EFFECT OF NITROGEN PLASMA IMMERSION ION IMPLANTATION ON SURFACE DISCHARGE BREAKDOWN VOLTAGE OF ALUMINIZED POLYIMIDE

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1. Introduction

Kapton™ (trademark from DuPont) is the most known polyimide film. Kapton is a polymer that has been used for many years in a great variety of applications due to its outstanding and unique properties. The combination of its properties makes Kapton ideal for use in harsh environments, especially in space. In space technology, thermal blankets are vital for regulating the temperature of most of the spacecrafts. The blankets usually consist of many layers of thin sheets with aluminized Kapton as the outer layer. Aluminized Kapton film is used to absorb/reflect the solar energy in order to avoid overheating and overcooling in the interior of the spacecraft. Kapton is a material widely used in thermal blankets due to its high strength-to-weight ratio, good mechanical properties, excellent thermal stability, chemical inertness and suitable thermal optical properties [1]. However, in space, Kapton is subject to several aggressive agents, including atomic oxygen, UV radiation, outgassing, energetic particle radiation, and meteoroids and debris. Prolonged exposure of the Kapton surface to those agents can significantly degrade Kapton, affecting the thermal control performance and resulting in premature failure of the mission. The multiple aggressive agents in space environment affect Kapton in different ways. Energetic charged particles are present throughout the Earth magnetosphere [2]. Energetic particles, particularly from the radiation belts and from solar particle events, cause radiation damage to spacecrafts. Many satellites have been lost and others have had significant operational anomalies due to spacecraft charging caused by the charge accumulation provided by the impact of energetic charged particles [3]. The energetic charged particles that impact the surface of Kapton cause both surface charging and internal charging in the bulk of the material. The charge accumulation can be damaging to the Kapton and compromises the thermal blanket function. Potential differences appear on the surface of the Kapton due to energetic charged particle impacts. When the potential difference exceeds a certain threshold, surface discharge happens [4]. The breakdown discharge on the surface of the Kapton causes damages in its structure and can affect other components of the spacecraft as antennas and on-board electronics. So, it is desirable to improve the flashover characteristic of the aluminized Kapton to turn the polymer less susceptible to surface breakdown discharges. It is well known that the polyimides can be strongly modified by ion implantation [5]. Plasma immersion ion implantation (PIII) is an evolving technique that has been used for a long time to promote surface modification in a wide variety of materials. In the last decades, several researchers have concentrated their attention on the surface modification of polymers using PIII. This technique has been used to improve different properties of many kinds of polymers [6,7], including Kapton [8]. In this work, we use PIII technique to improve the flashover characteristic of aluminized polyimide, that is, to increase the polymer surface breakdown voltage.

2. Experimental

Kapton used in this study was produced by DuPont as a thin film. The film was 25µm in thickness and metallized with a very thin layer (around 70nm) of aluminum in one side. The DuPont film sheet was cut in samples of two sizes (80mm x 130mm and 50mm x 360mm) which were then treated by nitrogen PIII using the same processing parameters. The samples were put inside the plasma using two sample holders. One sample holder was an aluminum cylinder in which the Kapton samples were wrapped around it, and the other one was a 4-inches diameter stainless steel tube in which the Kapton samples were put on its inner side. In both cases, the samples were treated with and without a stainless steel metallic grid placed over the samples. The use of the metallic grid is a well-known technique used to avoid charge accumulation when dielectric samples are treated by PIII. Some samples placed inside the tube were treated with the use of magnetic field which was applied to create a denser plasma around the sample. The surface breakdown voltages of the untreated and treated samples were measured using the experimental apparatus depicted in Figure 1. The apparatus is composed by a DC power supply to charge a high-voltage capacitor and two ignition coils used to elevate the discharge capacitor voltage. The samples were placed between two electrodes separated by a distance previously known. The voltage in the DC power supply was step by step increased up to the electric breakdown on the Kapton surface. After the capacitor charging at a value set previously, the closure of a manual switch allowed that pulsed voltages were applied to the samples to cause the dielectric breakdown discharge. The voltages across the two coils were measured by means of a digital

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oscilloscope as shown in Figure 2. The breakdown voltage is given by the peak to peak differential measurement on the voltage waveforms.

3. Results and Discussions

The dielectric strengths were obtained dividing the breakdown voltages by the linear distance between the electrodes. As a probability distribution of failure for each sample test was used, a minimum of five measurements was required for the statistic method. The obtained data were treated using the Weibull distribution and failure analysis. The results indicate that nitrogen PIII of aluminized Kapton can be advantageous to improve its dielectric strength, especially when the sample is treated without the use of the metallic grid and inside the tube. In this case, the increase in the dielectric strength reached circa of 59% compared to the untreated sample. A significant increase of 42% was also obtained in the same case when Kapton samples were treated with cylindrical sample holder. The treatments using metallic grid have shown no good results, regardless the type of holder. The treatments using magnetic field have provided an increase in the dielectric strengths, but not as relevant as in the case without the magnetic field.

Fig. 1. *Experimental apparatus used for the measurement of the surface dielectric strength of the untreated and treated samples.*

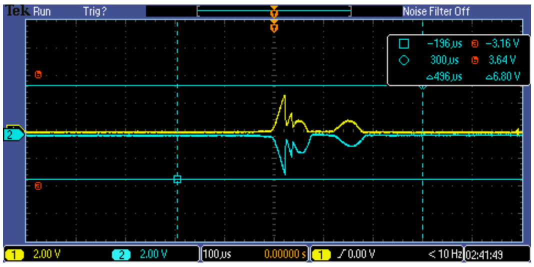

Fig. 2. *Waveform of the pulsed voltage applied to the Kapton sample. The abrupt fall on the waveform indicates the dielectric breakdown and the peak-to-peak value gives the surface breakdown voltage.*

4. References

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