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Space Charge Analysis in Polymers Irradiated by an E-Beam

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Abstract - The surface made of dielectric materials can therefore become probable sites for damaging electrostatic discharges. Thanks to a specially equipped chamber, the spatial environment can be reproduced experimentally in the laboratory. In this paper, the behavior of high energy electrons injected in polymers such as PolyMethylMetaAcrylate (PMMA) and Kpton is studied. Results obtained by surface potential technique, pulse-electro acoustic device and a cell based on the split Faraday cup system are analyzed and discussed.

1. Introduction

The space environment in which satellites evolve has been broadly characterized [1]. It has been shown that the various charged particles trapped in the magnetosphere interact with dielectric materials covering spacecrafts. These materials can therefore become probable sites for damaging electrostatic discharges [2]. In order to reduce or to get a better ontrol on the discharge initiation phenomena it is necessary to clarify the nature, the position and the quantity of stored charges with time. In our case, polymers irradiated by a quasi-monoenergetic electron beam have been investigated. Actually, these studies have been made in a specific irradiation chamber, initially only equipped only by a surface potential probe.

Recently, additional measurement techniques such as the Pulsed Electro-Acoustic (PEA) system and the surface current cell detection based on Split Faraday Cup (SFC) method have been installed into the chamber. Measurements performed with the three methods will be discussed in this paper and their complementarities shown.

2. Experiment

Materials used for space equipment must be tested under specific conditions. As it is costly and awkward to get back materials after a journey in space, it is of major importance to be able to reproduce this peculiar environment in the laboratory. Among all the irradiation chambers that have been developed at ONERA in collaboration with CNES, the one called "SIRENE" has been chosen for these studies. This chamber has been built to reproduce the electronic geostationary environment described by a reference spectrum named Kp>5. During these studies, in order to start with a simple arrangement, only the impact of quasi-monoenergetic irradiations was studied. To do so, one source was turned on at a time and only one diffusion foil was used to enlarge the signal and produce a homogeneous 5 cm radius irradiation zone perpendicular to the beam.

Between two periods of irradiation and during the relaxation under vacuum, it is possible to record the surface potential by using an electrostatic probe that is shifted a few millimeters in front of the sample. Initially, the data obtained was used to follow the charging state of the sample in order to stop the irradiation before a discharge occured. In addition, here the data is also used to make a rough estimation of the charge depth penetration.

The arrangement of the classical PEA device that has been described many times in the literature [3], has been modified and introduced in the irradiation chamber to record the charge distribution not only during the irradiation but also during the relaxation [4]. To keep the irradiation face free, both excitation and detection units are located at the back of the sample. The pulse probe voltage is applied through a thin metalized electrode that goes through one edge of the sample (Fig. 1).

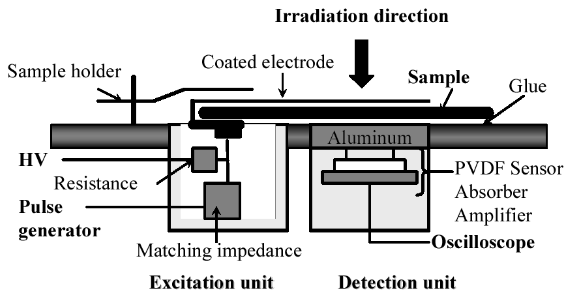

Fig. 1. PEA Set-up for in-situ measurements.

Recently the irradiation chamber has been implemented with a current detection cell (Fig. 2) based on the SFC technique. During the experiment presented here, both currents from the front (i_1) and rear (i_2) faces are recorded at the same time. Measurements are always performed during the irradiation as well as during the relaxation. It is checked that the sum of both currents is equal to the current collected from the controlling Faraday cage located near the detection cell. This set-up is small enough to be introduced in the chamber at the same time as the PEA detector and allows us to record data simultaneously on samples irradiated under similar conditions.

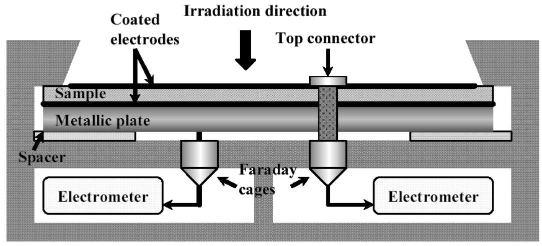

Fig. 2. Current detection system based on the SFC set-up.

3. Result and Discussion

During the irradiation, PEA measurements were recorded every 2 min. Already after the first minute of irradiation a negative peak due to the injected charges is detected at about 113 μm from the irradiated surface. Two positive peaks of induced charges appear simultaneously at the interface sample/electrode. As expected, all the peaks grow in amplitude with the irradiation time. Besides, after a 5 min irradiation another negative peak appears close to the irradiated surface. This peak could be due to lower energy electrons resulting from secondary emission produced in the chamber. When the energy is increased up to 150 keV, the negative peak detected is shifted deeper in the bulk. After 15 mn of irradiation, the position stabilized but the peak amplitude continued to increase. The negative peak detected near the surface continued to grow with time.

As it can be seen, the relaxation of the charges is a slow process (Fig. 3). Actually, after 11 days there is still a large amount of charges in the bulk. If the electric field is analyzed, it is observed that just after the end of irradiation the electric field is negative from the irradiated surface up to about 178 μm. In this area, the charges subjected to the negative field tend to be extracted toward the irradiated surface. The irradiated zone conductivity increased by the electron injection makes the charge displacement easier. Thus, after one week of relaxation most of the charges previously detected in this part have disappeared. At the same time, the negative electric field limit has been shifted to 192 μm. Charges located in this extra 14 μm can therefore be extracted toward the irradiated bulk. After 10 days, the negative electric field is quite small and the relaxation becomes really slow.

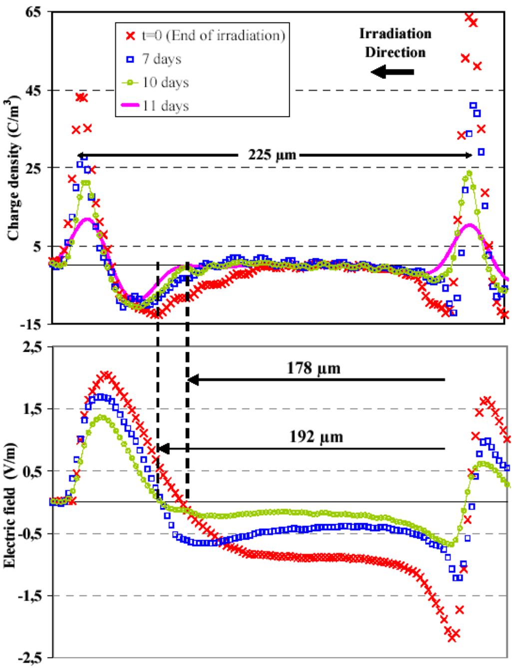

Fig. 3. Kapton sample 225 μm-thick charge density recorded by PEA and electric field calculated during the relaxation after 30 min irradiation under 150 keV with a flux of 125 pA/cm^2.

4. Conclusion

In this paper, data recorded during an electronic irradiation on Kapton by PEA, surface current and surface potential have been presented. The built-up of charges and the position of storage is clearly identified by PEA. These results are in good agreement with the ones obtained from surface potential data. However, when a quantitative analysis is made, there is a constant discrepancy between results obtained by PEA and current measurements, which probably requires an improvement in calibration.

[Acknowledgement]

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