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LOW ENERGY ELECTRON IRRADIATION INDUCED CHARGING OF DIELECTRIC MATERIALS: MEASUREMENTS AND ANALYSES

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Abstract

Charging of dielectric materials under electron irradiation is a commonly encountered problem in many space applications. Spacecraft charging due to solar and cosmic radiations may lead to critical discharge phenomenon. Indeed, under irradiation (especially electron irradiation), insulators as well as floating conductors may charge negatively or positively depending on the incident electron properties (energy, incidence angle, flux) and on the specific material properties (composition, surface roughness, contamination, temperature, etc.) The knowledge of the electrical properties (electron emission yield, conductivity and radiation induced conductivity) under electron irradiation for each material of the spacecraft is needed for spacecraft plasma interaction software. The energy distribution of the emitted secondary and backscattered electrons was measured dynamically with the help of high-speed hemispherical electron energy analyzer. The evolution of the surface potential of the irradiated sample can be derived from the energy shift of the secondary electron pic. The method is applied to 25- μm Kapton.

I. INTRODUCTION

Charging effects due to electron impact is a frequently encountered phenomenon in many space applications [1,2]. Spacecraft charging due to solar and cosmic radiations may lead to critical discharge phenomenon. Under irradiation, insulators or floating conductors may charge negatively or positively depending on the incident electron characteristics and the electron emission yield of the material. The study of charging behavior of spacecraft used material is therefore required. Several contactless experimental methods have been developed to measure the trapped charge or the associated surface potential under and after electron irradiation: electron spectrometry [3-5] and X-ray spectroscopy [4], electron mirror method [6], kelvin probe, ... The Kelvin probe and the electron mirror methods can only be used if the charging electron beam is switched off. Therefore, these methods are unable to evaluate the kinetic of charging under irradiation and in some situation (low resistivity dielectric) under estimate the charging magnitude.

The spectroscopic methods have the advantage of being able to measure the surface potential under irradiation. However, Until now, the relatively high acquisition time of the electron energy analyzers (EEA) or X-ray spectrometers impedes the measurement of the evolution of the surface potential during the irradiation. The new generations of EEA equipped with multichannel plate detectors that can operate with a very short acquisition time (second) allow the investigation of charging kinetic. In this contribution the charging kinetic of 25 μm Kapton HN is studied with a help of the electron spectroscopy. The surface potential, V_s , is deduced during the irradiation from the shift of the secondary electron pic.

II. NEGATIVE CHARGING UNDER ELECTRON IRRADIATION

When an electron beam of energy E_0 , impacts a solid surface, low energy secondary electrons (SE), and backscattered electrons (BSE), with energies ranging from 50 eV to E_0 , are emitted in the vacuum. If E_0 is higher than the second crossover energy E_{C2} or lower than the first crossover energy E_{C1} , a net negative charge is injected in the sample (Electron emission yield, EEY lower than 1). The induced electric field in the vacuum slows the incident electrons and shift their landing energy down to $E_0 + eV_s$, ($e = 1.6 \cdot 10^{-19}$ C). This decrease of the impact energy leads to an increase of the electron emission yield. The charging steady state is reached when the $EEY=1$ and $E_0=E_{C2}$.

III. EXPERIMENTAL

A. Experimental setup

The used experimental setup is shown in Fig. 1. Experiments were made at room temperature and under ultra-high vacuum conditions ($3 \cdot 10^{-10}$ mbar). The electron beam of 45° incidence angle was produced with Kimball Physics ELG2. The used EEA is Aspect from Sigma surface Science. Thanks to multichannel plate detector (128 channels), the EEA is able to acquire (in survey acquisition mode) the electron spectrum in the electron energy range of 0-3.5 keV in few seconds.

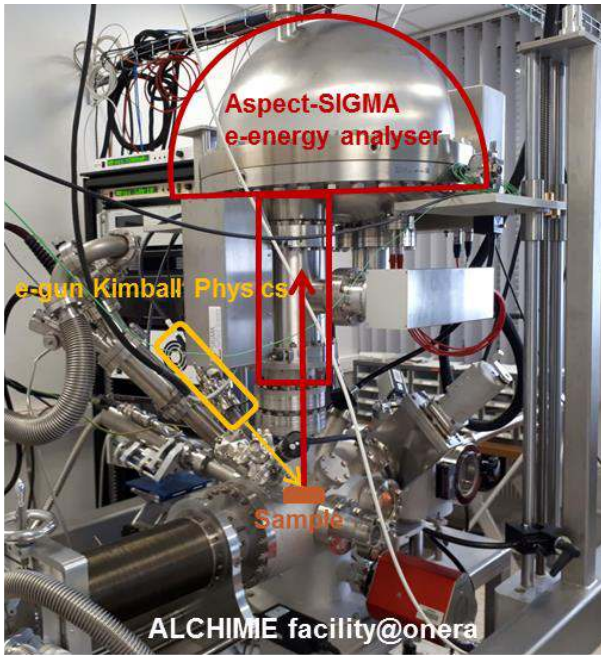


Figure 1. Experimental setup

The Fig. 2 shows an electron energy spectrum measured from the silver plate sample holder at 90 eV incidence energy. The pic at 90 eV is that of the elastically backscattered electrons and the second pic at low energy is associated to the secondary electrons.

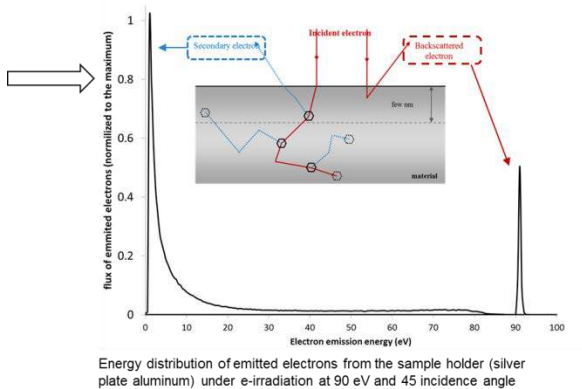


Figure 2. Electron energy distribution of electrons emitted from silver plate sample under electron irradiation at 90 eV.

B. Measurement principle

When the sample is negatively charged, the generated electric field between the sample surface and the grounded entrance of the EEY accelerate all the emitted secondary electrons. The onset of the SE pic shifts from about 0 eV to $-eV_s$, here V_s is the negative surface potential of the sample. To demonstrate the effectiveness of the method, the sample holder was connected to a power supply and in order to induce a controlled a

negative surface potential. The SE pics emitted measured under electron beam of 90 eV at $V_s=0$, $V_s= -20$ V and $V_s= -50$ V are shown in Fig. 3. The SE pics shift to higher energy. Note that the elastic pic remains at 90 eV. Indeed, incident electrons that are, first decelerated before the impact with the surface and thereafter accelerated after the backscattering. Therefore, the energy balance is zero.

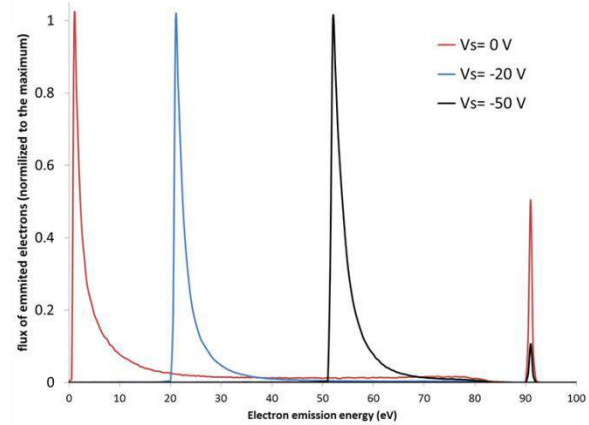


Figure 3. SE pics emitted measured under electron beam of 90 eV at $V_s=0$, $V_s= -20$ V and $V_s= -50$ V

The SE pic onset energy is plotted as function of the applied surface potential on the Fig. 4. The onset energy shift corresponds perfectly to the applied surface potential bias.

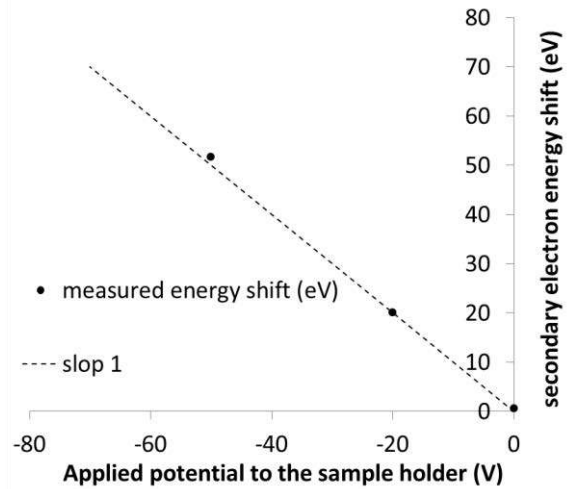


Figure 4. Secondary electron pic energy shift as function of the applied bias to the sample holder

IV. RESULTS

The Kapton sample (25 μm HN from Dupont) was irradiated with an electron beam of 1.5 keV at 45°C and about 10 nA/ cm^2 . The electron energy distributions were acquired in the fast mode of the EEY (survey mode) every 1s. The obtained SE pics are shown in the Fig. 5.

present results seems to be in agreement with the EEY properties of Kapton

V. CONCLUSIONS

The new generation of electron energy analyzer with fast acquisition time capabilities may be very helpful to investigate the negative charging kinetic of dielectrics under electron irradiation. The capabilities of such techniques are illustrated on a kapton sample.

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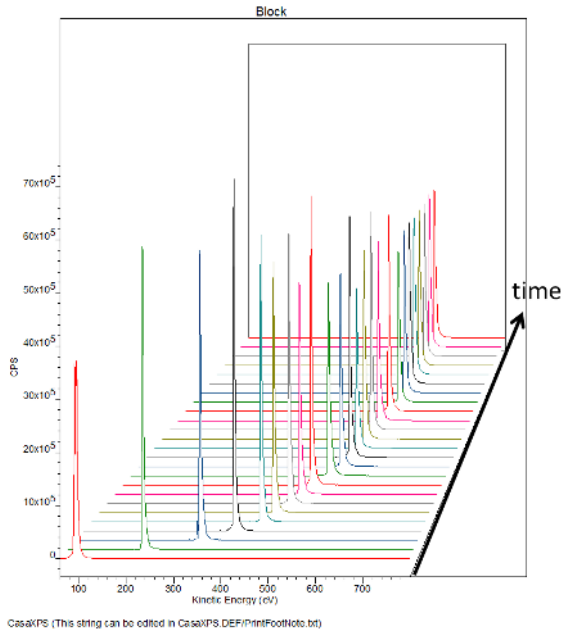


Figure 5. SE pics acquired every 1 s during the irradiation of kapton at 1.5 keV electron beam.

The evolution of the surface potential as function of the irradiation time deduced from the shift of the SE pic is shown in Fig. 6.

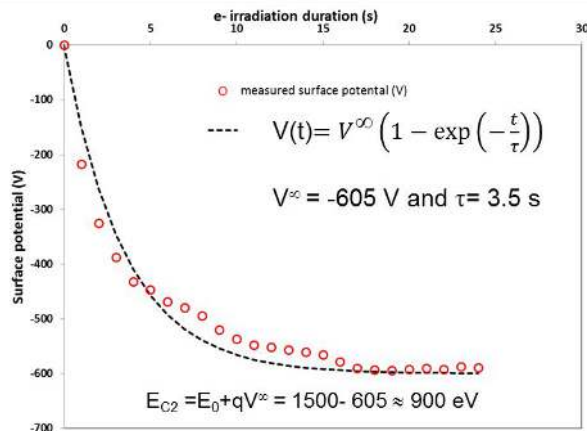


Figure 6. Evolution of the surface potential of as function of the time under 1.5 keV electron irradiation.

The surface potential starts to decrease rapidly at the first steps of irradiation and thereafter reaches a steady state situation with $V_s = -605$ V. The impact energy at the steady states about 900 eV. If we suppose that the leakage current is negligible, this steady state impact energy should correspond approximately to E_{C2} . In previous work [8], we have measured the EEY at normal incidence of Kapton HN and found E_{C2} about 700 eV. Knowing that E_{C2} increases with the incidence angle increases, the