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Round Robin Tests of Electron Irradiated Polymers via Pulsed Electroacoustic Measurements

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Overview

• Motivation
  • Validate Comparison of PEA Results

• Experiment
  • PEA System Comparison
  • Sample and Irradiation Details

• Results
  • Compare PEA Measurements

• Conclusions
Motivation – Validate Comparison of PEA

• PEA is a well established method for measuring internal charge distributions in dielectric materials

• There is a standard method of calibration
  • Apply known amount of charge and measure with PEA
  • Use as reference for calibration

• Calibration is a tough issue
  • Difficulties arise when calibrating samples with embedded charge or when using open PEA
  • Potential issues can result from applied pulsed voltage, electrode material, coupling media, semi-conducting layer, etc.
Overview of PEA System – Key Components

- High Voltage DC Power Supply
- High Voltage Pulse Generator
- Computer (Data Processing)
- Oscilloscope

*Not to scale*
Comparing PEA Systems

**Utah State University PEA System**
- Ambient, parallel plate capacitor
- ~5 ns, ~300 V exciting pulse
  - 1 kV pulse through 8 dB attenuator and short cable
- 50 Ω impedance match
- PVC semiconductor film
- Al electrodes
- 9 µm PVDF piezoelectric sensor
- 40 dB gain (1 amplifier)
- Light machine oil (coupling media)
- 5000 traces averaged/measurement
- Data is filtered with modified Gaussian
- Reference obtained with charged sample

**Université Paul Sabatier PEA System**
- Ambient, parallel plate capacitor
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Signal Processing

**Processing Steps:**
- Average multiple measurements and compute statistics (not shown)
  - The rest of the processing is done on the averaged measurement
- Compute FFT to determine filter parameters
- Modified Gaussian filter used on data
- Take difference of DC on – DC off to obtain reference wave (Chen 2006)
- Use system response to perform deconvolution

**Calibration**
- Multiply by calibration factor
  - \[ \text{Calibration Factor} = \frac{\epsilon_r \epsilon_0 V_{DC}}{d \int V_{RefSignal} dx} \]
- Calibrate x-axis to distance using the speed of sound calculated from the measured thickness and peak-to-peak time difference of the two interfaces
Signal Processing – Filtering Effects

No Filter
- Higher spatial resolution
- Very noisy
- Overestimate charge density

Too Much Filtering
- Very low spatial resolution
- Underestimate charge density
- Low noise

Approximately Optimized Filtering
- Optimal charge density
- Low noise
- Optimal spatial resolution

(Gibson 2022)
Experimental Details – The Experiment

• Experimental Overview:
  • Measure pristine sample with DC bias only
  • Measure samples with embedded charge
  • Compare PEA measurements in ambient conditions at Utah State University (Logan, UT) and Université Paul Sabatier (Toulouse, France)

• Sample details
  • Samples must be very resistive so charge will not migrate during transportation
  • Materials used are polytetrafluoroethylene (PTFE) and polyether-etherketone (PEEK) of 200-250 µm thickness

• Irradiation chamber details
  • Samples irradiated with 50, 60, or 70 keV electrons with a flux of ~1 nA/cm² for 10 min
  • Irradiation completed at UPS with MATSPACE chamber
Comparing PEA – PTFE DC Bias

• Basically the same results
• The charge magnitude agrees by definition
• Slight difference in analysis/processing

PEA measurements of 200 µm thick PTFE with 2 kV DC bias. Inset depicts internal electric field calculated from the measured charge.
Comparing PEA – 70 keV PEEK

- Features are similar
- Charge magnitude greater for USU data
Comparing PEA – 50 keV PTFE

- Features are similar
- Charge magnitude greater for UPS data

- Attenuation/dispersion is apparent in “incident right” plot for PTFE
Comparing PEA – 50 keV PTFE – Classic Calibration

- Classic calibration only changes charge magnitude slightly
- Changes in the “wrong” direction (less agreement)

- The USU data was also calibrated with “classic” method (pristine sample)
Comparing PEA – Other Results

• Similar results were obtained for the rest of the measurements
  • PEEK irradiated with 60 keV electrons
  • PTFE irradiated with 60 keV and 70 keV electrons

• It was attempted to calibrate USU data with pristine sample reference but this provided a minimal change, and in the “wrong” direction

• There is no obvious answer to the discrepancies in the charge magnitude of the measurements
Conclusions

- The **shape** of measurements are in **agreement**
- The **distance scale** is in **agreement**
- The **charge magnitude** is **not in agreement** for measurements with embedded charge distributions

- Possible issues:
  - Electrode materials, coupling media, data analysis/processing, pulse effects, temperature, clamping pressure, humidity, errors (applied voltage, etc.)
  - Calibration used is from *surface charge*, perhaps allowing surface effects to contribute to error

- Ideal calibration for comparing absolute charge magnitude:
  - Known charge magnitude and distribution in bulk of material used for calibration
    - This is much more difficult to achieve
    - Perhaps an irradiated sample of PEEK or PTFE with magnitude of charge verified by surface potential measurement
References


• Gibson, Z., Dennison, J.R., Beecken, B., and Hoffmann, R., “Comparison of Pulsed Electroacoustic Measurements and AF-NUMIT3 Modeling of Polymers Irradiated with Monoenergetic Electrons,” Journal of Spacecraft and Rockets (2022) (under review)
Questions?
Backup slides
Other Results – PEEK
Other Results – PTFE