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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 polymethylmethacrylate (PMMA) 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. Static 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.

PEA Method

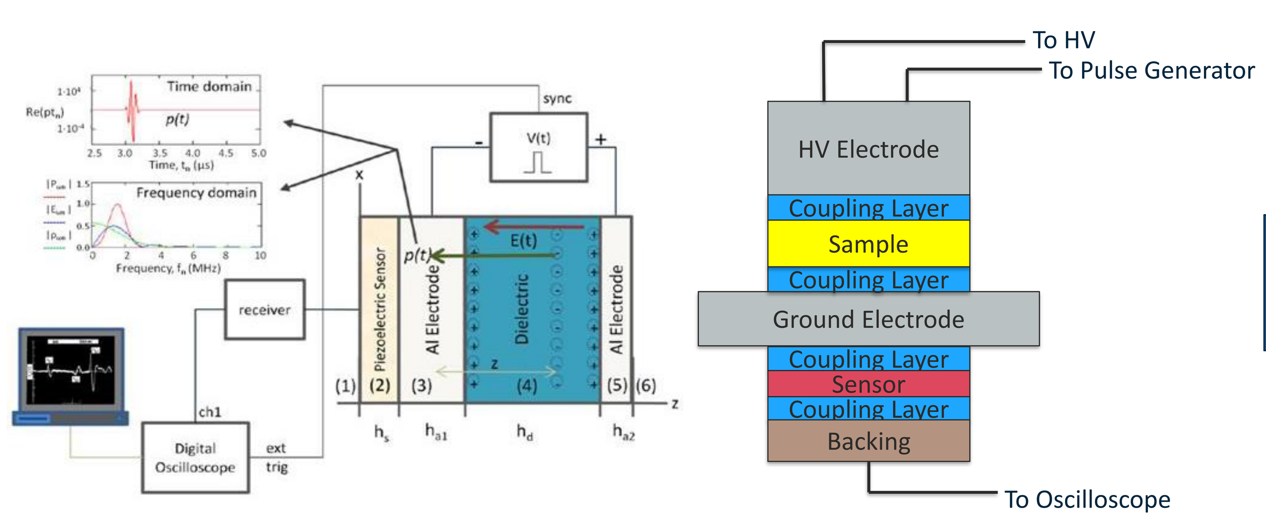


Figure 1: Simplified graphic of PEA system (left). Typical PEA sample stack set-up, emphasizing the coupling layers (right).

PEA measurements nondestructively probe internal charge distributions. Referring to Figure 1, dielectric material (4) is placed directly in contact with the cathode (5) and anode (3) electrodes. A signal generator produces a pulsed electric field. This causes pressure waves from embedded charge perturbed by the pulsed field, which are in turn detected by the piezoelectric sensor (2), and recorded on a digital oscilloscope. Simple time of flight calculations determine the spatial distribution of charge. Signal processing is required to obtain charge distribution plots.[1]

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.[2-4] Light machine oil used is All Purpose Oil (Singer brand). Silicone oil used is 100% silicone oil (MicroLubrol Type 200 50 cSt). 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 every interface as seen on the right side of Fig. 1.

Table 1: Relevant coupling material properties

	Light Machine Oil	Silicone Oil	Cyanoacrylate
Speed of Sound (m/s)	*1400* [a]	*1000* [a,b]	*3250* [a]
Relative Dielectric Constant	*1.91* [a]	*2.76* [a], *2.71* [c]	*2 - 3.5* [d]
Resistivity (Ω-cm)	10^{15} [a]	10^{15} [c]	10^{16} [a,d]
Coupling Layer thickness (μm)	$\lesssim 1$ [a]	$\lesssim 1$ [a]	$\lesssim 1$ [a]

[a]Measured in lab at Utah State University, [b][4], [c][3], [d][2]

Measurements

To compare the effects of these coupling media, measurements were made on 250 μm thick polymethylmethacrylate (PMMA) samples obtained from Goodfellow.[5] Measurements were made with a custom ambient PEA test apparatus.[1] 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 polyvinylidene 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.

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.

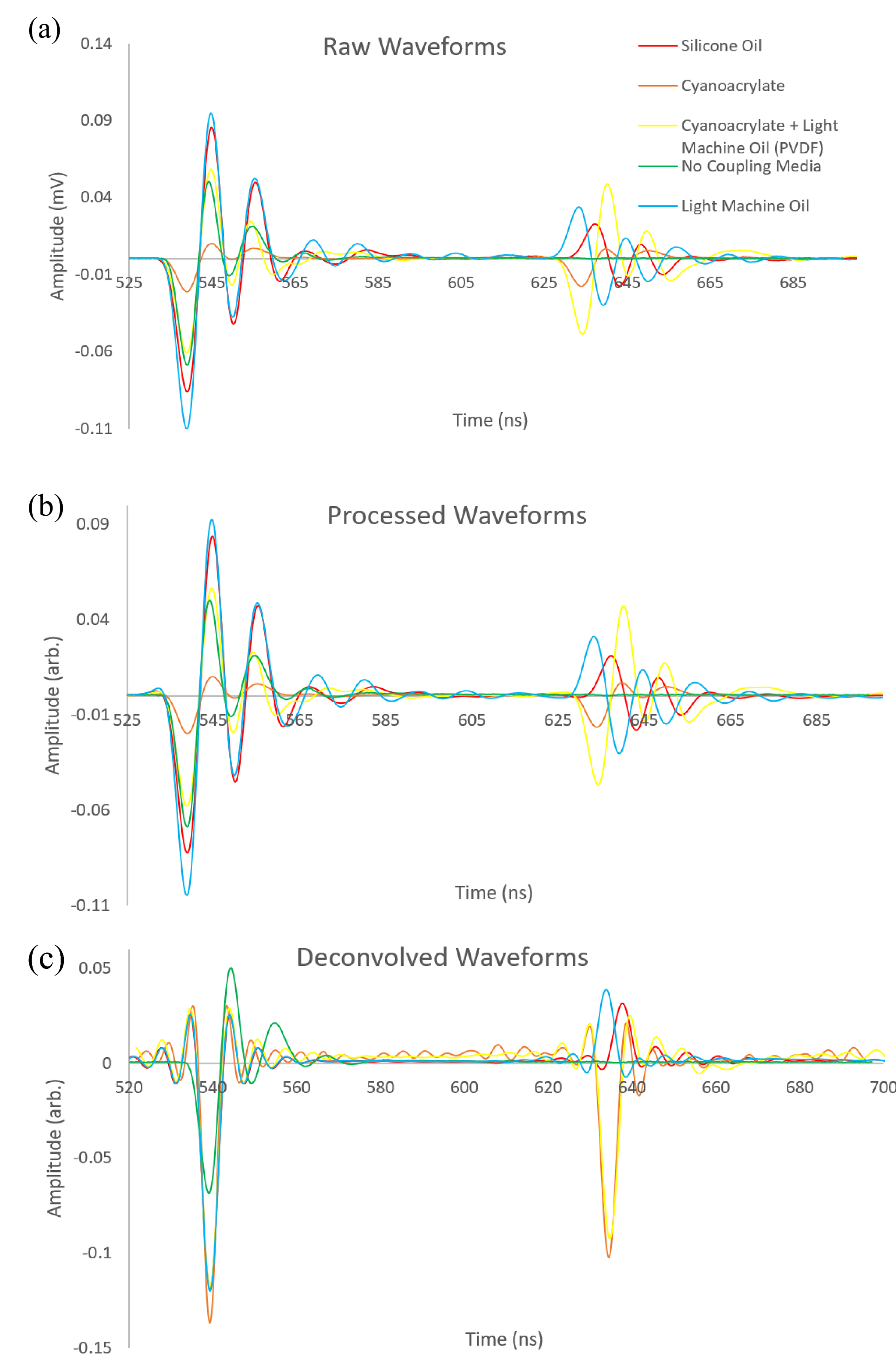


Fig. 2. Waveforms from the first round of testing. (a) Raw data. (b) Processed data, with DC offset and bandpass filter. (c) Deconvolved data.

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
- Best 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

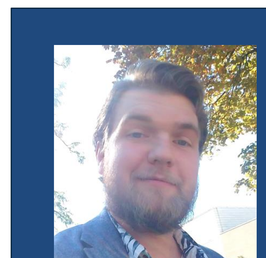
Cyanoacrylate *only* on ground electrode-sample interface:
- Lowest ground peak amplitude
- Highest ground/HV electrode peak ratio
- Best spatial resolution by 15% after signal processing

Cyanoacrylate plus light machine oil on PVDF interfaces
- 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.

Table 2: Relevant waveform measurements/characteristics

	None	Light Machine Oil	Silicone Oil	Cyanoacrylate (ground electrode interface)	Cyanoacrylate (light machine oil on sensor)
Raw					
Ground Peak Ampl. (mV)	-68.7	-109.9	-86.0	-21.3	-60.5
HV Peak Ampl. (mV)	0.4	33.7	22.8	-18.0	-48.4
Ratio of Ground/HV Peaks	1%	31%	27%	-84%	-80%
Peak-to-Peak (ns)	92.6	94.5	98.3	95	95.3
Peak-to-Peak (μm)	237	242	252	243	244
Peak-to-Peak Speed of Sound (m/s)	2624	2571	2472	2558	2550
FWHM Peak 1 (μm)	10.8	12.1	12.2	12.1	12.0
FWHM Peak 2 (μm)	11.5	12.4	13.0	12.9	12.3
Processed					
Ground Peak Ampl. (mV)	-65.1	-104.2	-82.9	-19.8	-57.5
HV Peak Ampl. (mV)	0.3	31.2	20.9	-16.5	-46.4
Ratio of Ground/HV Peaks	0%	30%	25%	-83%	-81%
Peak-to-Peak (ns)	92.6	94.435	98.3	95.09	95.409
Peak-to-Peak (μm)	237	242	252	244	244
Peak-to-Peak Speed of Sound (m/s)	2624	2573	2472	2555	2547
FWHM Peak 1 (μm)	10.6	11.8	11.8	11.9	11.7
FWHM Peak 2 (μm)	11.3	11.9	12.4	12.6	11.8
Deconvolved					
Ground Peak Ampl. (mV)	-142.0	-120.1	-118.3	-137.0	-118.1
HV Peak Ampl. (mV)	1.2	38.7	31.5	-102.5	-92.4
Ratio of Ground/HV Peaks	1%	32%	27%	-75%	-78%
Peak-to-Peak (ns)	93.2	94.6	98.4	95.2	95.5
Peak-to-Peak (μm)	239	242	252	244	245
Peak-to-Peak Speed of Sound (m/s)	2608	2570	2470	2553	2546
FWHM Peak 1 (μm)	8.5	10.0	10.1	8.5	9.9
FWHM Peak 2 (μm)	6.8	10.2	10.9	9.5	10.0



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