The Effects of Absorbed Water on Electrostatic Breakdown Testing

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INTRODUCTION

A critical property of electrical insulators is the breakdown voltage. When exposed to a high enough voltage, the insulator will be permanently damaged and unable to block significant current flow which can lead to the compromise of important electrical equipment [2]. The risk of breakdown increases as thinner insulators are used. This becomes a concern for applications such as:

- spacecraft missions
- high voltage direct current cables
- microelectronics
- plasma chambers
- high voltage switches

Preliminary testing suggests that absorbed water on the surface of insulators may increase their breakdown voltage and influence phenomena such as partial discharges, partial breakdowns, and surface flashovers [6]. Water vapor is naturally deposited by the atmosphere in terrestrial applications. This study is to determine how humidified insulators respond to electrostatic breakdown testing.

METHODS

Thin film PEEK (polyether ether ketone) was used as the highly insulating material in this study [4].
The experimental process was as follows:

- 24 samples were cut into 2.5 cm diameter circles, cleaned using methanol, and baked at 90 C under vacuum (<10^-4 Pa) for 3 days to remove water vapor from their surface
- Half of the samples were immediately tested using the Materials Physics Group's Electrostatic Discharge chamber under vacuum. This serves as the control group.
- The other half were placed in a closed container with a tray of water and a humidity sensor for 60 hours. The humidity inside this container fluctuated between 35% to 60% compared to about 15% humidity in normal laboratory conditions
- The ESD chamber houses a parallel plate capacitor where samples are clamped between copper electrodes and metal sample plates and exposed to a voltage ramping up at 20 V per 4 s (see Figure 1). The current passing through the sample is monitored until an abrupt jump in current marks breakdown [1,3] (see Figure 3).

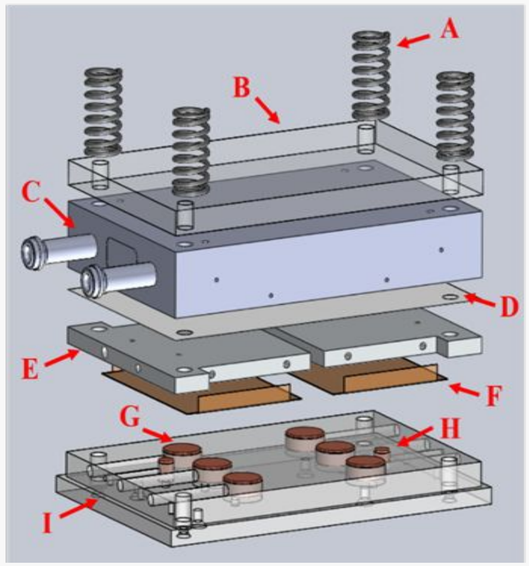


Figure 1: ESD test fixture
A. pressure springs
B. insulating layer
C. cryogen reservoir
D. electrically isolating layer
E. sample plate
F. sample
G. high voltage electrode
H. thermocouple
I. insulating base [5]

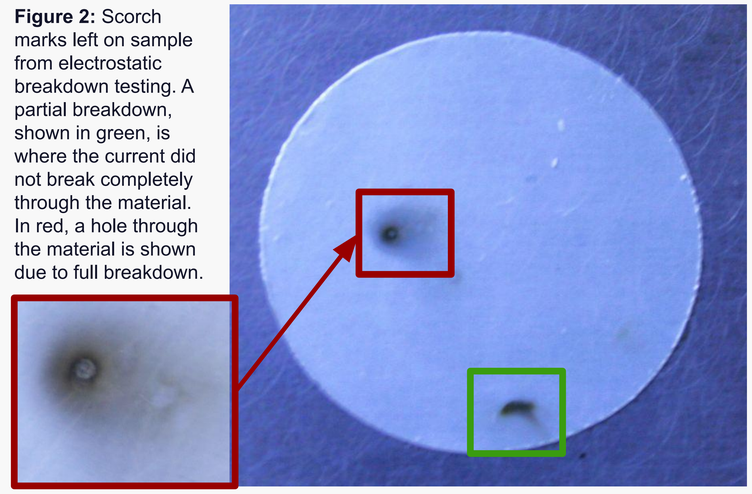
RESULTS

Ultimately, this round of testing was inconclusive.

Average breakdown voltage for the fully baked samples:
5430 ± 960 V
Average breakdown voltage for the humidified samples:
6200 ± 880 V.

While on average the humidified samples did break down at slightly higher voltages, the difference is not large enough to suggest a significant change in material properties for humidified samples. There was also not a significant difference observed in other phenomena during testing.

Figure 2: Scorch marks left on sample from electrostatic breakdown testing. A partial breakdown, shown in green, is where the current did not break completely through the material. In red, a hole through the material is shown due to full breakdown.



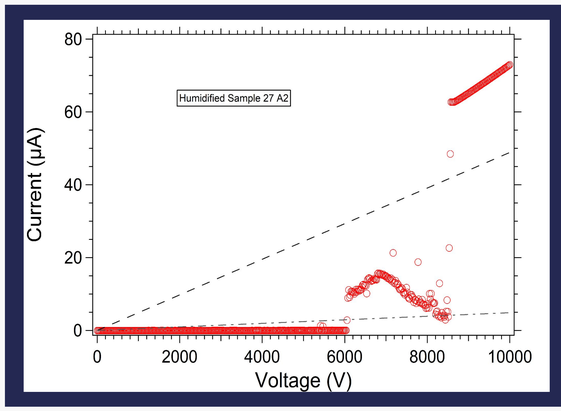


Figure 3: Voltage and current data collected for the humidified sample pictured in Figure 2. This data shows evidence of a partial breakdown and full breakdown.

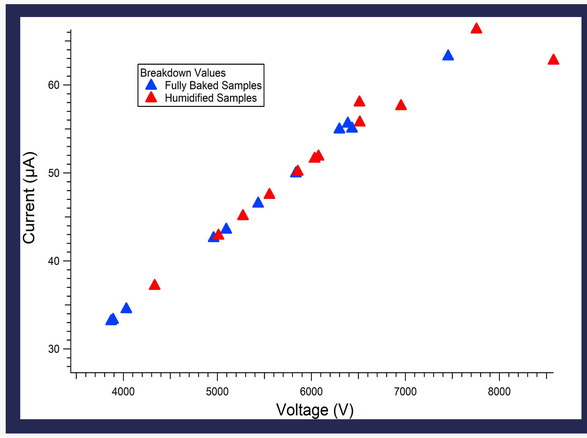


Figure 4: Plot of the current and voltage measurement at breakdown for each sample. There does not appear to be a significant difference in values between fully baked and humidified samples.

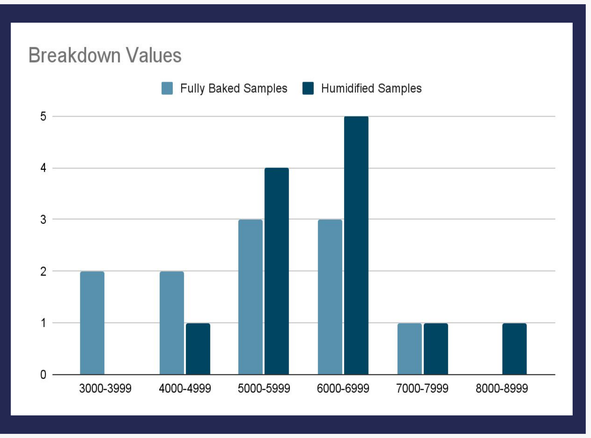


Figure 5: Frequency of fully baked vs humidified samples having breakdown voltages in each 1000 V range between 3000 V and 9000 V.

CONCLUSION AND FUTURE WORK

Exposing thin film PEEK samples for 60 hours to air with 35-60% humidity does not appear to have a significant effect on breakdown voltage values or on other phenomena observed during electrostatic breakdown testing.

Future work includes:

- Longer exposure times to high humidity
- Repeating measurements for different kinds of insulators
- Exposure to normal atmosphere for multiple months with tests at several increments

REFERENCES

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