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Effects of Exposure to Atmospheric Humidity on Breakdown Field Strength Measurements of Polymers

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Introduction

Electrostatic breakdown occurs as a result of an electron cascade [1] and is defined by the voltage at which an insulator no longer blocks significant current flow [2]. Conducting breakdown tests under sample conditions appropriate for different applications is essential; i.e., space dielectrics are in dry vacuum conditions, while territorial HVDC cables are in higher humidity atmospheric conditions. If breakdown field strength is overestimated for an application, an insulator may be used inappropriately in high electric fields where they are more likely to break down.

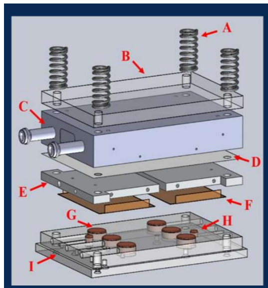
This study investigates the effects of absorbed water introduced via exposure to atmospheric humidity on electrostatic breakdown field strength measurements. Comparisons are made between sets of pristine samples, samples that underwent a thorough vacuum bake out, and samples subject to subsequent incremental prolonged atmospheric exposure.

Specifically, we compared:

- Changes in measured *EESD,* [Figure 4(a)]
- Pre-breakdown arcing (DC partial discharge) rate [Figure 4(b)], and
- Rates of flashover signatures, [Figure 4(c)]
- Images of the arc damage sites.

We report results for 3 different prototypical polymeric dielectric materials:

- Hydrophobic low density polyethylene (LDPE),
- Intermediate polyether-etherketone (PEEK), and
- More hydrophilic Nylon 66.



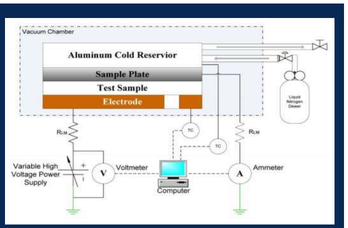


Figure 2 – Schematic of ESD chamber.

Figure 1 – ESD test fixture assembly diagram. **A.** adjustable pressure springs **B.** insulating layer **C.** cryogen reservoir **D.** thermally conductive, electrically isolating layer **E.** sample and mounting plate **F.** sample **G.** high voltage copper electrode **H.** copper thermocouple electrode **I.** insulating base [3]

Experiment

Samples were divided into seven groups of a dozen samples each; an unbaked control group, a fully baked group, and five groups of samples exposed to extended humidity conditions [three left at atmosphere after bakeout for one, three, and five* months (*tests in progress) and two stored in a high humidity container for 2 days and 2 weeks]. Samples for the unbaked control group were tested without further treatment. The rest of the samples underwent vacuum bakeout (~380 K at <10-3 Pa for >72 hrs) while in contact with a grounded surface to remove absorbed water and other volatile contaminates and any residual stored charge before being separated for their respective exposures.

Samples were tested under vacuum (<10^-4 Pa) in a parallel plate capacitor geometry using a modified [4] ASTM method [5], monitoring sample current as the applied voltage across the samples of up to ~18 kV (~720 MV/m) was incremented at a relatively slow rate of 20 V per 3.5 sec until breakdown was observed.

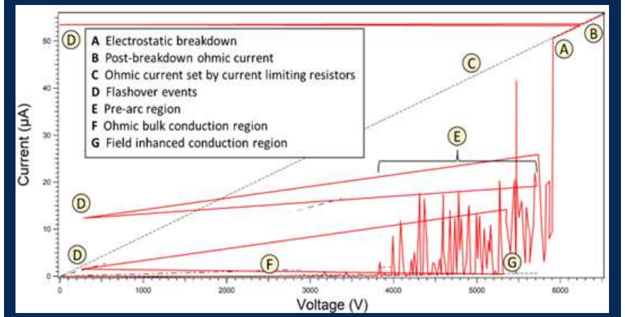


Figure 3- IV curve illustrating various features of a breakdown test.

Results

The observed slopes suggest a trend of positive changes in electrostatic breakdown potential and number of pre-arcs per test for more hydrophobic materials (LDPE and PEEK) and negative slopes for more hydrophilic materials (Nylon 66). There is a strong correlation between the observed trends (slopes) for electrostatic breakdown potential and number of pre-arcs per test as functions of effective exposure time when compared for each material. This correlation supports the contention that the distributions of the number of pre-arcs are correlated with those of electrostatic breakdown potential. The numbers of flashover events for all three materials are found to be nearly statistically independent of effective exposure time; hence the are perhaps better measures of their lack of dependence on effective exposure time.

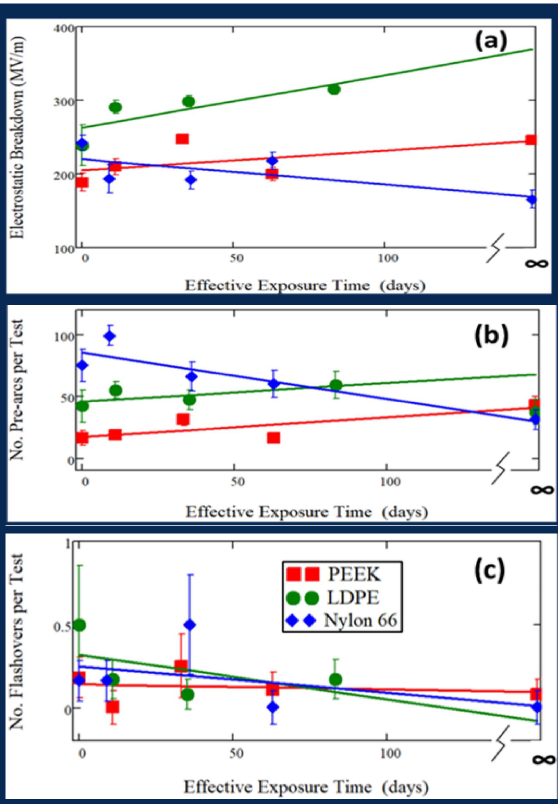


Figure 4- Signatures of breakdown as functions of effective exposure time for PEEK, LDPE, and Nylon 66. Lines are linear fits to the data. (a) Electrostatic breakdown potential, (b) number of pre-arcs per test, and (c) number of flashover events per test.

Conclusions

The results of this study showing up to ~50% differences in breakdown field strength due to bakeout reinforce the need to tailor tests to conditions for the intended applications. For example, electrostatic breakdown potential measurements for terrestrial applications in ambient conditions should be performed on unbaked samples, while measurements for space applications should be done on well baked samples [6].

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