Pulsed Electroacoustic Measurements of Polymers Irradiated With Low Energy Monoenergetic Electrons

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Understanding the dynamics and accumulation of embedded charge in dielectric materials is paramount for many applications from HVDC power transmission to spacecraft charging [1,2]. The pulsed electroacoustic (PEA) method allows for nondestructive measurements of embedded charge distributions in dielectrics. The spatial resolution of PEA measurements is typically ~10 µm. However, some of the most deleterious spacecraft charging events result from electron fluxes with 10 keV to 50 keV energies, resulting in electron ranges of 1 to 10% of µm [3]. Due to the resolution of the PEA method and the superposition of the interfacial charge with the deposited charge distribution, it is difficult to measure charge deposited at these critical energies. A novel analysis method is proposed to measure these shallow charge distributions.

**Space Environment**

Representative Space Environments

Figure 1: Representative differential electron fluxes versus electron energy. Modified from [4] and based on values from Minow.

There appears to be a critical charging regime for spacecraft charging events in the region of 10 keV to 50 keV incident electron energies [4,5]. This region is highlighted in Fig. 1.

**PEA Method**

Schematic Representation of PEA method

Figure 2: Representative schematic of the pulsed electroacoustic system.

Pulsed Electroacoustic Method:
- Sample in parallel plate capacitor configuration
- Pulse applied to sample creating an acoustic pressure wave
- Pressure wave converted to voltage signal by piezoelectric
- Signal amplified then measured with an oscilloscope
- Distance scale calibrated with speed of sound material
- System response removed with deconvolution
- Amplitude calibrated with a reference signal

To push the limits of the PEA method, an experiment was devised to shallowly deposit charge and attempt to remove the effect of the interfacial charge. The idea is that the signal at the interface can be removed through simple subtraction using a reference measurement.

Note that the data presented in this study is not filtered to remove noise, deconvolved to remove system response, or calibrated for charge magnitude. The distance scale was calibrated to determine the peak deposition depth using the speed of sound (2519 ± 75 m/s) as determined by the measured thickness (129±1 µm) and the peak-to-peak time for the pristine reference sample.

**Measurements**

Measurements of a pristine 125 µm thick sample of PEEK were obtained with DC bias from 0 – 258 V to use as references, refer to Fig. 3. The irradiated sample was measured with DC bias from 0 – 387 V, refer to Fig. 4.

**Analysis**

For each irradiated sample measurement, a corresponding reference measurement was found to remove the interfacial charge. Scaling of the reference is often needed. An example of the charge removal is shown in Fig. 5. All results are presented in Fig. 6 and are also compared to a simulation from AF-NUMIT3 [6].

**Conclusions**

A simple method for removing the effects of the interfacial charge was demonstrated and validated with an AF-NUMIT3 simulation. This allows for PEA measurements of shallowly deposited charge distributions. The reference measurements with varying applied DC bias show that the peak position is a good determination of the position of charge.

Future work should include measurements with more deposited charge for higher signal to noise ratios. This method should also be attempted for lower energies/deposition depths.