A SYNTHETIC TYMPANIC MEMBRANE FOR MIDDLE EAR ACOUSTIC SENSOR TESTS OF A FULLY IMPLANTABLE COCHLEAR PROSTHESIS

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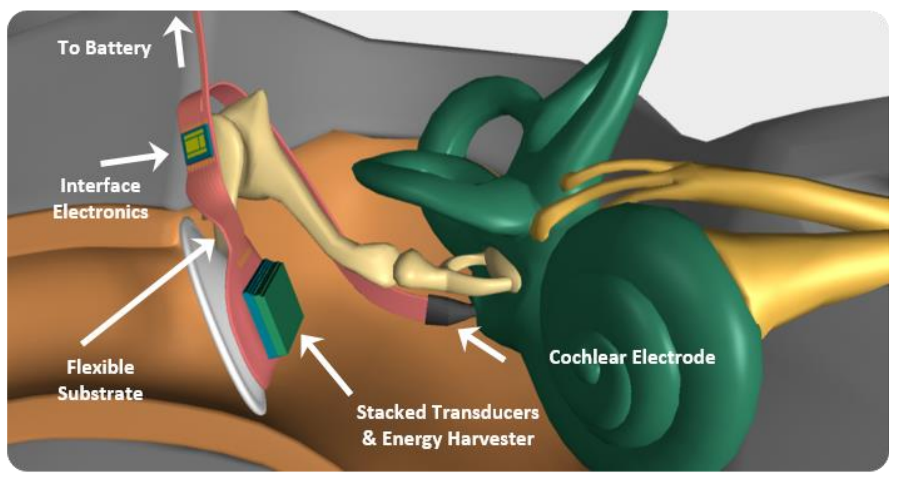
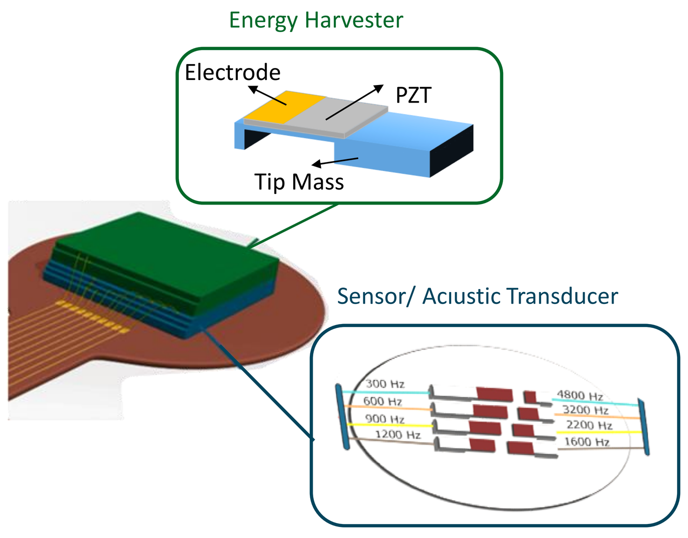
ABSTRACT

A physical model of human Tympanic Membrane (TM), based on PDMS, as an easily accessible test platform for acoustic transducers was designed and fabricated.

- A primitive ear canal simulator (TM holder) design was done using COMSOL FEA.
- Vibration behavior of TM was tested with a Scanning Laser Doppler Vibrometer (SLDV).
- Effect of an attached mass on the membrane was performed utilizing 32 mg and 57 mg accelerometers.
- The model reproduced the basic vibrational characteristics of a human TM.

OBJECTIVE





A realiable in-vitro testing platform for implants:

1. TM driven piezoelectric Sensors & Harvesters
2. TM driving Electromagnetic Transducers.

EAR CANAL SIMULATION

Ear Canal Acoustic Simulations

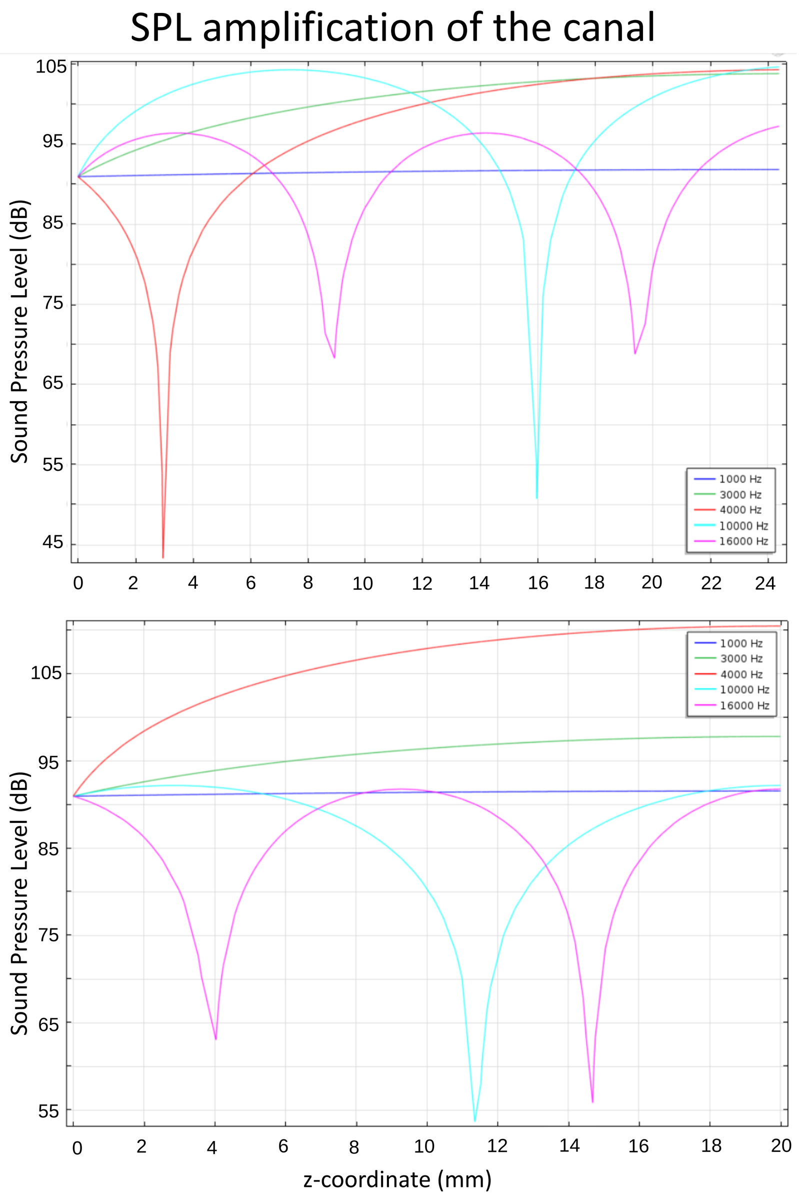
FACTS:

- Ear canal amplifies the incoming acoustic wave pressure. (10 dB at 3.5-4 kHz)
- TM is located with a 57° angle at the end of the ear canal increasing the active surface area.

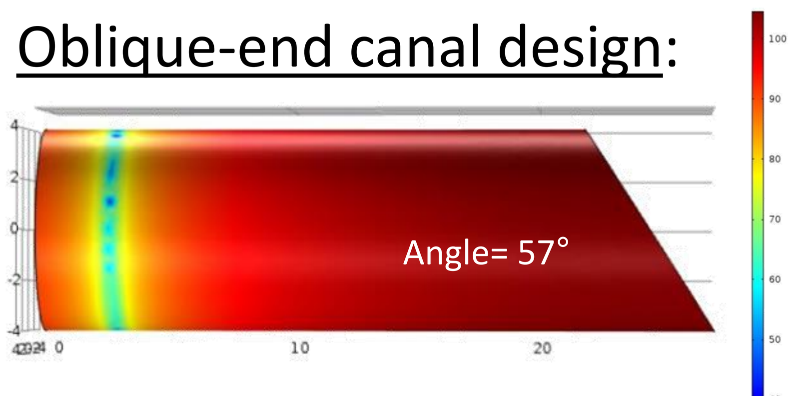
GOAL:

- Design parameters of the ear canal simulator (length, diameter, shape).
- Pre-evaluation of microphone position to prevent coincide with standing-waves.

SPL amplification of the canal

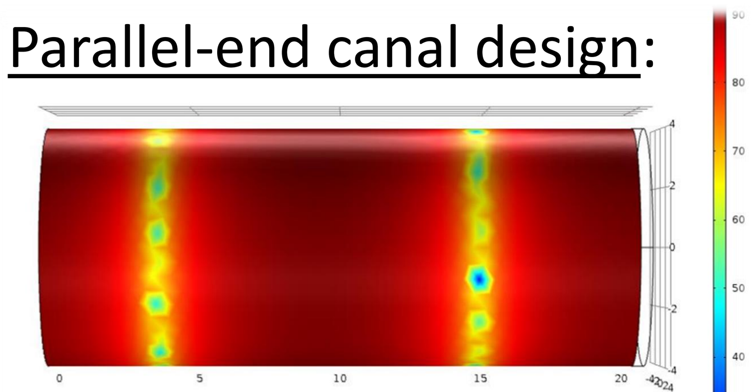


Oblique-end canal design:



Sound pressure level (dB SPL) at 4 kHz.

Parallel-end canal design:



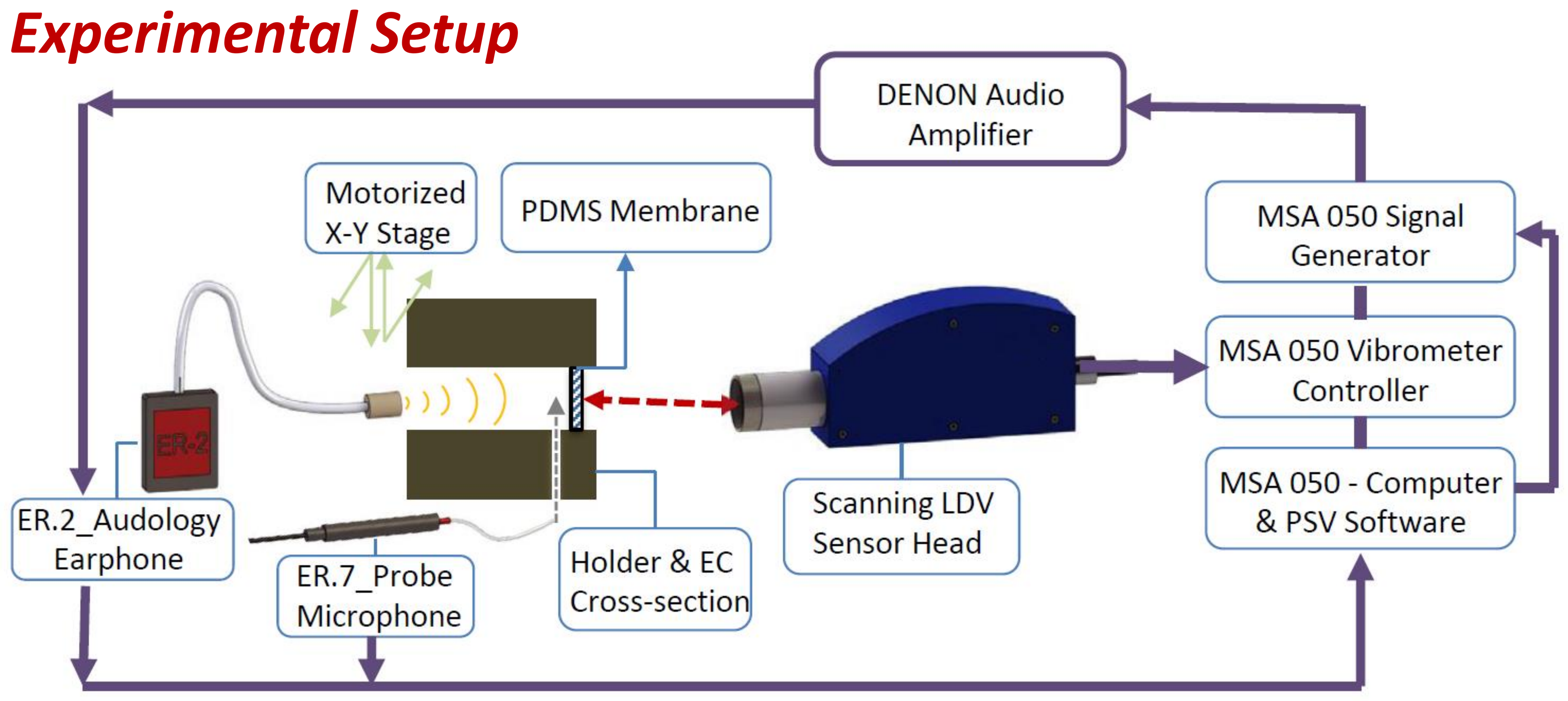
Sound pressure level (dB SPL) at 16 kHz.

$$\frac{d}{dz}\left(\frac{A(z)\,dp(z)}{dz}\right) + k^2 A(z)p(z) = 0 \quad [1]$$

z: length coordinate,
k = w/ c: wave number,
w: angular frequency,
C: speed of sound in air (340 m/s)
A: cross-sectional area (constant).

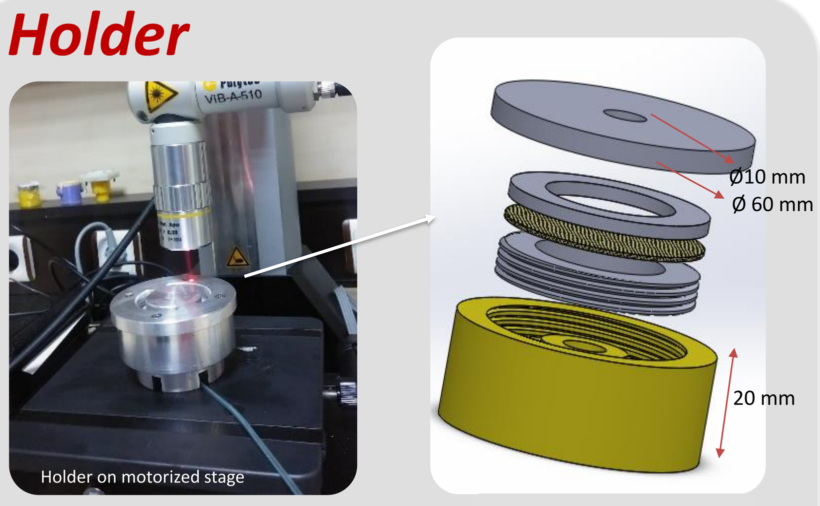
EXPERIMENTAL WORK AND RESULTS

Experimental Setup



Frequency sweeps from 200 Hz to 8 kHz were used.

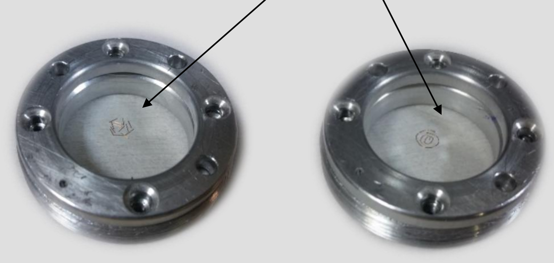
Holder



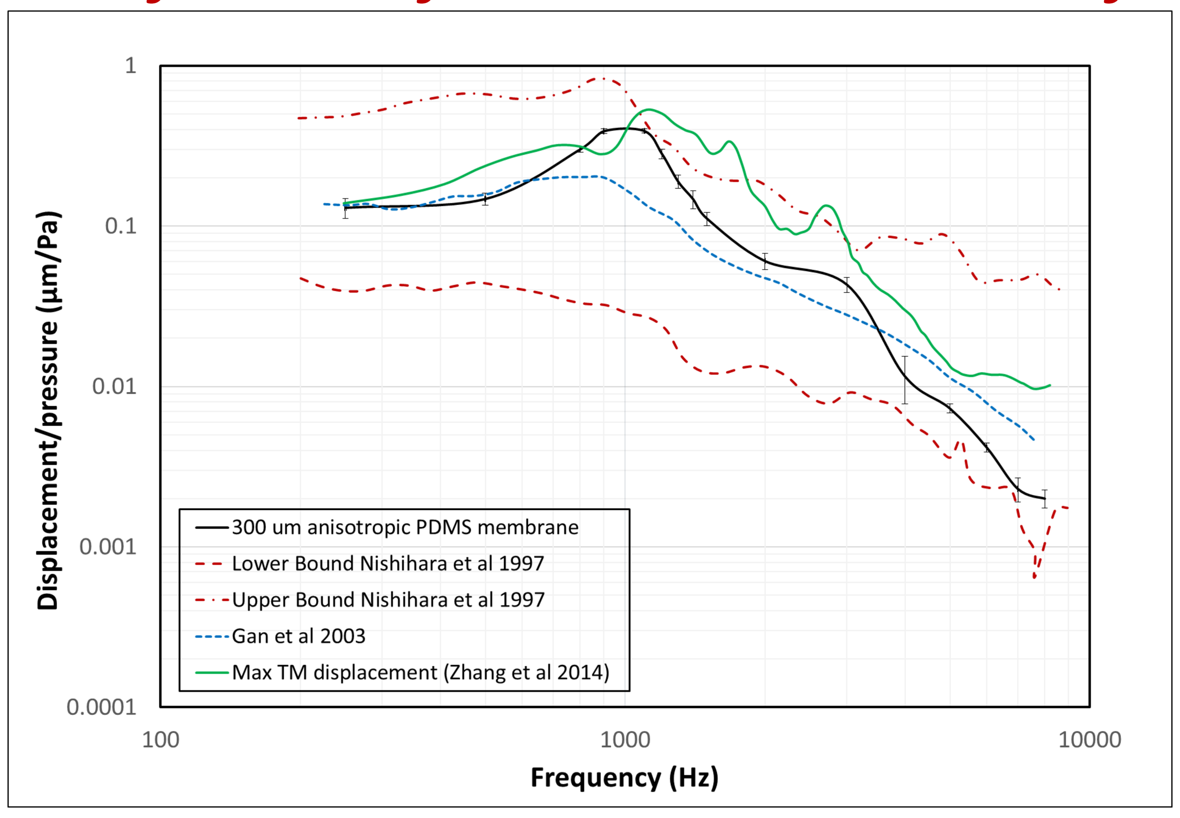
- Parallel-end canal selected for EC design (simple design, no drawbacks)
- Pre-straining and clamping mechanism

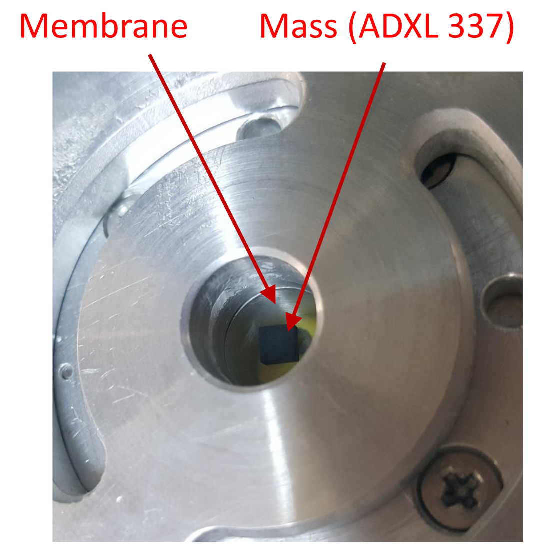
Materials

- Aluminum holder
- 100-500 µm thick TMs
- 120 µm thick Cu fibers

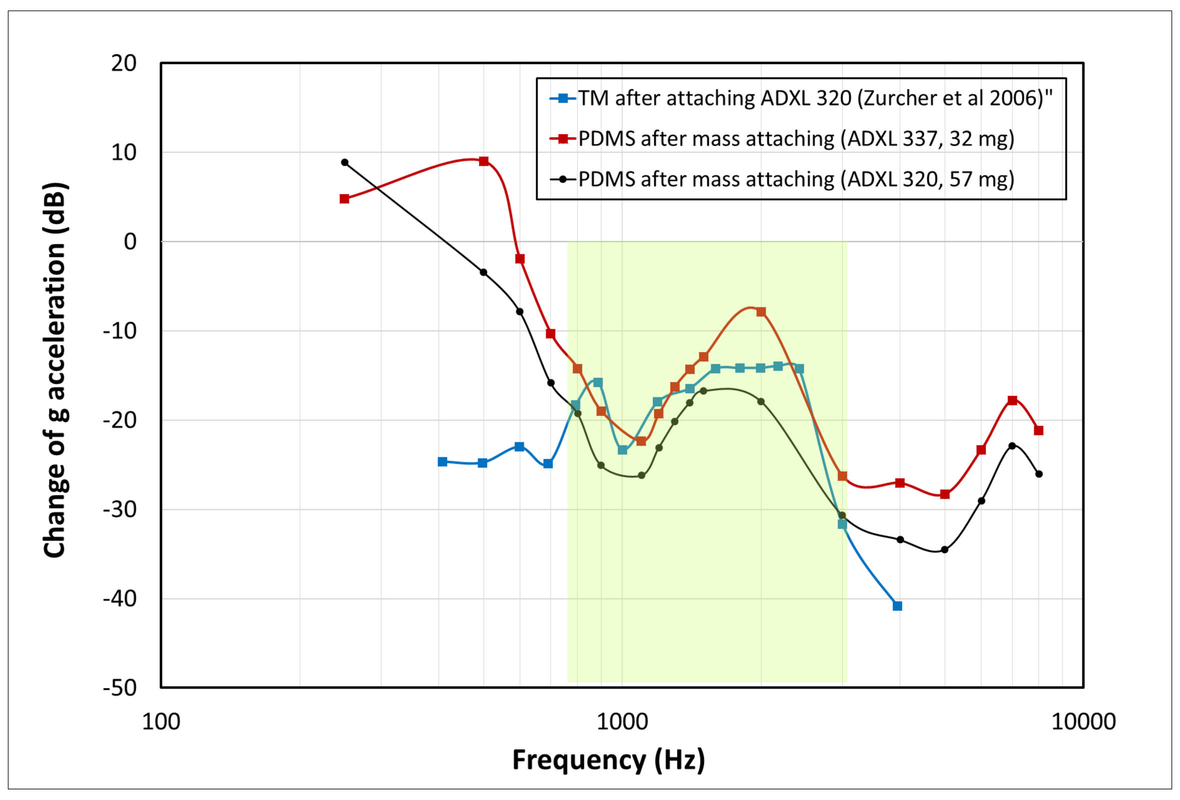


Verification of Vibrational Behavior of TM



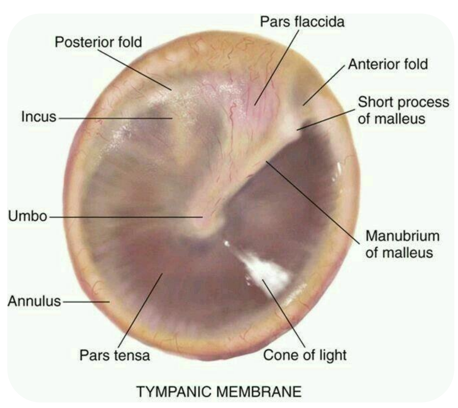


Close-up view of membrane with the attached mass



- Quantifying the effect of attaching a mass.
- Bare membrane (without mass) as reference.
- Similar trend at 800 to 3000 Hz
- Trend differences because of resonance frequency difference in compared experimental data.

FABRICATION of TM

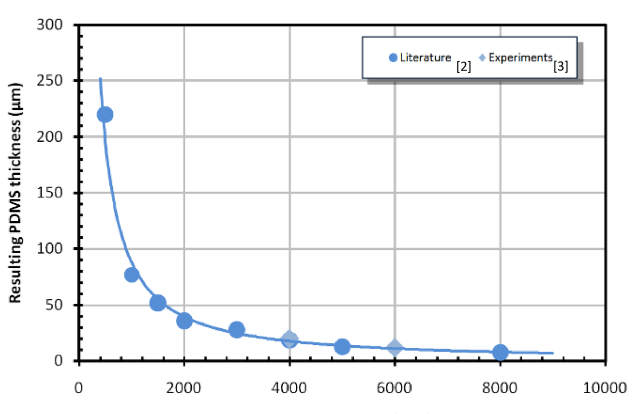


Tympanic Membrane (TM) dimensions:

- Vertical axis: 8.5 to 10 mm
- Horizontal axis: 8 to 9 mm
- Thickness: 0.1 mm

- Because of its flexibility, ease of access, and ease of fabrication, PDMS was chosen as membrane material

PDMS layer thickness as a function of spin-coating speed



- Sylgard-184 (10:1 ratio)
- Spin Time: 60 seconds, Acceleration: 20 rpm/s
- Solid line is the theoretical fit $W=0.23\ \omega^{-1.14}$ (W in meters, ω in rpm)

CONCLUSIONS

- Vibration magnitude of 300 µm thick PDMS membrane with Cu fibers inside the allowed limits of TM, up to 8 kHz when it's first resonance frequency is found to be about ≈1 kHz ,similar to TM
- Comparable results with literature for acceleration change with attached mass.
- Promising results for further development of a future complete middle ear acoustic test platform which can be used to simulate the vibrational characteristics of middle ear sensors and eardrum driving transducers in primary steps of their design for minimizing the need for cadaveric TMs and animal's TM.

REFERENCES

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