MEASUREMENT OF DEGRADATION PROPERTIES OF DIELECTRIC MATERIALS USED ON
SPACECRAFT POWER SYSTEMS

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Abstract

This paper reports the results of tests and measurements made on Kapton type H films of varying thicknesses. The quantities measured are capacitance, dissipation factor, surface resistivity and volume resistivity. The test variables are voltage, temperature, frequency and pressure.

The electrical insulating materials suffer degradation primarily due to the interaction of high energy protons, electrons and space plasma. Furthermore, the degradation is brought about by the thermal cycling due to the extreme temperatures to which the spacecraft is subjected when the spacecraft is facing the sun or eclipsed from the sun. The properties of the insulating materials targeted for measurement are Volume Resistivity, Surface Resistivity, Capacitance and Dissipation factor.

The volume resistivity is used to indicate, indirectly, the uniformity of an insulating material either with regard to processing or to detect conductive impurities which affect the quality of the insulating material. It is often used as an indirect measure of moisture content, mechanical continuity and deterioration of various types.

The surface resistivity is used to indicate the level of the contamination that happens to be on the surface of the sample at any time. It is often used as a measure of moisture absorption and contaminant deposition on the surface (1) and deterioration, which affect the materials insulating properties.

The capacitance is used to indicate the property of a dielectric which permits the storage of electrically separated charges when potential
difference exists between the dielectric surfaces. The change in capacitance or dielectric constant indicates the changes in the bulk molecular properties of the material.

The dissipation factor is used to indicate the A. C. power loss. The change in dissipation factor is a measure of the stability of the insulating properties, whereas the value of the dissipation factor is a measure of the quality of the insulating properties under specified service conditions.

Test and Measurement Systems

The following test and measurement systems were developed at the Tuskegee University for the accurate measurement of the volume resistivity, dissipation factor, and capacitance under controlled conditions. However, it should be noted that the control conditions do not represent the space environment under which the space craft operates.

D. C. Measuring System

This system consists of two test set ups; one to measure volume and surface resistivity according to ASTM standards in atmosphere; the other to measure the volume and surface resistivity at various temperatures (150°C max) and voltages (1.5 kv) in a vacuum of 1.33 Pa.

A. C. Measurement System

It also consists of two systems. One to measure the capacitance and dissipation factor under various temperatures in a vacuum of 1.33 Pa to atm. The measuring frequency can be varied from 100 Hz to 100 KHz. A GR 1650 A Capacitance bridge is used for the measurement. The second system is used to measure the capacitance and dissipation factor at high frequencies (range 22 MHz to 70 MHz) under atmospheric conditions. An HP 4342A Qmeter working on a resonance method is used for these tests. The details of the instrumentation systems are described previously (2).

Test Results

Figures (1-5) show selected examples of the test results in graphical form.

Discussion

The volume resistivity decreases as the temperature increases as seen in figure 1. The slope $\Delta \rho / \Delta T$ is negative but varies with temperature. $|\Delta \rho / \Delta T|_{T_1} < |\Delta \rho / \Delta T|_{T_2} \ \text{where} \ T_1 < T_2$

Some physico chemical changes are suspected at elevated temperature (3). The surface resistivity decreases with temperature. The decrease is more or
less linear as seen in the figure 2. The capacitance changes with frequency slowly over the range from 100 Hz to 100 kHz as seen in figure 3. However, the rate of drop is greater at the higher temperature conditions. This suggests charge carriers build up at at elevated temperatures. The data in figure 4 shows that the dissipation factor increases sharply with the source frequency. This may be explained by the charge build up in the material. The charge and discharge currents are plotted in figure 5. It is seen that the discharge is almost opposite to the charge process. However, the discharge time is found to be shorter than charging time. This might be due to different space charge and relaxation function between charging and discharging. It is felt that more tests need to be carried out under extended conditions.

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References


Fig 2. Surface Resistivity vs. Temperature at 1.33 Pa and 500v (Kapton H)

Fig 3. Capacitance vs. Frequency at 1 atm and 10v (Kapton H, 28 microns)

Fig 4. Dissipation Factor vs. Frequency at 1 atm, 10v (Kapton H, 28 microns)

Fig 5. Charge and discharge current at 140°C, 2 Pa and 100v (Kapton H, 78 microns)