the gap a sample. The sample was connected to a measurement circuit, and the tree propagation was observed using a USB digital microscope (30 fps, 1000x). An AC voltage (60 Hz) with a voltage rise rate of approximately 1 kV/s was applied to the sample. After the electrical tree generated, the voltage was quickly reduced to 7 kVrms, and the PD waveform generated as the electrical discharge progressed was observed. Note that the point at which the voltage reached 7 kVrms was defined as 0 min.

Results and Discussion

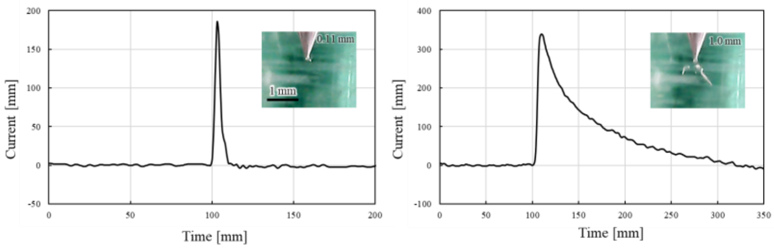
Figure 1 shows typical PD waveforms observed at 0 and 16 minutes. Assuming the tree tube is a single cylinder, its size is defined by its diameter and length. Figure 2 illustrates the cumulative probability of PD current magnitude and full width at half maximum (half-width).

As the tree grows, PDs with negative polarity become dominant, likely due to the negative charging tendency of silicone gel. However, since electrical breakdown under AC voltage typically occurs during the positive half-cycle, we focus on analyzing positive PD waveforms in detail.

The half-width of positive PD waveforms varies with the size of the tree channel. This trend is also observed when the insulating material is changed from silicone gel to epoxy. Under positive polarity, initial electrons in the gap move toward the needle electrode, promoting avalanche development. In contrast, under negative polarity, the electric field at the needle tip plays a dominant role in initiating avalanches, as electron emission from the electrode is more efficient. Thus, the development of positive polarity avalanches is more sensitive to the geometry of the discharge space. Considering the polarity effect on avalanche properties, the waveform characteristics are reasonable.

Conclusion

We believe that the electrical tree can be characterized in terms of the PD waveform characteristics, even if the sample is opaque, such as composite material.



(a) 0min PD wave from (b) 16min PD wave from

Figure1 Extracted PD waveform

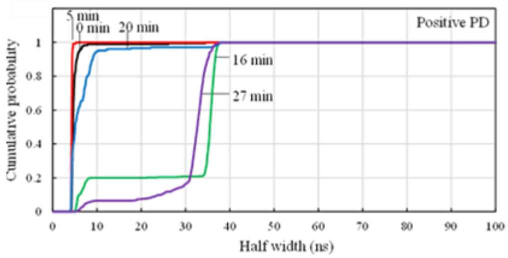


Figure2 Cumulative probability distribution of half-width

References

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