Construction and Characterization of an Economical PVDF Membrane Hydrophone for Medical Ultrasound

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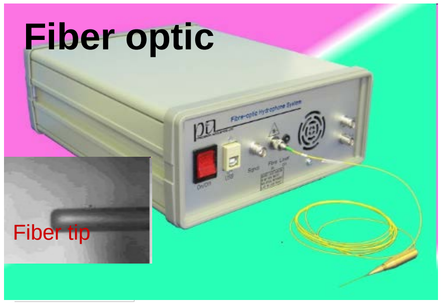
PVDF Membrane Hydrophone

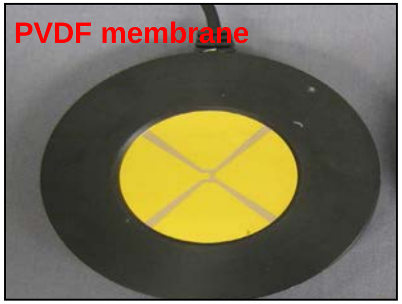
- PVDF (Polyvinylidene fluoride) material is a clear piezoelectric polymer film (<50 µm thickness) that generate electrical signal under acoustic wave.
- Sensing element is 0.2-1.0 mm in diameter.
- Provide high sensitivity, consistency and uniform broadband frequency response
- Gold standard for medical ultrasound pressure measurement during bench testing for regulatory reviews

Ultrasound Hydrophones

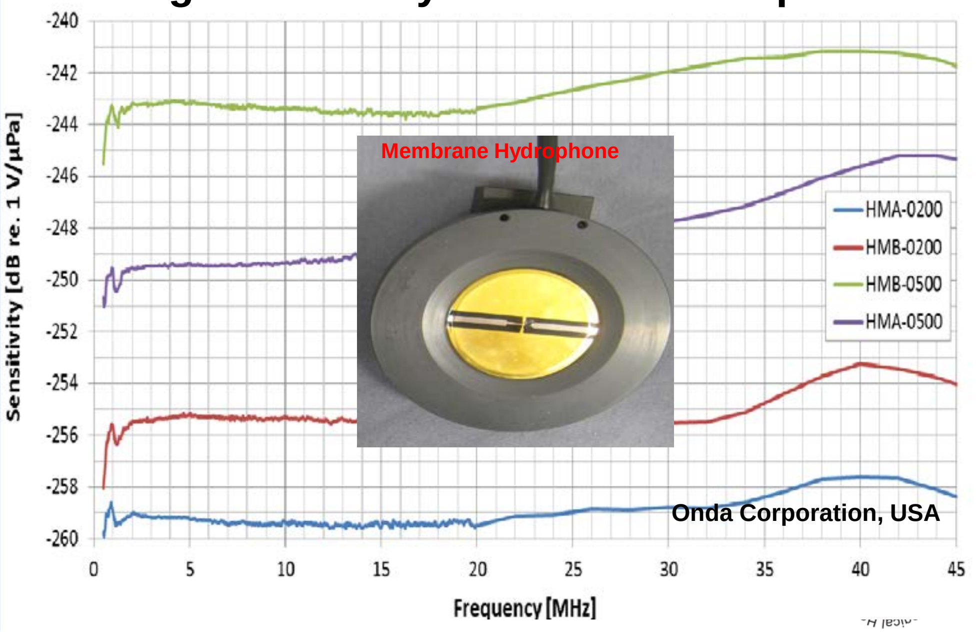
Piezoceramic needle

PVDF Capsule





High sensitivity and uniform response



Materials and Methods

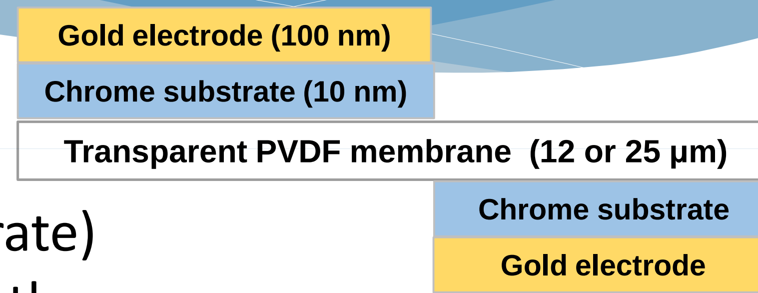
- Commercial membrane hydrophone and its calibration process are expensive.
- The device is relatively susceptible to damages and not repairable.
- Only a few small vendors around the world with limited technical supports
- This work aims to provide economical and convenient membrane hydrophone resources for both academic and clinical labs.

1. Electrode Vacuum Deposition
2. Membrane mounting and connection
3. High voltage poling under high temperature
4. Backing, shielding and electrical connection
5. Pre-amplifier design and integration
6. Full scale in-house sensitivity calibrations
7. Functional acoustic pulse measurements

Manufacturing

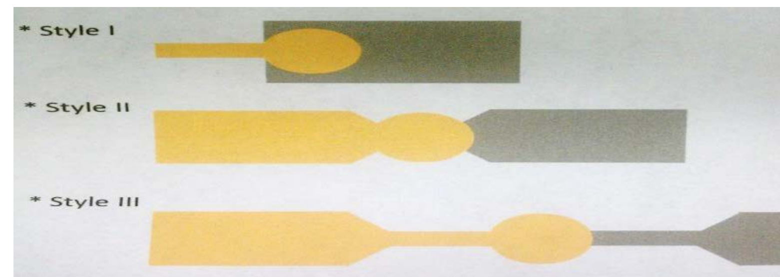
Characterization

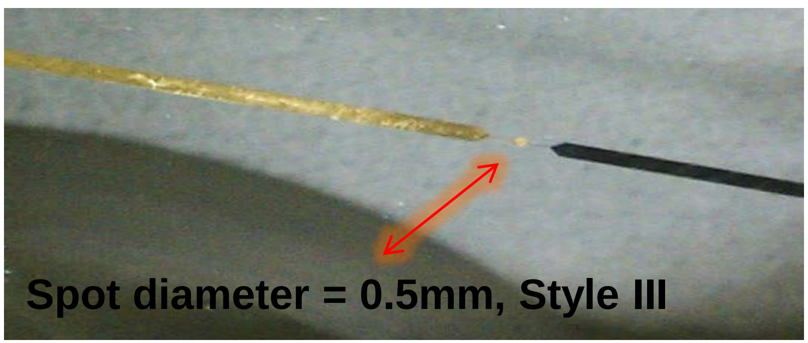
Manufacturing



1. Electrode Vacuum Deposition

- Gold line electrode (Chromium as substrate) is evaporated/coated onto both sides of the transparent PVDF films using various masks/electrode shape designs.





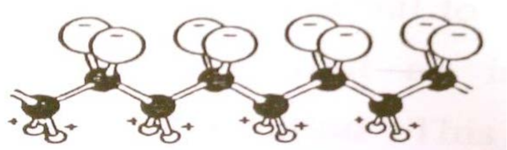
2. Membrane mounting and connection

- 5 cm diameter stainless steel ring hoop for mounting
- Conductive silver epoxy sputting for hot and ground wires under microscope

Manufacturing

3. High voltage poling under high temperature

- The polarization of piezoelectric polymer PVDF molecule must be induced under DC electrical poling (100 KV/mm) and high temperature (80 °C) for 30 min.



PVDF molecule
(Fluorine, Carbon, hydrogen)

- High voltage mineral oil to avoid high voltage arching and breakdown in the air

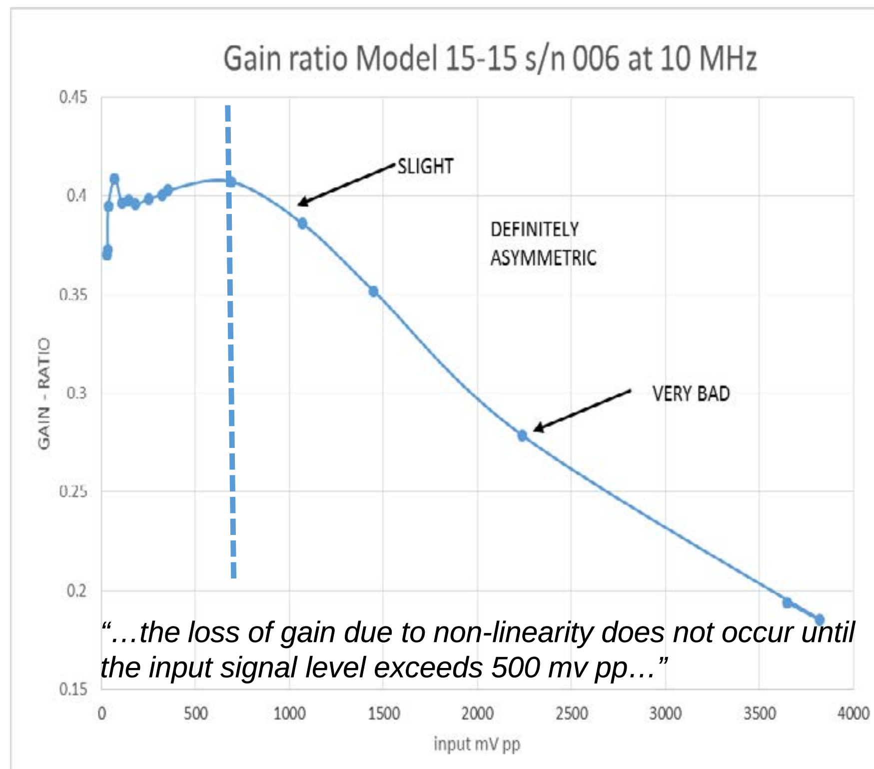
4. Backing, shielding and electrical connection

- Backing (sylgard 170 rubber) to displace air and improve sensitivity
- Shielding (metal coating) to minimize EM noise reception

Manufacturing

5. Pre-amplifier design and integration (Gammell Tech, LLC)

- Keep the pre-amplifier (buffer amplifier) as close to the sensing element as possible to maximize the device sensitive by avoiding the cabling loss
- Pre-amplifier saturation effects is well evaluated.



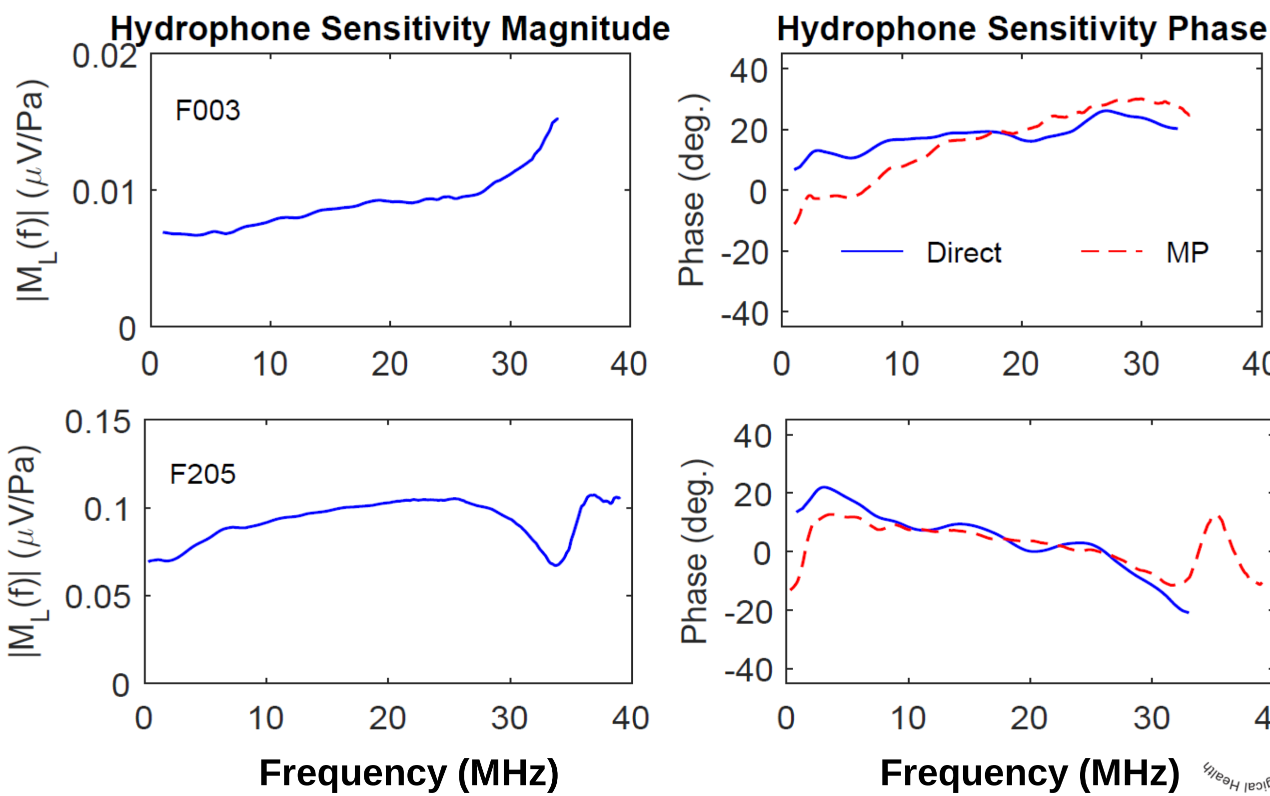
Characterization

6. Full scale in-house sensitivity calibrations

- Time Delay Spectrometry (TDS) system with frequency sweeping technique
- Sensitivity calibration for the manufactured membrane hydrophones
  - Substitution method with commercial membrane hydrophone as reference
  - 0-40 MHz bandwidth sweep (comparable to the metrology institutes)
  - Both amplitude and phase measurements (critical for deconvolution)

ULMH0: lowest sensitivity

ULMH2: highest sensitivity



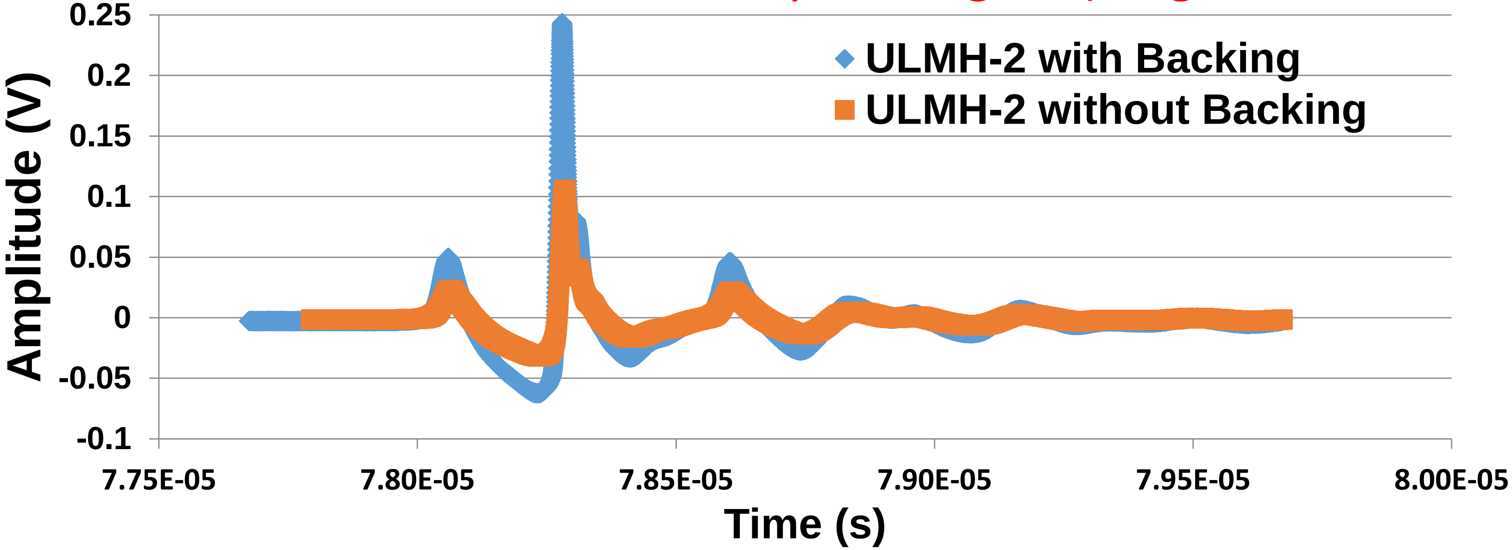
Characterization

Hydrophone Name	ULMH-0	ULMH-1	ULMH-2	ULMH-3
Spot size (mm)	0.3	0.5	0.5	0.5
Spot type	I	I	I	III
Film thickness (μm)	25	25	25	12
Backing material	N	Y	Y	N


Hydrophone Sample

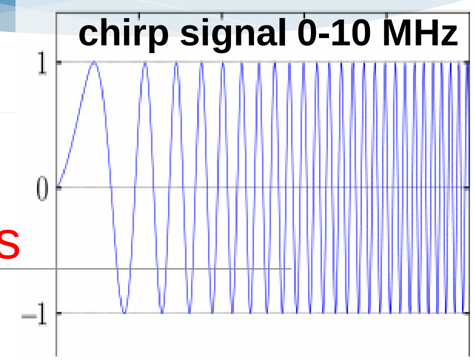
6. Functional acoustic pulse measurements

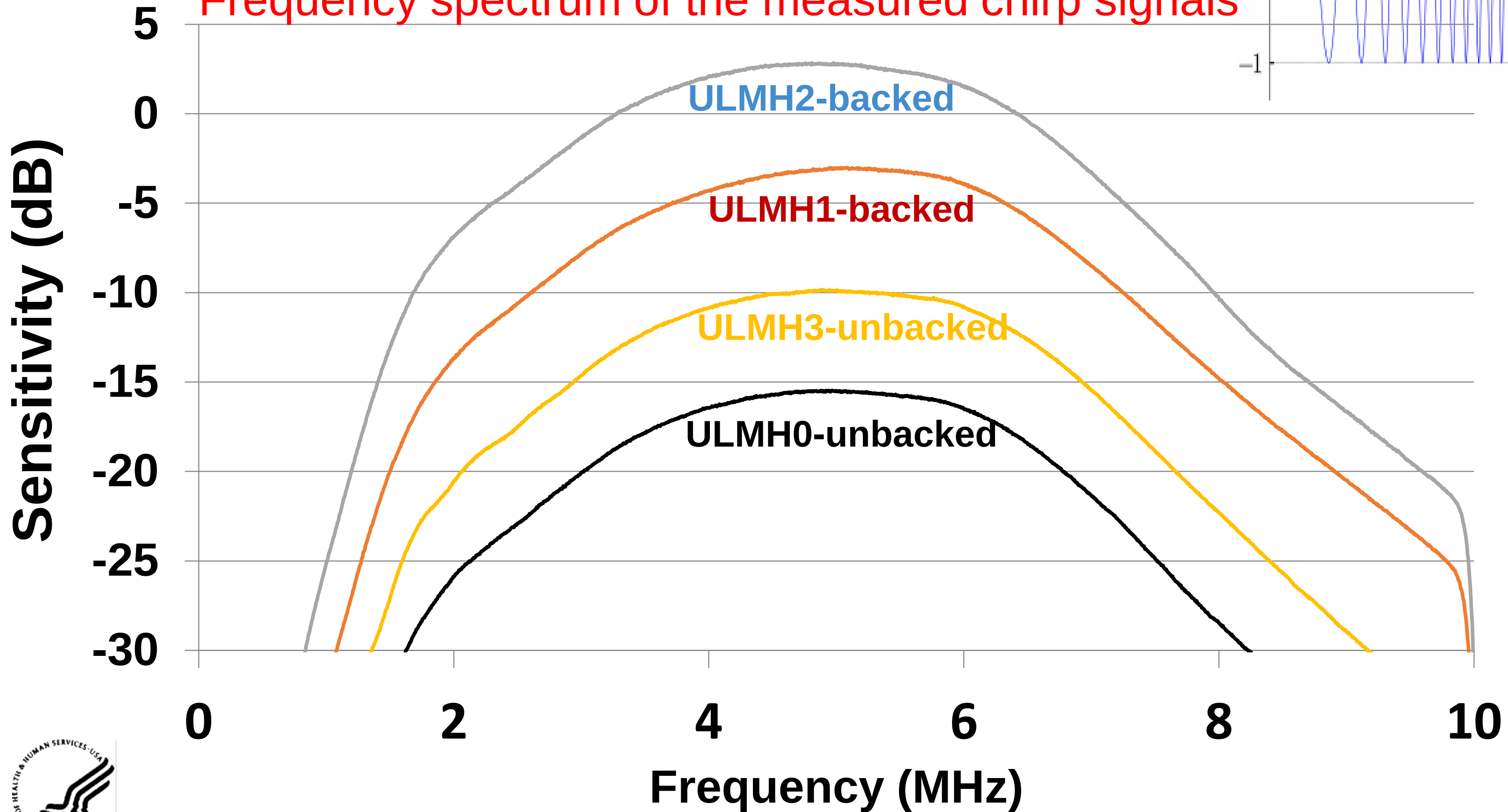
ULMH0 &2 for 2.25 or 3.5 MHz impulse signal (diagnostic and CW pulse)



Characterization

6. Functional acoustic pulse measurements





Conclusion

- Membrane hydrophone is the gold standard for pressure output characterization of both Class II and Class III medical ultrasound devices.
- Commercial membrane hydrophones are expensive ($20K) and delicate with limited vendor selection and technical supports.
- We established a small production line for making prototype units in the medical ultrasound lab.
- Manufacturing and processing technique could be further streamlined and optimized.
- Full scale broadband (40 MHz) sensitivity calibration provided.
- Medical ultrasound waveforms was measured with deconvolution analysis.

Thank you