Effects of Sample Adhesives Acoustic Properties on Spatial Resolution of Pulsed Electroacoustic Measurements

Zachary Gibson

JR Dennison
Utah State University

Lee Pearson
Box Elder Innovations

Erick Griffiths
Utah State University

Anthony Pearson
Box Elder Innovations

Virginie Griseri
Universite de Toulouse

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Effects of Sample Adhesives Acoustic Properties on Spatial Resolution of Pulsed Electroacoustic Measurements

Zachary Gibson1, JR Dennison1, Lee Pearson2, Erick Griffiths2, Anthony Pearson2, Virginie Griseri3
1Material Physics Group, Physics Department, Utah State University, 2Box Elder Innovations, LLC, 3Université de Toulouse, UPS, INP, LAPLACE (Laboratoire Plasma et Conversion d’Energie)

Overview

The media chosen to couple the PEA stack (electrode/sample/sensor/backing) can affect the spatial resolution and shape of the response from a Pulsed Electroacoustic (PEA) system significantly. The PEA stack layers must be electrically and acoustically coupled to optimize the amplitude, quality, and spatial resolution of the PEA measurements. Various coupling layer materials were used with 250 μm thick polyvinylidene fluoride (PVDF) samples and a standard ~10 μm thick PVDF sensor. Coupling layers tested in this study include no media (with substantial pressure applied), light machine oil, silicone oil, and cyanoacrylate (super glue). Pulse amplitudes of 2000 V and 5 ns width were used in an 8 kV DC bias was applied to the sample in order to detect a signal, as the samples were initially free of charge, to see the interfaces more clearly and showcase the differences in response from the various coupling media.

Coupling Media

Coupling layers used in this study include no coupling media, light machine oil, silicone oil, and cyanoacrylate glue. The relevant electrical and acoustic properties of these materials are listed in Table 1.[2] Light machine oil used is All Purpose Oil (Singer brand). Silicone oil used is 100% commercial silicone oil (MicroLubr Type 200 50 cS). The glue used is cyanoacrylate (Bob Smith Industries, Super Thin Insta-Cure Cyanoacrylate, super glue). The relative dielectric constants range from 1.9-3.7 and speed of sound ranges from 1000 – 3250 m/s for the coupling media. The glue was applied only on the ground electrode-sample interface. Theses curves are seen in orange in Fig. 2. In yellow, the results of adding light machine oil to the surfaces of the piezoelectric sensor are evident. In all other cases the coupling media is applied at each interface as seen on the right side of Fig. 1.

Analysis

“Raw” data are the data as it is measured from the oscilloscope. “Processed” data denotes that the waveform has undergone a DC offset correction as well as applying a bandpass filter. “Deconvolved” data denotes that a deconvolution using a reference waveform has been performed. The reference waveform used is the ground electrode peak unless there is charge within the sample, which is not the case for this study.

Table 1: Relevant coupling material properties

<table>
<thead>
<tr>
<th>Media</th>
<th>Speed of Sound (m/s)</th>
<th>Relative Dielectric Constant</th>
<th>Coupling Layer Thickness (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Machine Oil</td>
<td>~2440</td>
<td>~2.95</td>
<td>~0.2</td>
</tr>
<tr>
<td>Silicone Oil</td>
<td>~3250</td>
<td>~2.0</td>
<td>~0.2</td>
</tr>
<tr>
<td>Cyanoacrylate</td>
<td>~2570</td>
<td>~3.05</td>
<td>~0.2</td>
</tr>
</tbody>
</table>

Table 2: Relevant waveform measurements/characteristics

<table>
<thead>
<tr>
<th>Waveform Type</th>
<th>Peak (µm)</th>
<th>Peak (ns)</th>
<th>HV Peak (mV)</th>
<th>Peak (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deconvolved</td>
<td>~104.2</td>
<td>~18.0</td>
<td>~18.0</td>
<td>~18.0</td>
</tr>
<tr>
<td>Processed</td>
<td>~104.2</td>
<td>~18.0</td>
<td>~18.0</td>
<td>~18.0</td>
</tr>
<tr>
<td>Raw</td>
<td>~104.2</td>
<td>~18.0</td>
<td>~18.0</td>
<td>~18.0</td>
</tr>
</tbody>
</table>

Conclusions

Overall instrument spatial resolution is approximately 10 µm. Results from this study allow specific conclusions to be drawn for each of the five options of coupling media presented. Refer to Table 2 below.

- No coupling media:
  - Viable option if the HV electrode is in direct contact with the sample
  - 25% spatial resolution for raw and processed data

Light Machine Oil:
- Largest raw amplitude signal for both HV and ground peaks
- Ground/HV peak ratio comparable to silicone oil at ~30% Silicone Oil
- Increases peak-to-peak distance
- Raw ground peak amplitude is 78% of light machine oil

Cyanoacrylate only on ground electrode-sample interface:
- Lowest ground peak amplitude
- Highest ground/HV electrode peak ratio
- Best spatial resolution by 15% after signal processing

Tripled raw peak amplitudes compared to only cyanoacrylate on the ground electrode-sample interface

The best option for high spatial resolution was found to be a single layer of cyanoacrylate at the ground electrode-sample interface; this is the only viable option for in vacuo PEA measurements of the media tested. For increased amplitude, light machine oil may be applied to the sensor interfaces.

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References:

Measurements

To compare the effects of these coupling media, measurements were made on 250 µm thick polyvinylidene fluoride (PVDF) samples obtained from Goodfellow.[3] Measurements were made with a custom ambient PEA test apparatus.[2] Pulse amplitudes of 2000 V and widths of 5 ns were used. A static 8 kV DC bias was applied across the sample to induce charge on the electrodes and near the surface of the sample. The sensors used were commercial polyvinyliden fluoride (PVDF) piezoelectric sensors (cut from film made by Measurement Specialties Inc.) with nominal 9 μm thickness (measured to be 11-14 µm thick).

Multiple sets of data were taken to validate the results. The datasets were consistent within error aside from a few small caveats. Only one set of data is presented here.

Zachary Gibson
Material Physics Group
Physics Department
Zackgibson5@gmail.com

Fig. 1: Simplified graphic of PEA system (left). Typical PEA sample stack set-up, emphasizing the coupling layers (right).

Fig. 2: Waveforms from the first round of testing. (a) Raw data. (b) Processed data, with DC offset and bandpass filter. (c) Deconvolved data.