Electric Field Dependence of the Time to Electrostatic Breakdown in Insulating Polymers

Charles Sim  
*Utah State University*

Alec Sim  
*Utah State University & Irving Valley College*

JR Dennison  
*Utah State University*

Follow this and additional works at: [https://digitalcommons.usu.edu/mp_presentations](https://digitalcommons.usu.edu/mp_presentations)  
Part of the [Physics Commons](https://digitalcommons.usu.edu/mp_presentations)

Recommended Citation  
Sim, Charles; Sim, Alec; and Dennison, JR, "Electric Field Dependence of the Time to Electrostatic Breakdown in Insulating Polymers" (2012). National Council of Undergraduate Research. Presentations. Paper 64.  
[https://digitalcommons.usu.edu/mp_presentations/64](https://digitalcommons.usu.edu/mp_presentations/64)
Electrostatic Breakdown Theory

Electric aging occurs when the molecular bonds in a material are disrupted. In polymeric insulators, this electric aging causes a breakdown described as electrostatic breakdown or discharge (ESD). The literature has shown that electric aging can be characterized by the barrier energy between bond sites, bond destruction energy or cohesion energy, trap creation within the material, and stress upon the bonds due to local and applied electric fields [2, 3, and 4]. The barrier energy between bond sites is given by an energy of activation which is decreased by the applied stress. The theoretical model describes two competing processes that explain the breakdown of the applied stress for insulating polymers [2, 3, and 4]. The first process is due to the formation of new traps (broken bonds) resulting from charge injection on molecular-scale fields. The second process (called a recoverable breakdown event) is due to energy to begin; is dominant in low electric fields (Fig. 1a) and can be described as a rate process of the reconfiguration and de-cohesion of the bonds. These recoverable events are evidenced by spikes in the measured current prior to breakdown and are absent at the electric field (Fig. 1b). The second process describes the breakdown caused by the direct stress applied to the segments leading to permanent damage (Fig. 1c). This is known as the irreversible breakdown. This process is dominant at higher fields (Fig. 2b).

The Utah State University Materials Physics Group (USU MPG) has developed a model that bridges the two processes and provides a way to calculate the increase in trap concentration (rate of bond breaking) as a function of time and applied stress [5]. This model is the USU MPG dual mechanism multiparameter trapping model given by:

\[ t_{breakdown} = \frac{1}{k_1 + k_2} \left( \frac{1}{N_0} + \frac{1}{N_1} + \frac{1}{N_2} + \frac{1}{N_3} \right) \]

where \( t_{breakdown} \) is the time to breakdown. The activation energy, \( k_1 \), the number density of defects, \( N_0 \), and probability function, \( \Delta E \), are the fitting parameters of the model. Planck's constant \( h \), the Boltzmann distribution constant \( k_B \), and the permittivity constant \( \epsilon_0 \) are fundamental physical constants. The value of \( k_1 \) is the materials dielectric constant and a property of the material. The applied field \( F \) and temperature \( T \) are variables that can be changed with each test.

Acknowledgements

Research was supported by a USU USRO grant, the Howard L. Blood Memorial Scholarship, and funding from the NASA/JWST Electrical Systems Working Group at Goddard Space Flight Center.

References