DESIGN AND SIMULATION OF A MEMS-BASED CMUT FOR VISCOSITY SENSING APPLICATIONSAND

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COMSOL CONFERENCE
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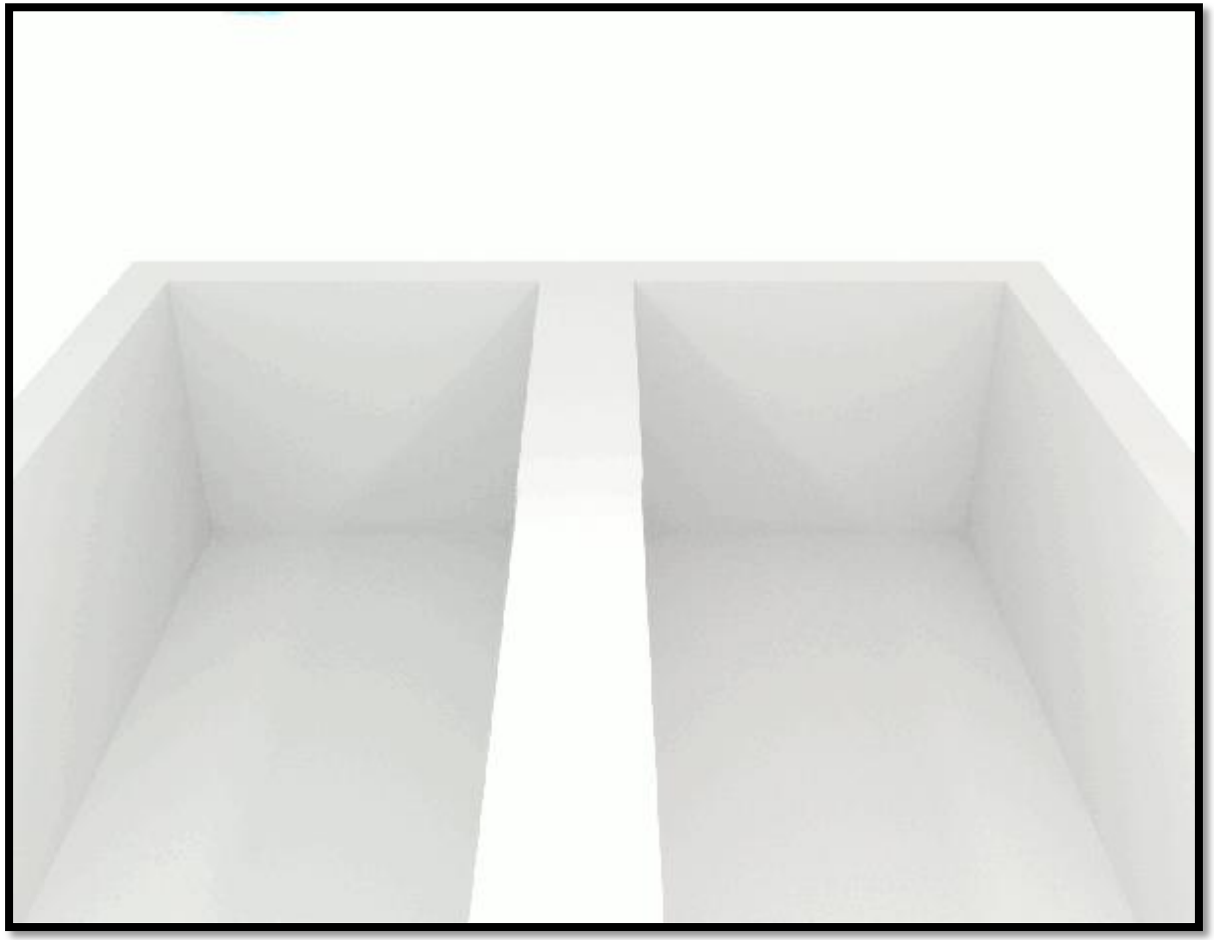
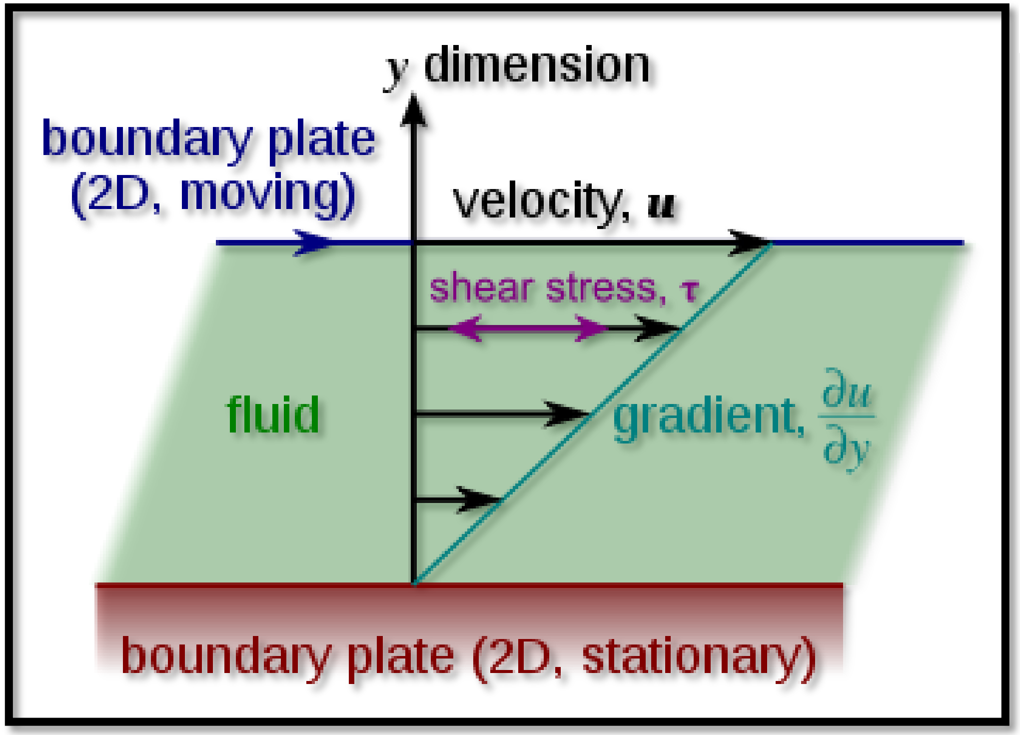
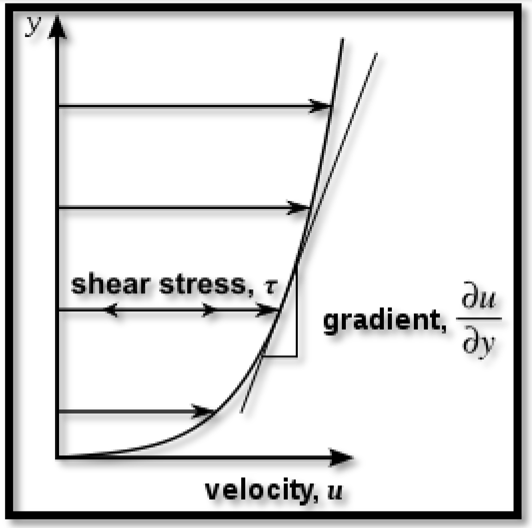
OUTLINE

1. Viscosity and why sensing it is important
2. Need for MEMS viscometer
3. Novel idea of the viscosity sensor
4. Working of the sensor
5. Simulation of sensor using COMSOL
6. Results

VISCOSITY



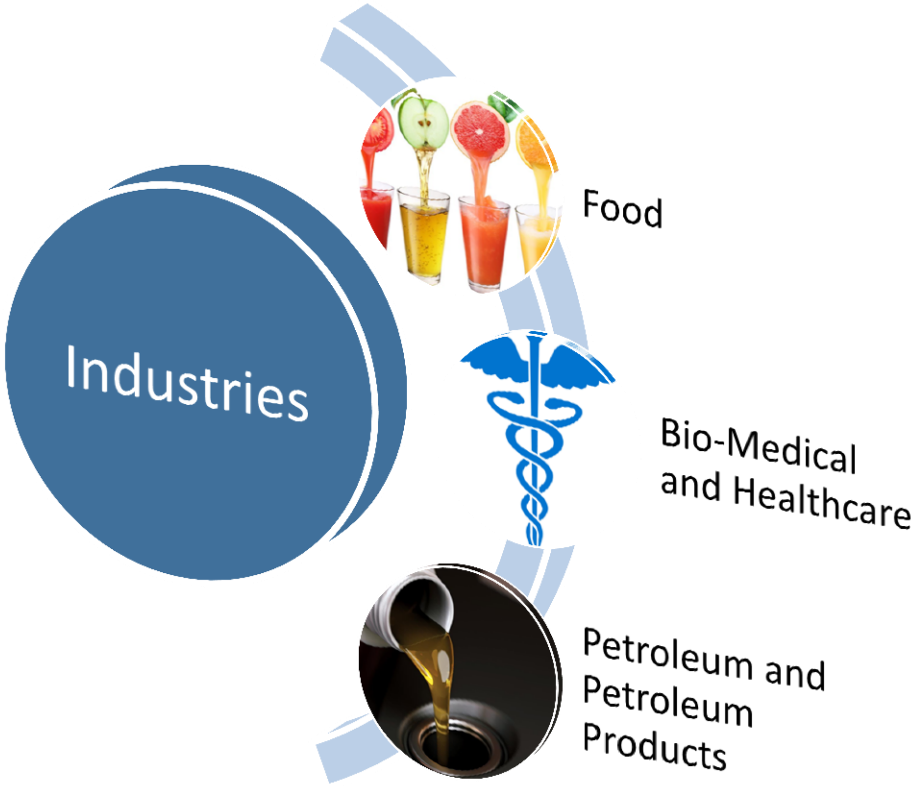




Source: Wikipedia

WHY VISCOSITY MEASUREMENT IS IMPORTANT?

- Predict material behavior.
- Helps design transportation and processing parameters.
- Set standards for Quality Control.
- Correlate liquid composition.

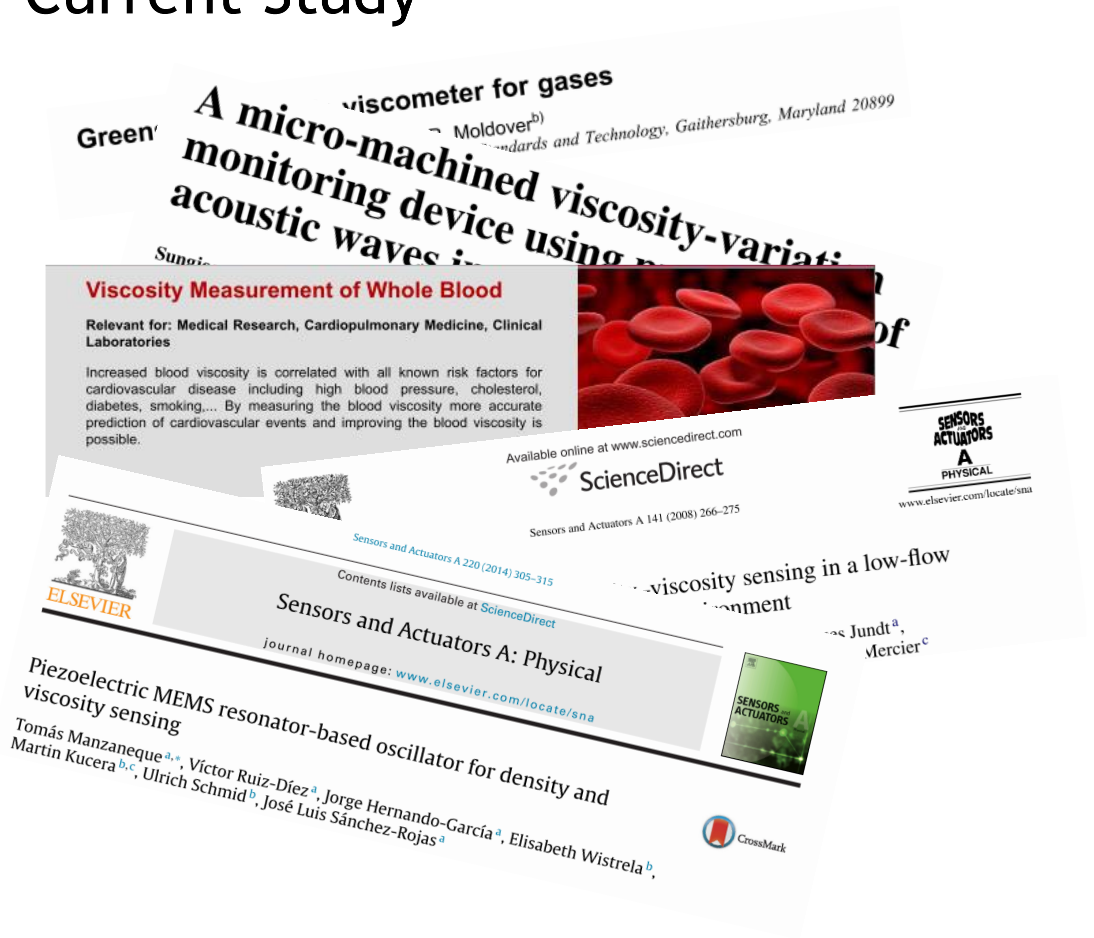


WHY MEMS VISCOMETER?

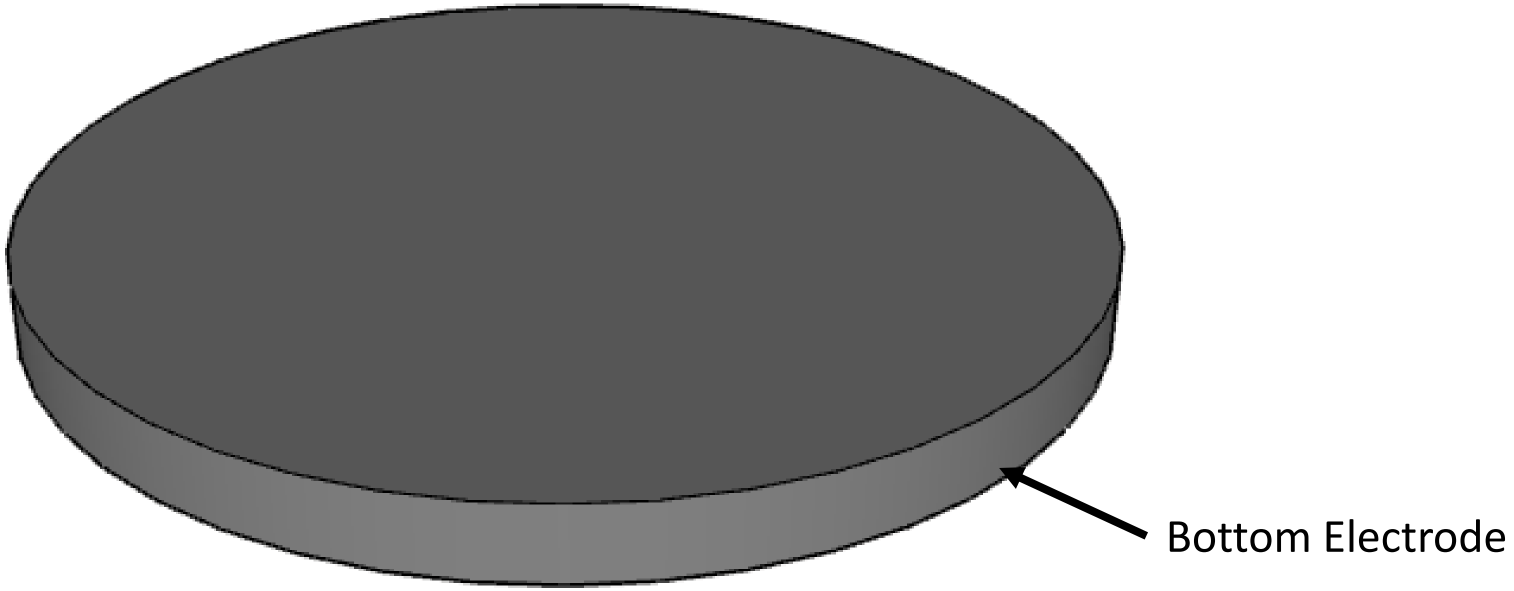
Conventional Viscometers are:

- Slow
- Bulky
- Costly
- Require Human Intervention
- Not suitable for Inline measurements
- Though have become more sophisticated with time.

Current Study



CAPACITIVE MICROMACHINED ULTRASONIC TRANSDUCER (CMUT)



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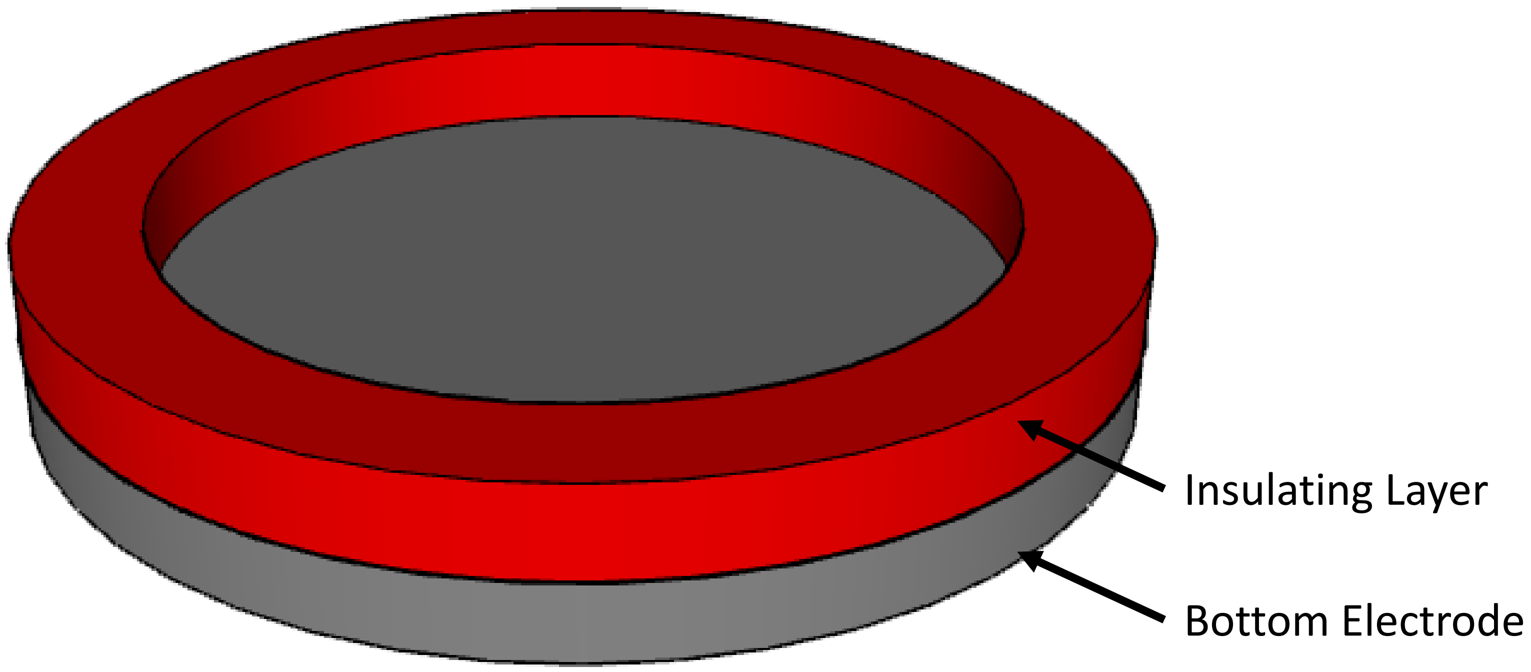

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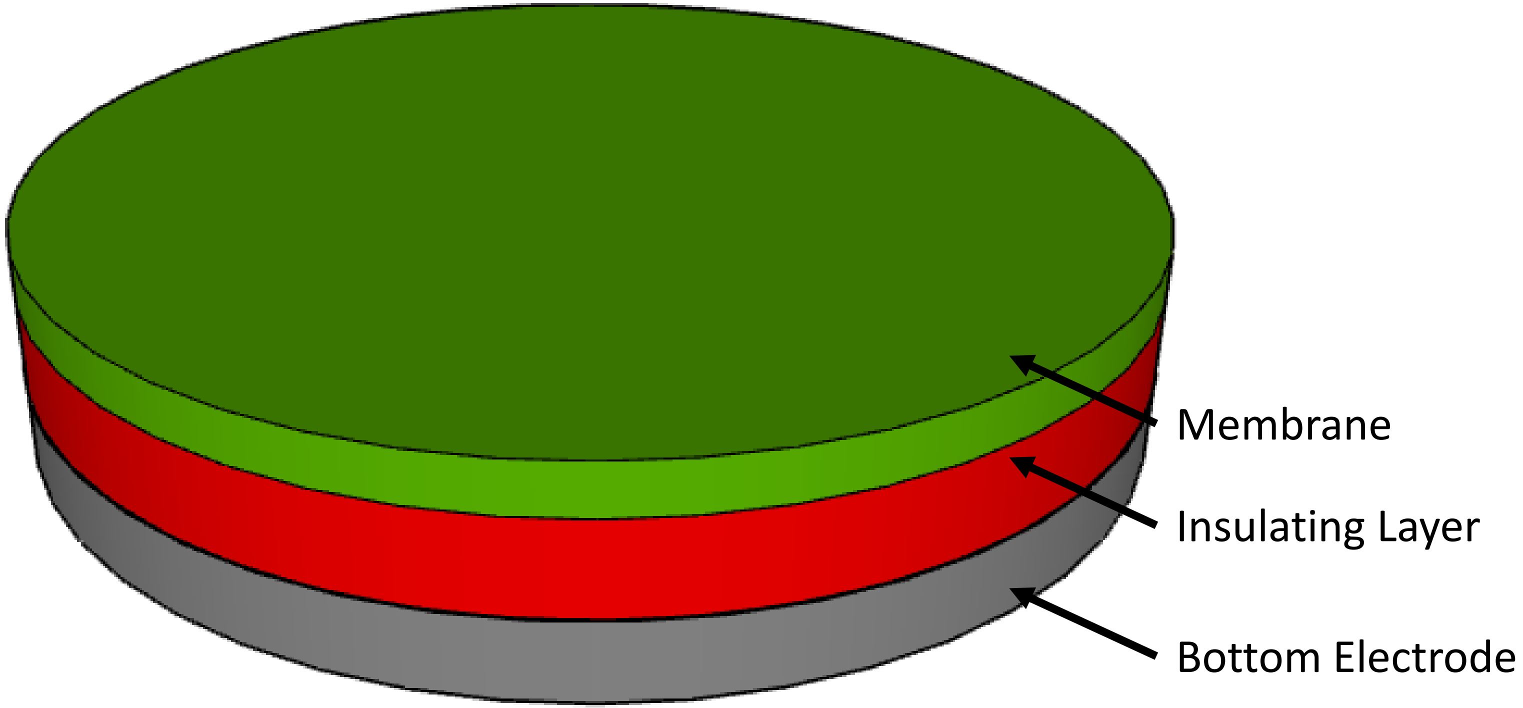

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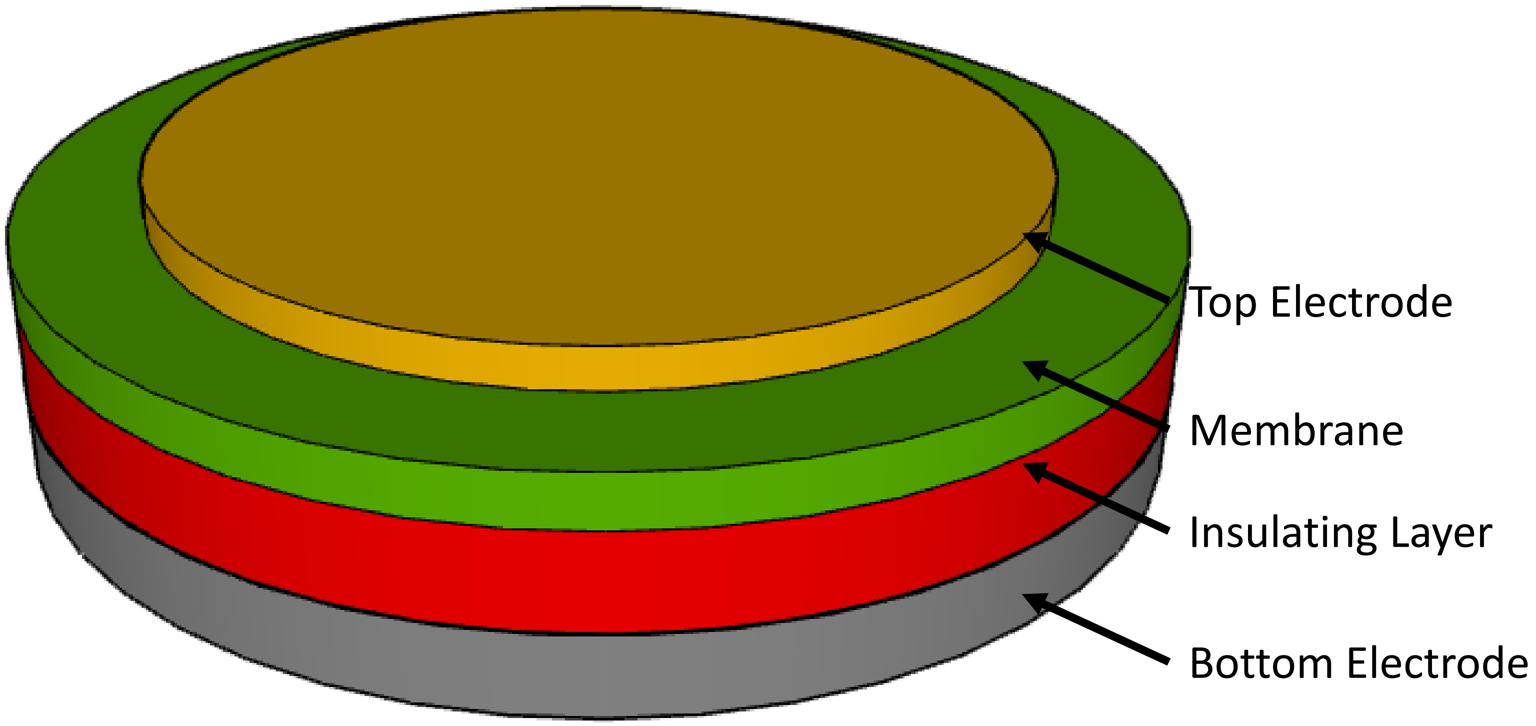
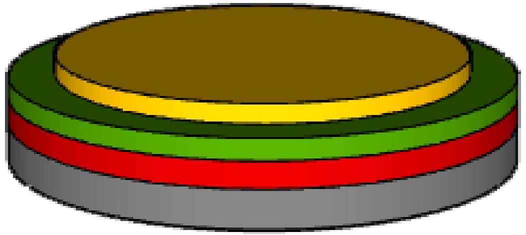


CMUT VISCOMETER

- Transmitter CMUT

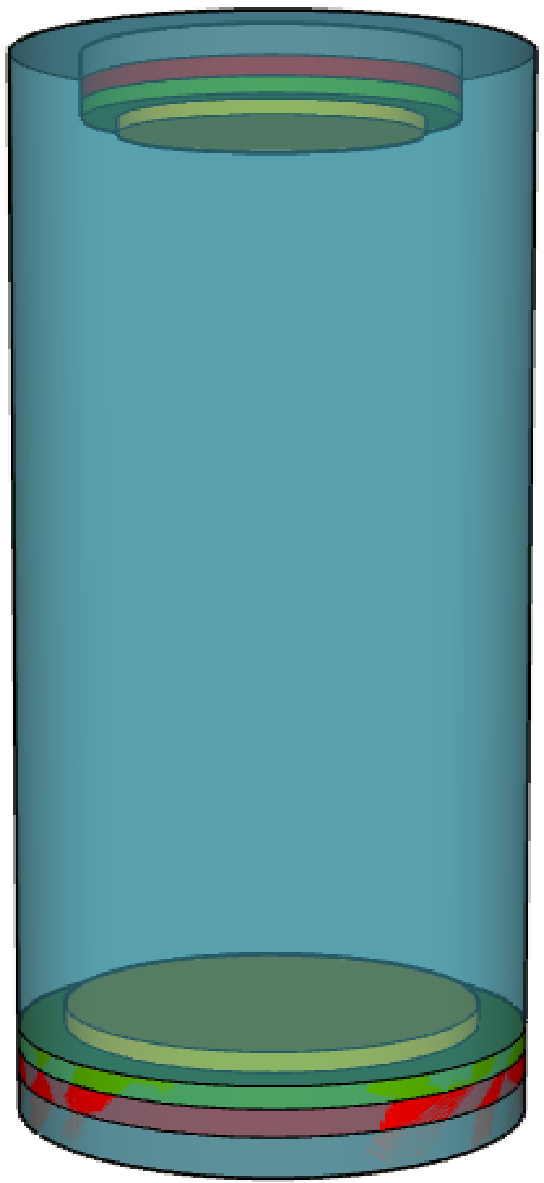
CMUT VISCOMETER

- Transmitter CMUT
- Receiver CMUT



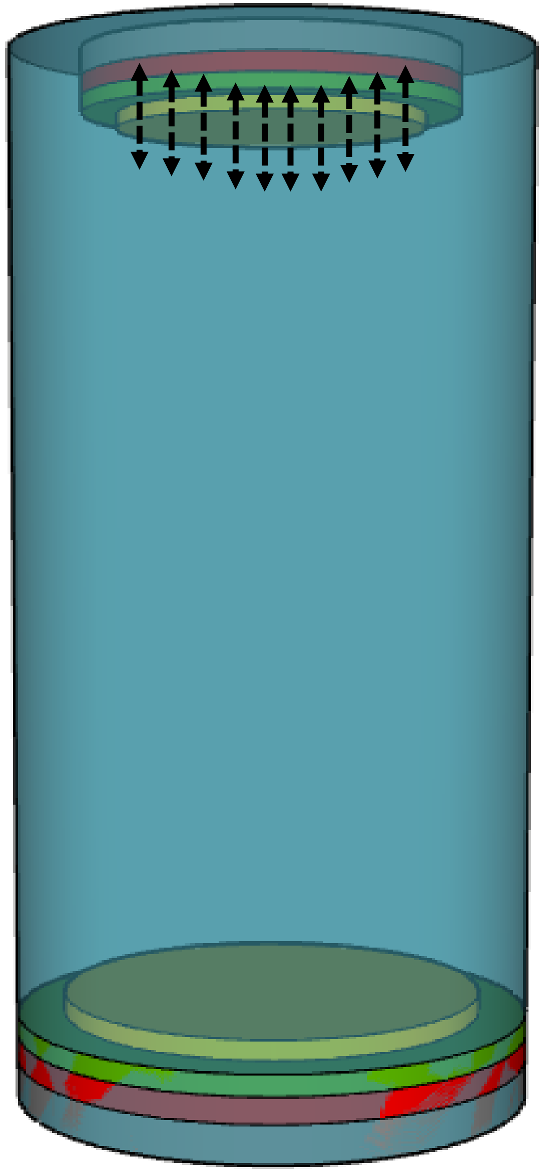
CMUT VISCOMETER

- Transmitter CMUT
- Receiver CMUT
- Fluid Under Inspection



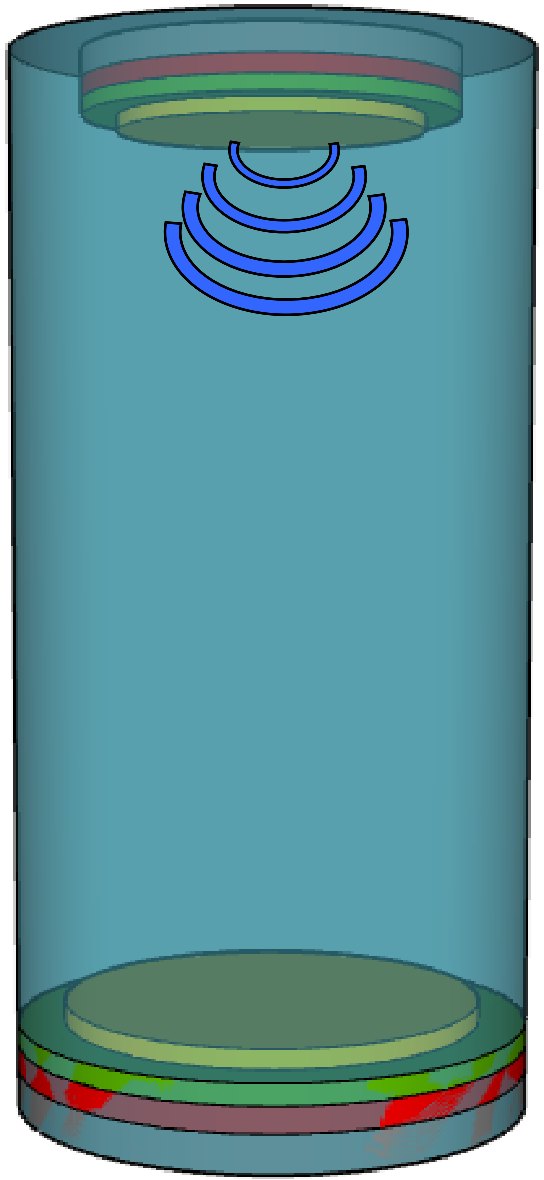
WORKING

- Actuation of CMUT



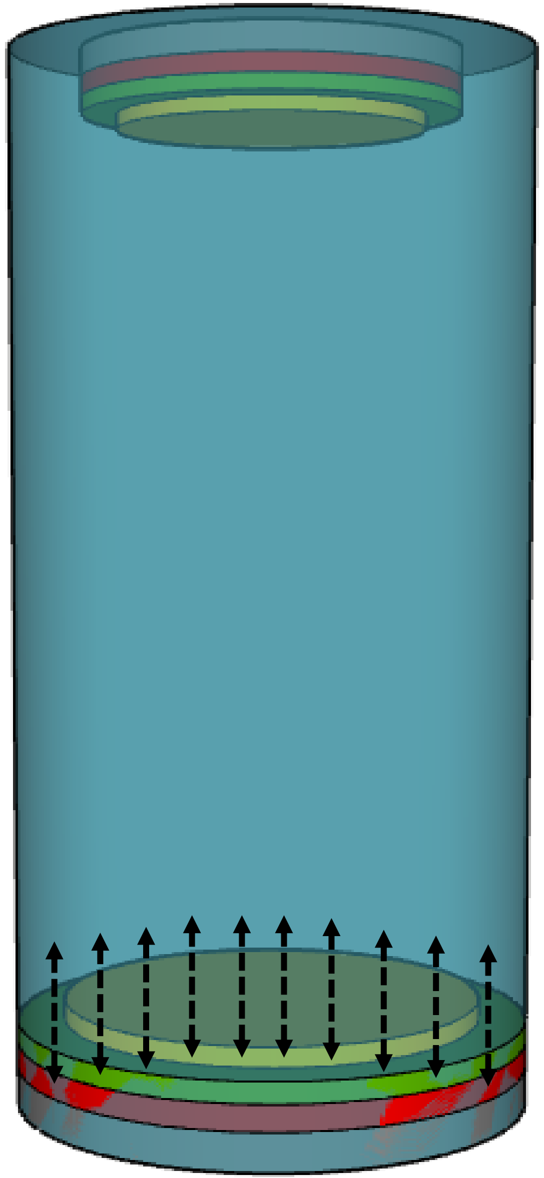
WORKING

- Actuation of CMUT
- Transfer of Pressure wave in liquid column



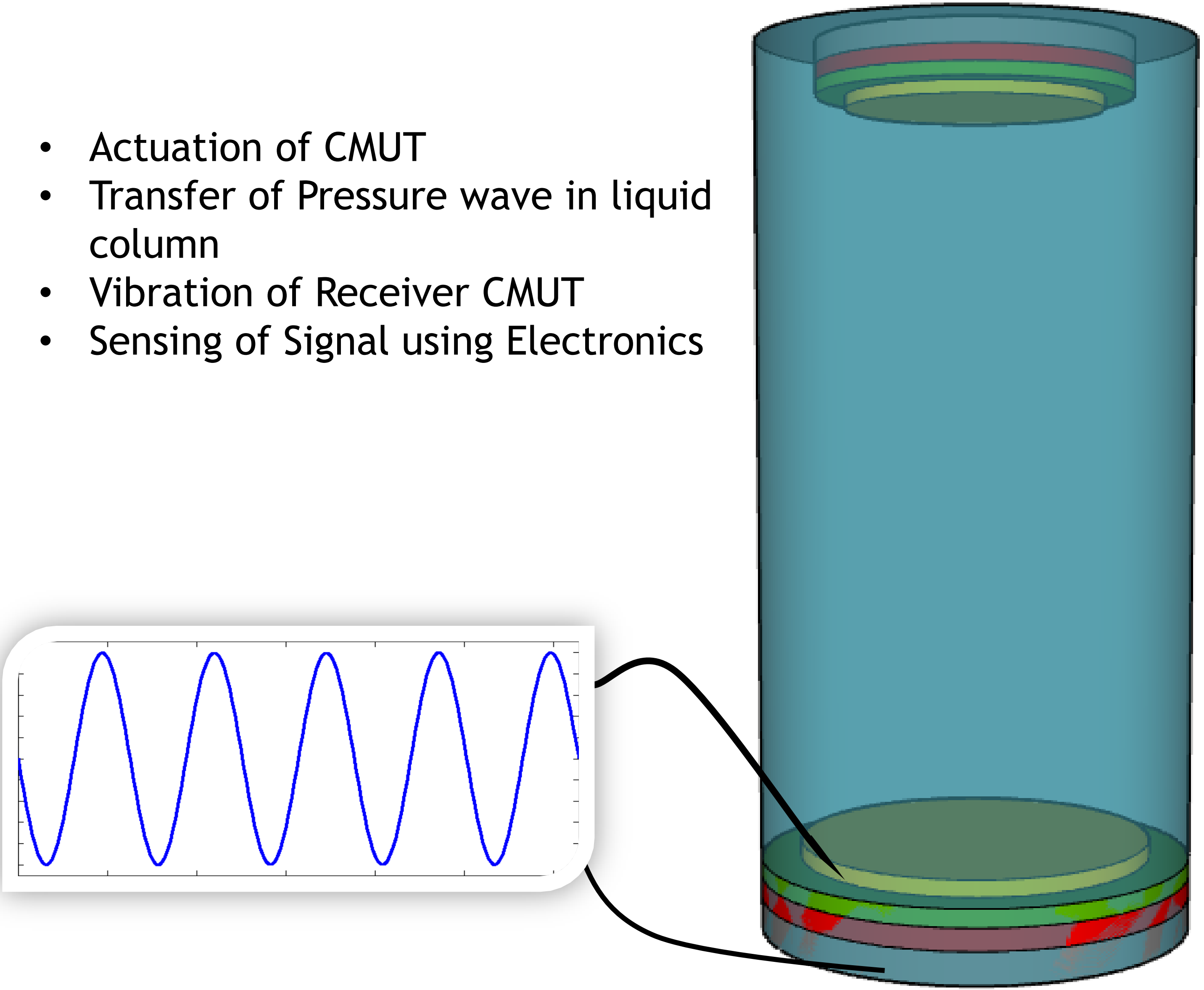
WORKING

- Actuation of CMUT
- Transfer of Pressure wave in liquid column
- Vibration of Receiver CMUT



WORKING

- Actuation of CMUT
- Transfer of Pressure wave in liquid column
- Vibration of Receiver CMUT
- Sensing of Signal using Electronics



USE OF COMSOL MULTIPHYSICS

1. CMUT Parameters
2. Actuation of Transmitter CMUT
3. Pressure Induced in the Liquid Column
4. Vibration of the Receiver CMUT
5. Sensing of Signal

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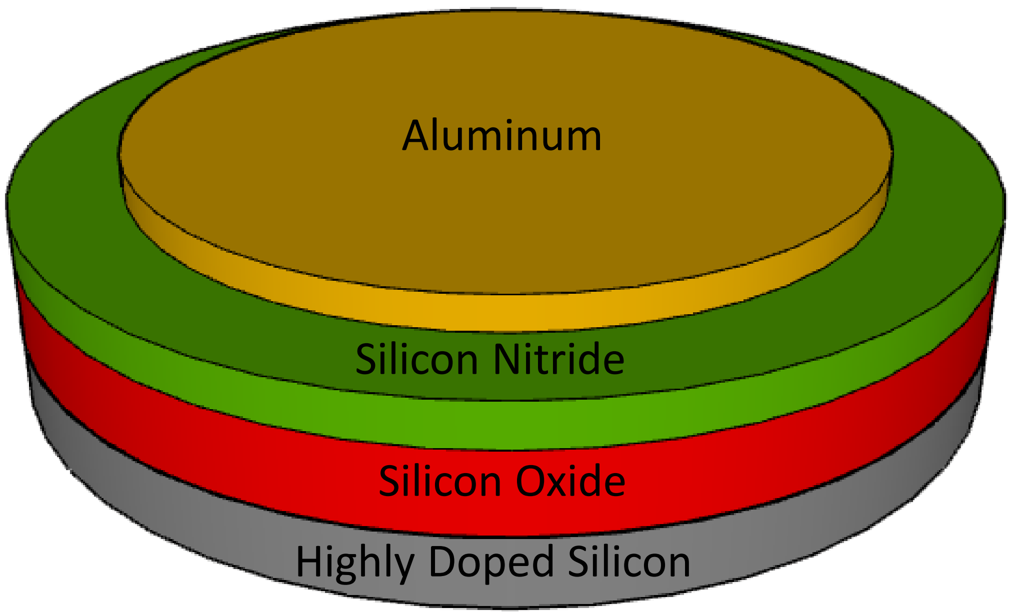
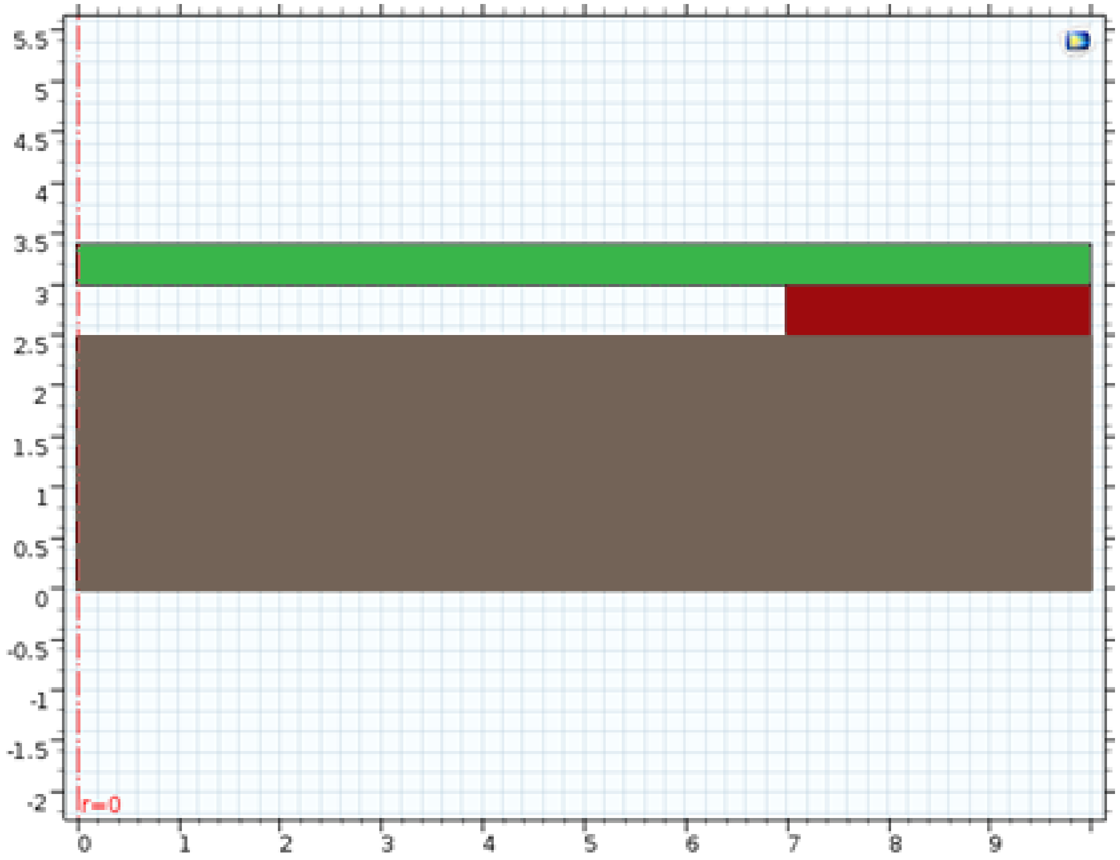
CMUT PARAMETERS – MATERIALS USED

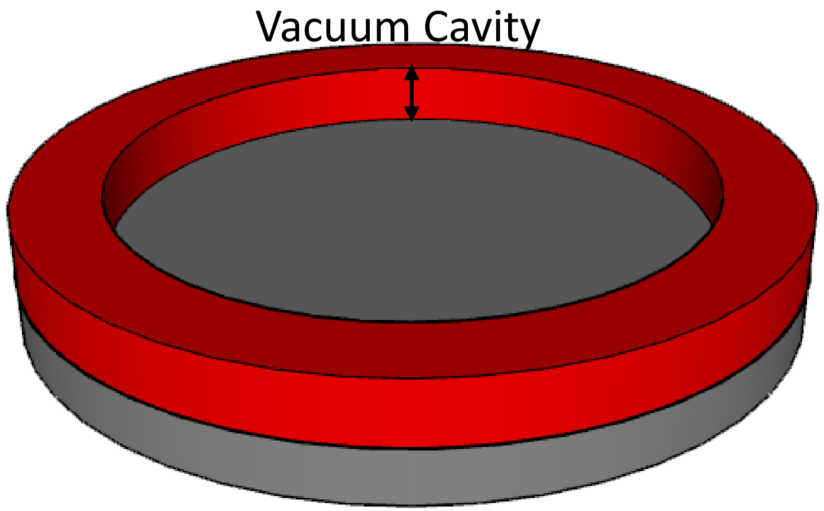
*PHYSICS USED: SOLID MECHANICS

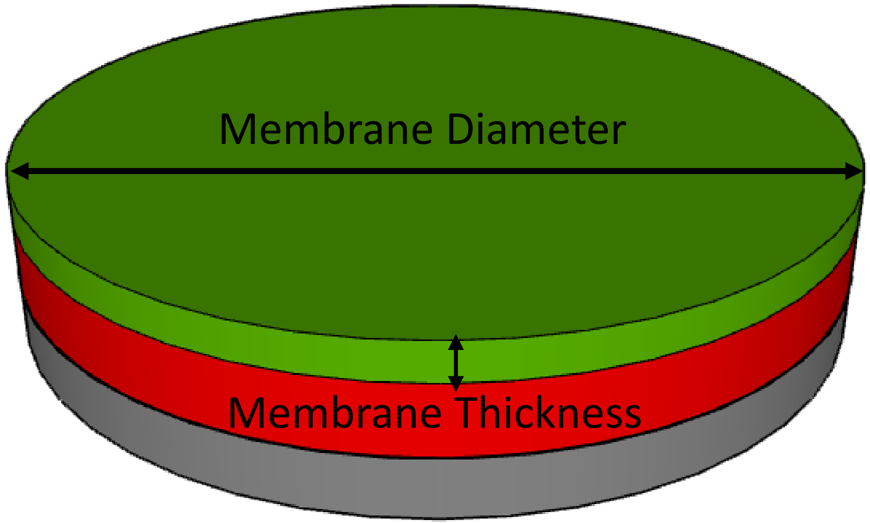




CMUT PARAMETERS - PARAMETRIC SWEEP

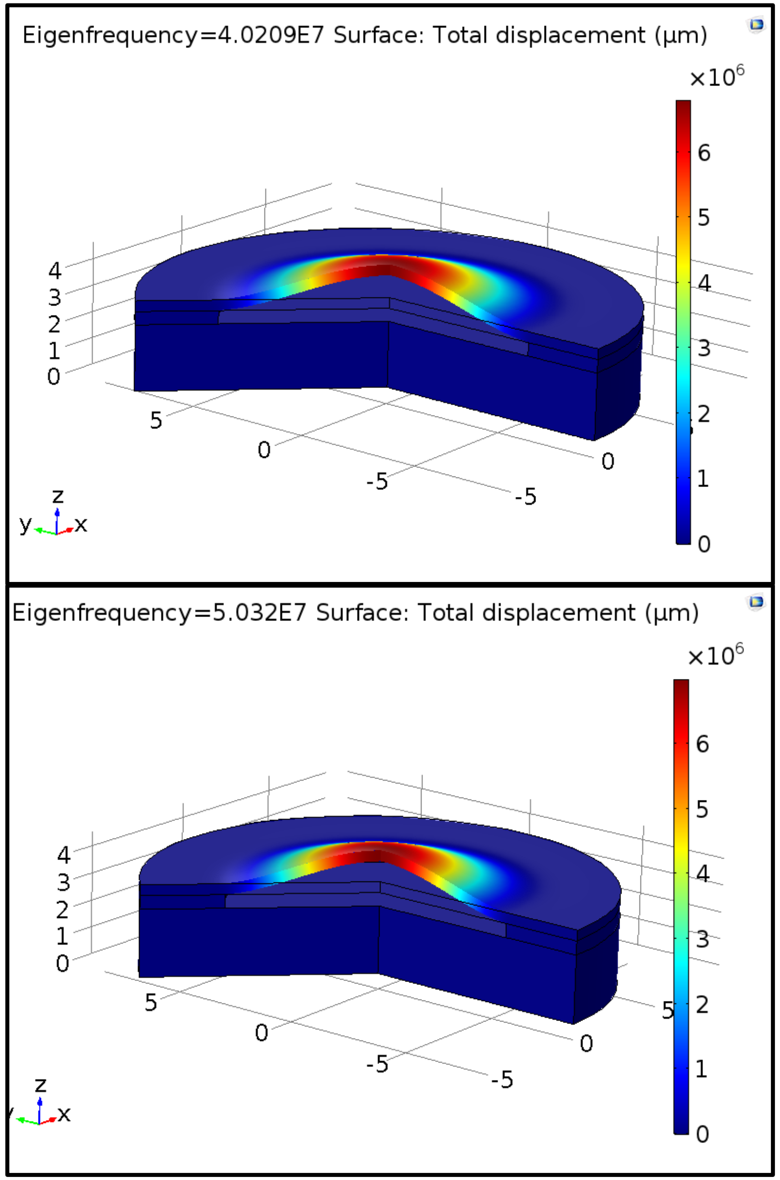
*PHYSICS USED: SOLID MECHANICS





CMUT PARAMETERS – COMPUTED

Parameters	Transmitter	Receiver
Resonance Frequency	40 MHz – 50 MHz	40 MHz – 50 MHz
Membrane Thickness	100 nm	400 nm
Membrane Diameter	5.85 µm – 6.35 µm	11.65 µm - 13 µm
Vacuum Cavity	0.1 µm	0.5 µm
Pull-in voltage	67 v	> 67
DC voltage	30V	10V
AC voltage	5V V_{pp}	-



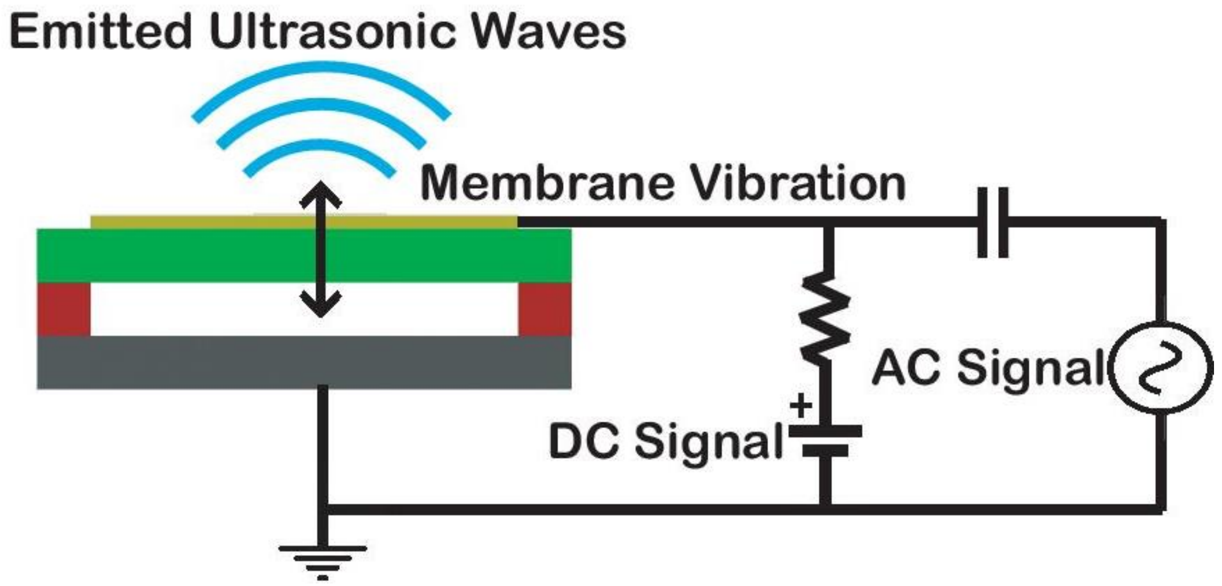
ACTUATION of Tx-CMUT

VOLTAGE APPLIED

V_{DC} = 30 V

V_{AC} = 5 V_{PP}

FREQUENCY OF AC SIGNAL: 21.16 MHZ



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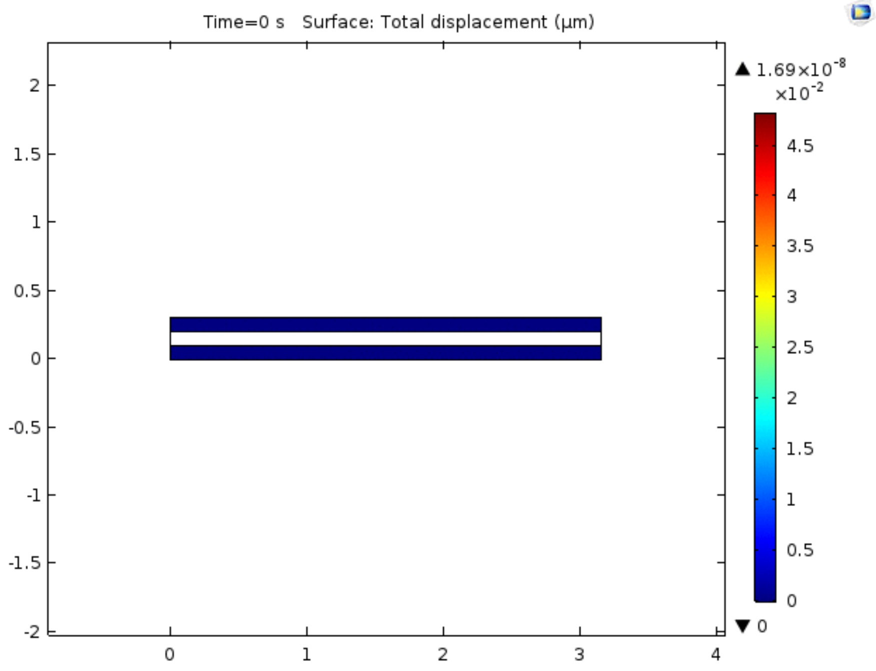

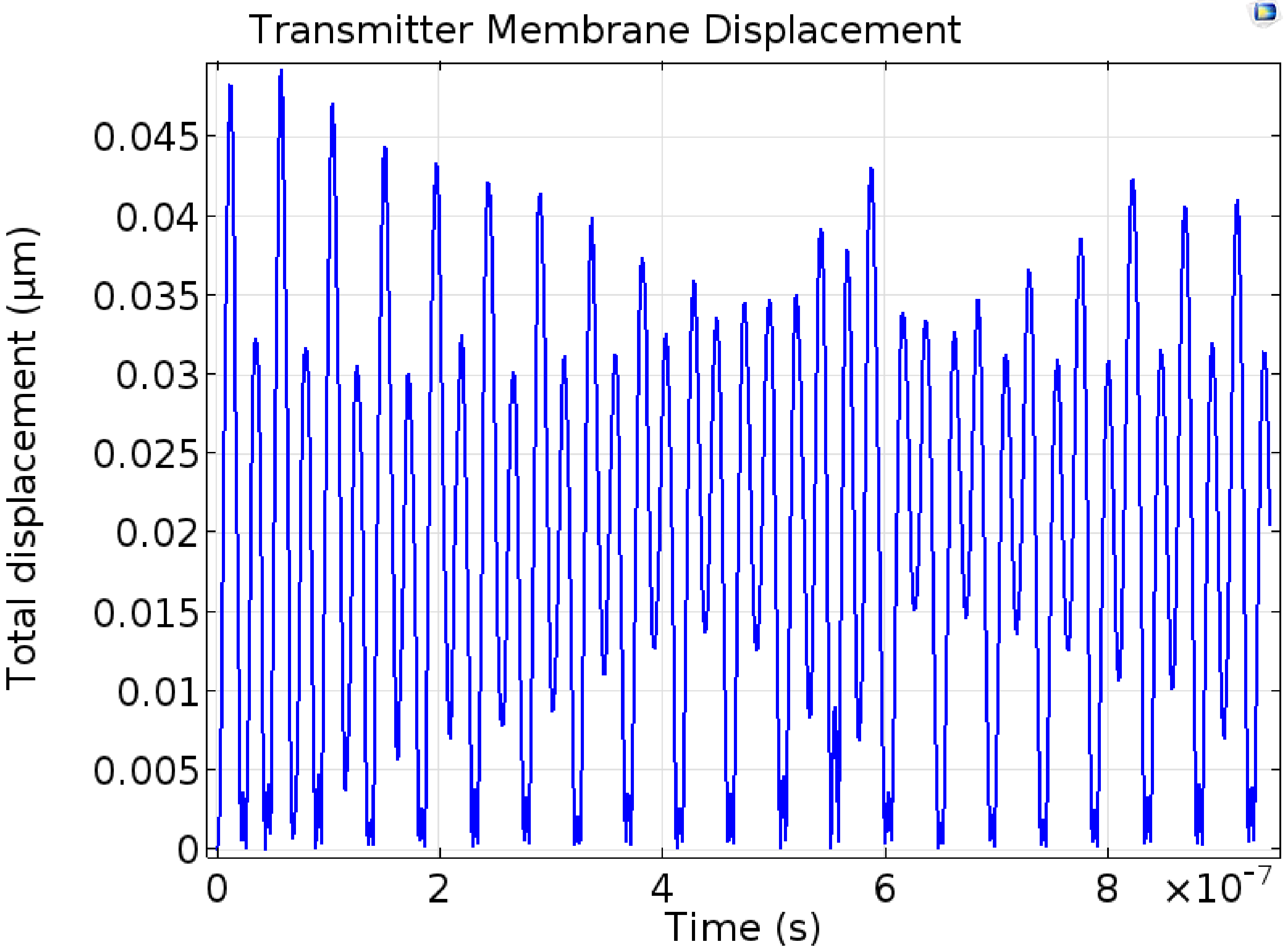

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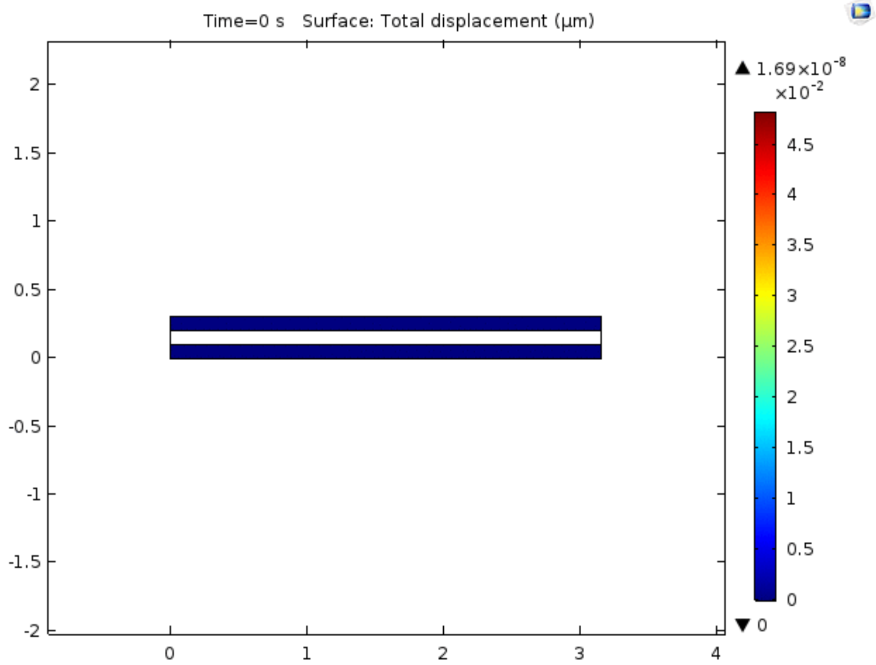
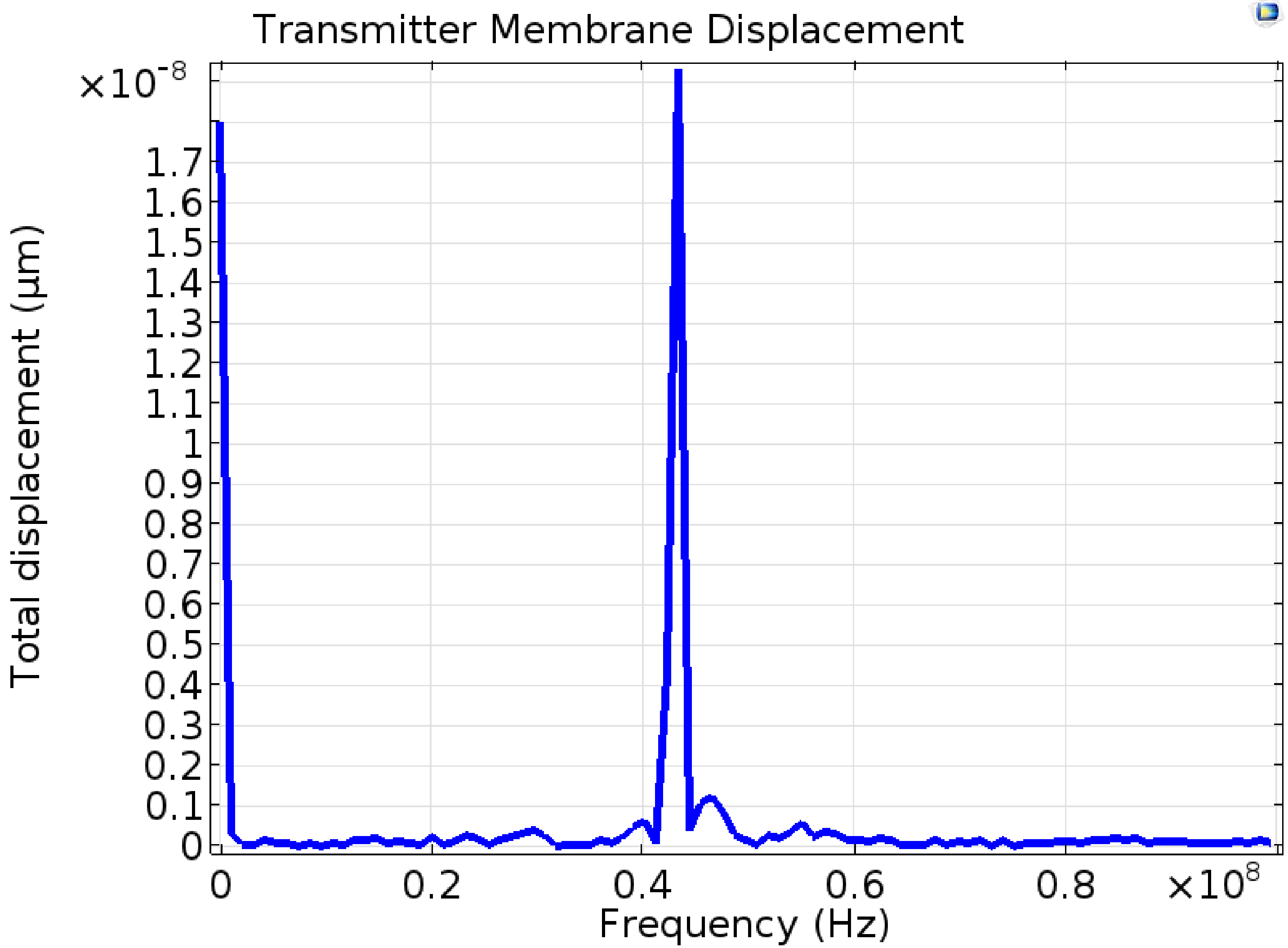
***PHYSICS USED: ELECTROMECHANICS**

ACTUATION OF Tx-CMUT





VOLTAGE APPLIED

V_{DC} = 30 V

V_{AC} = 5 V_{PP}

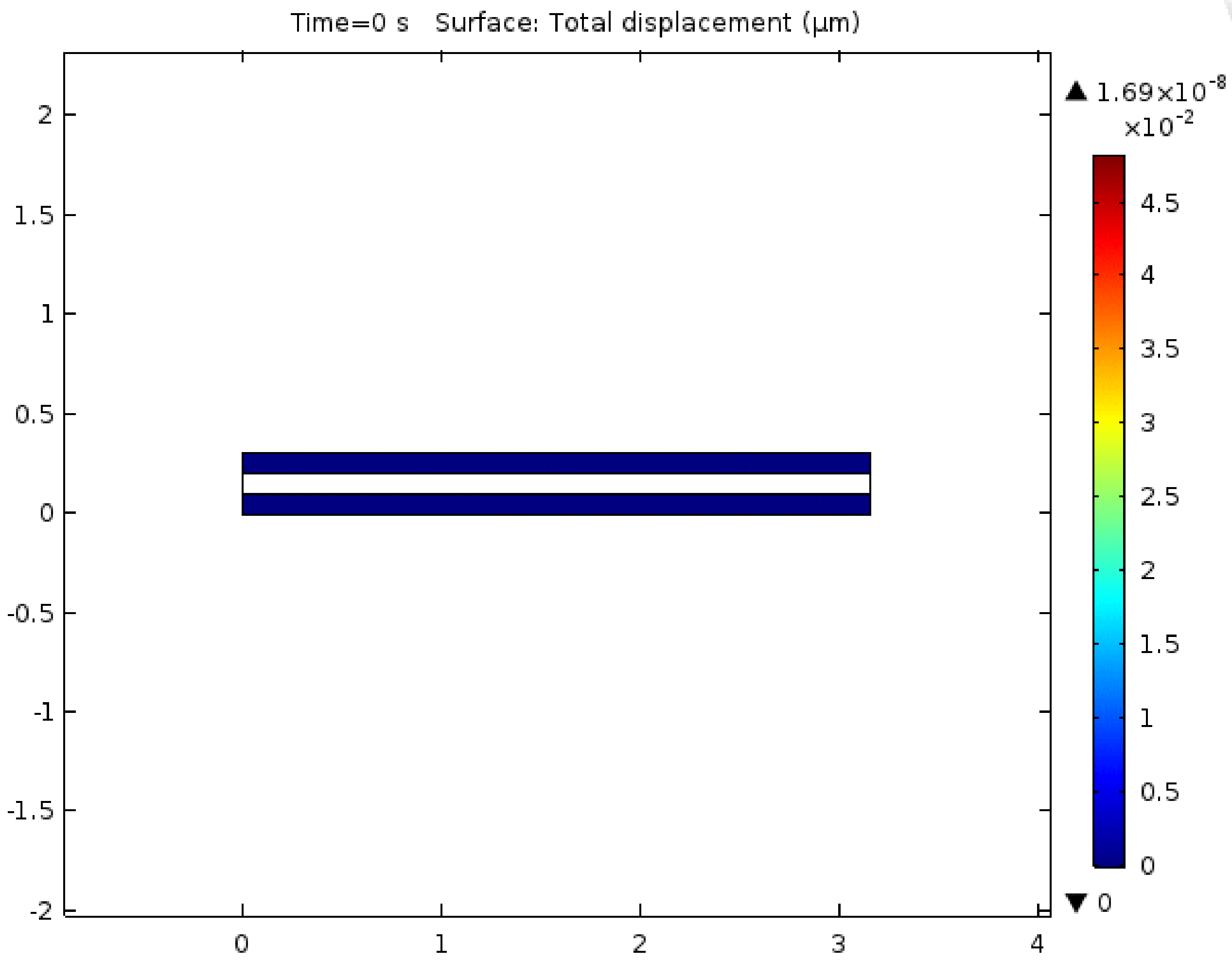
FREQUENCY OF AC SIGNAL: 21.16 MHZ

***PHYSICS USED: ELECTROMECHANICS**

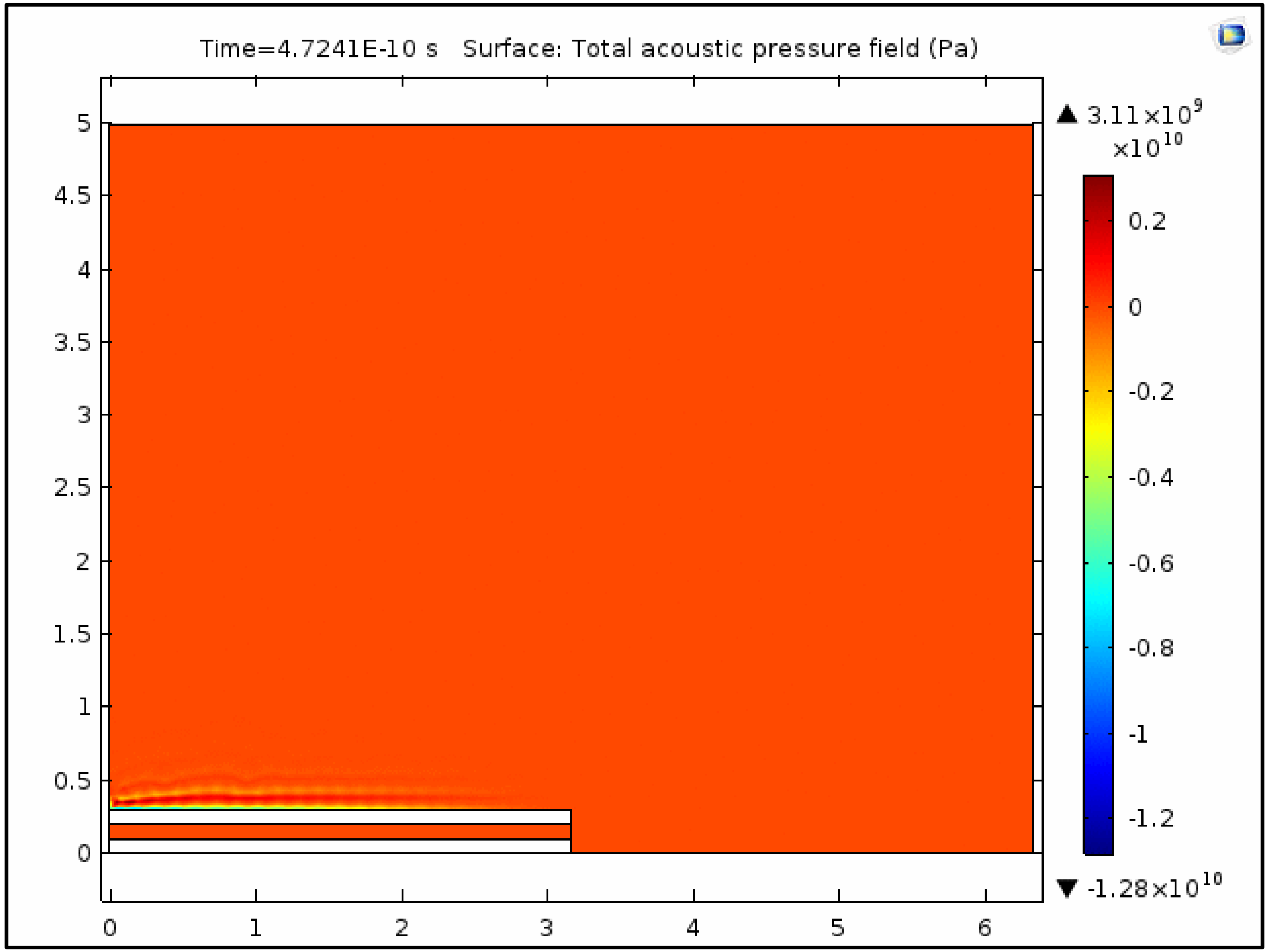
PRESSURE GENERATED BY CMUT

PHYSICS USED: ACOUSTIC STRUCTURE INTERACTION

USED PRESCRIBED DISPLACEMENT AS A FUNCTION OF RADIAL DISTANCE



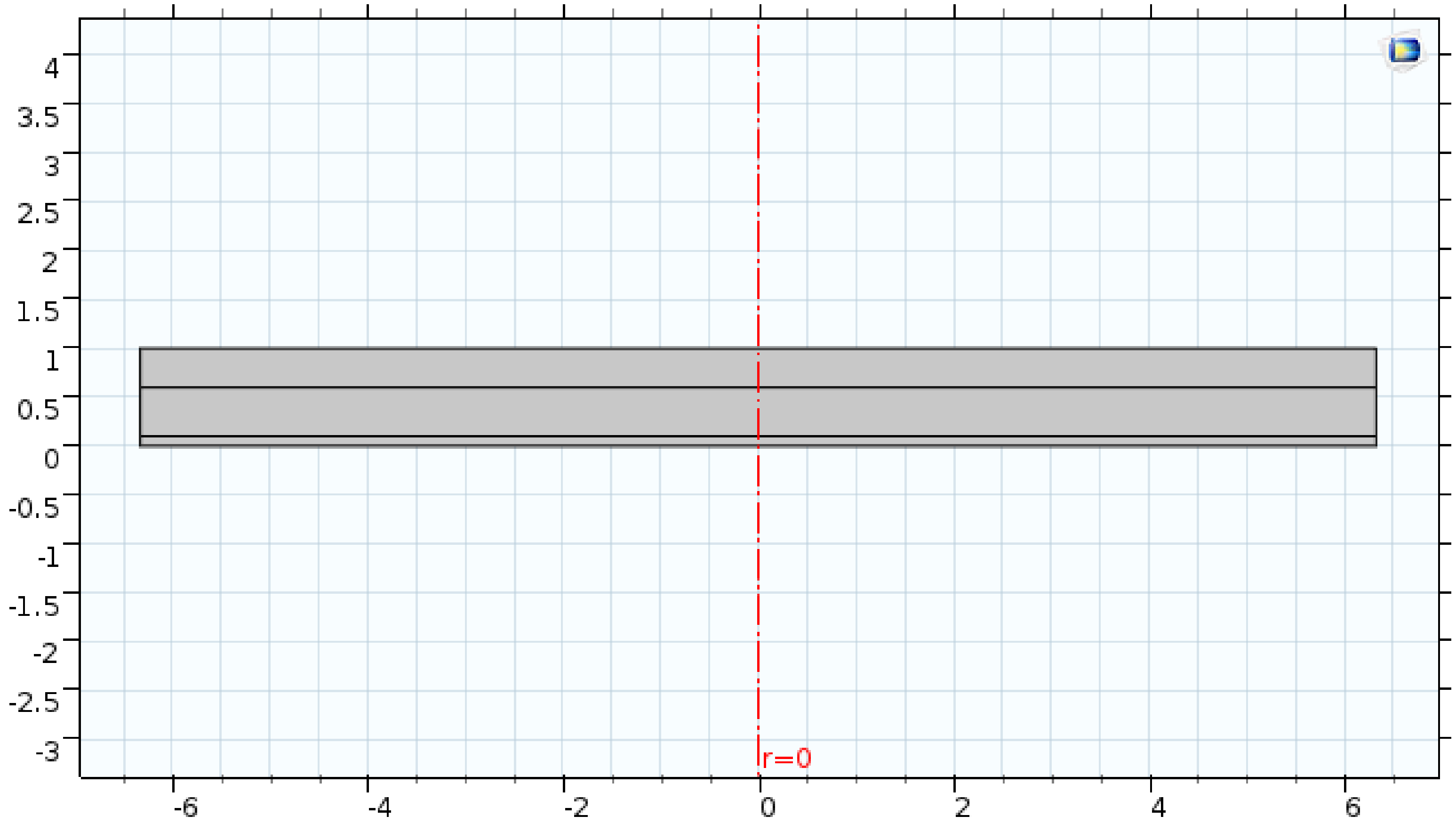
GENERATION OF PRESSURE BY CMUT



Peak Pressure = 10 MPa

*PHYSICS USED: : ACOUSTIC STRUCTURE INTERACTION

VIBRATION OF RECIEVER MEMBRANE WHEN IMPULSE BOUNDARY LOAD IS APPLIED



***PHYSICS USED: SOLIDMECHANICS**

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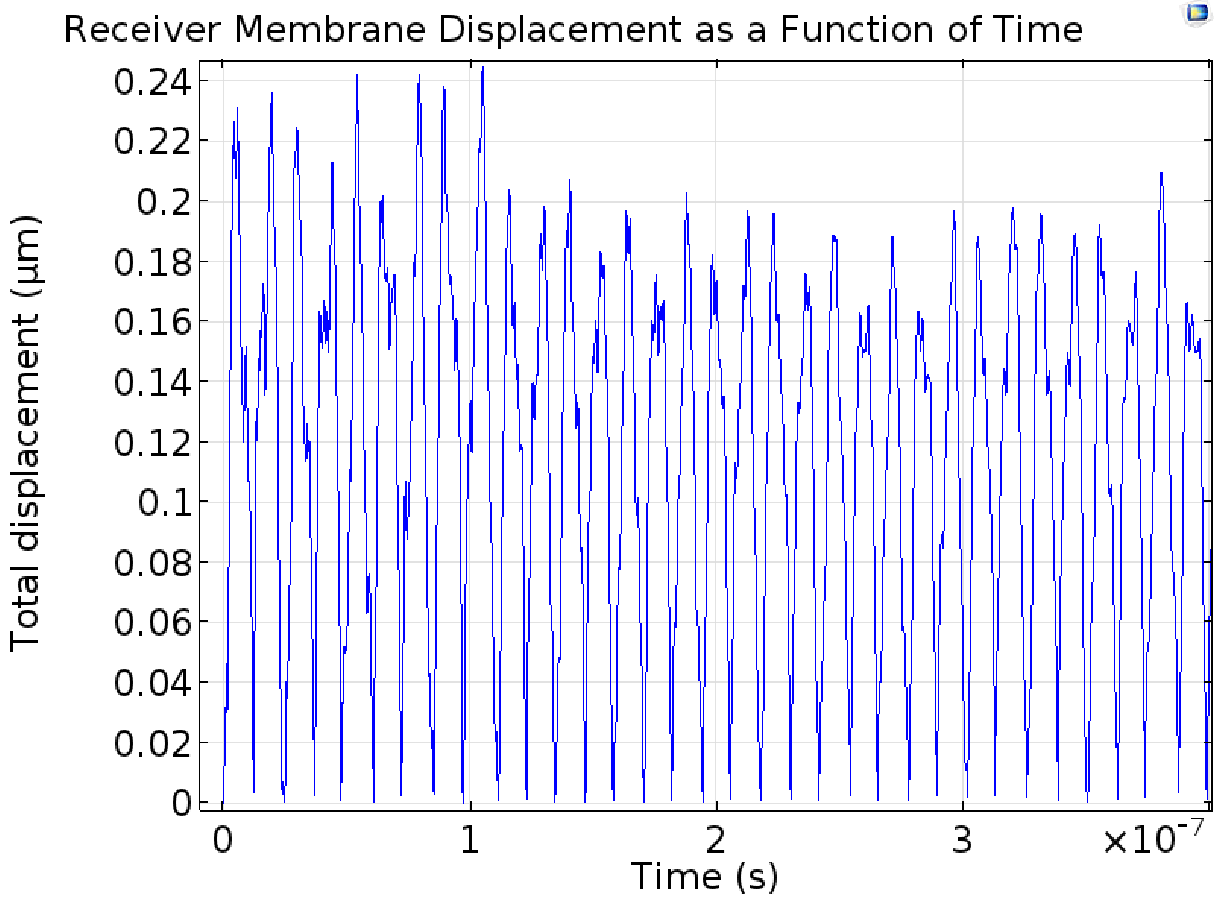
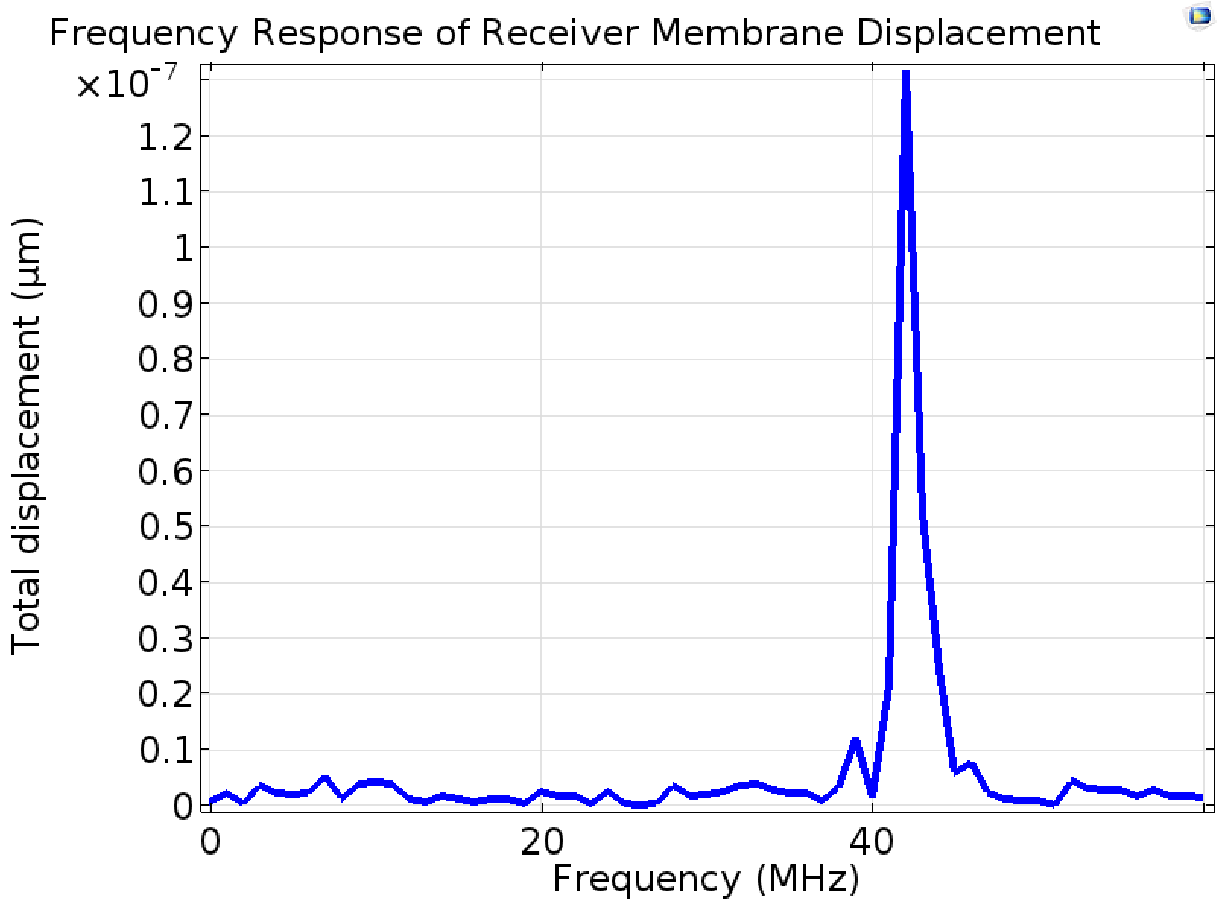
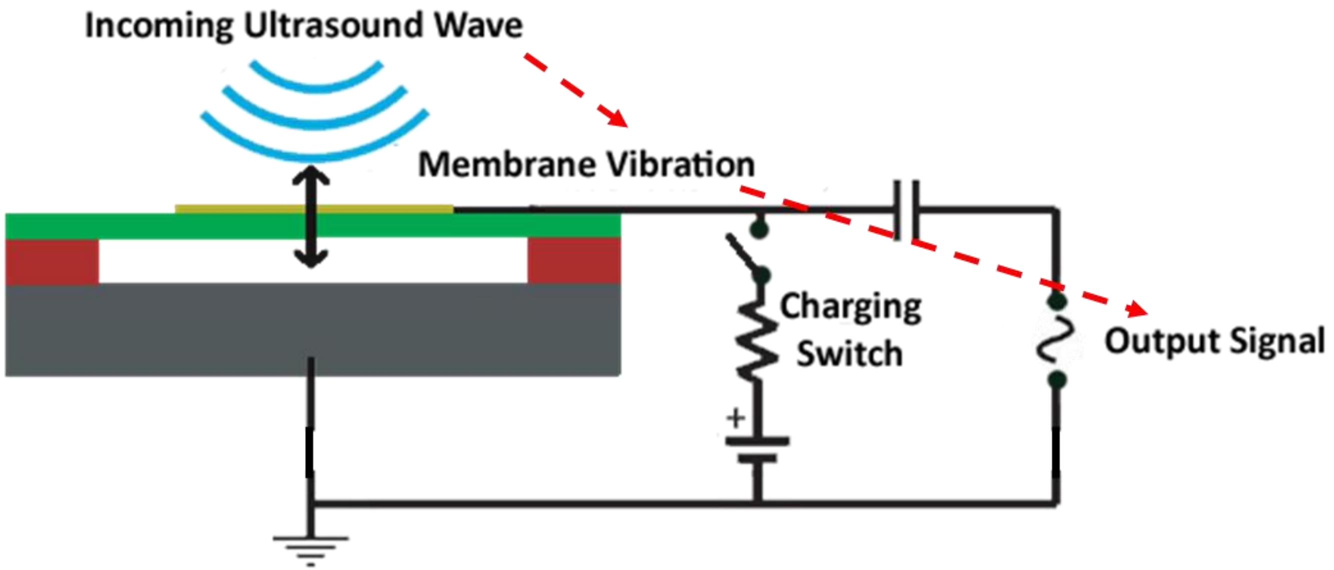




***PHYSICS USED: SOLIDMECHANICS**

OUTPUT SIGNAL SENSING

VOLTAGE APPLIED	10 V
C AT STEADY POSITION	2.23 fF
CHARGE	22.3 fC



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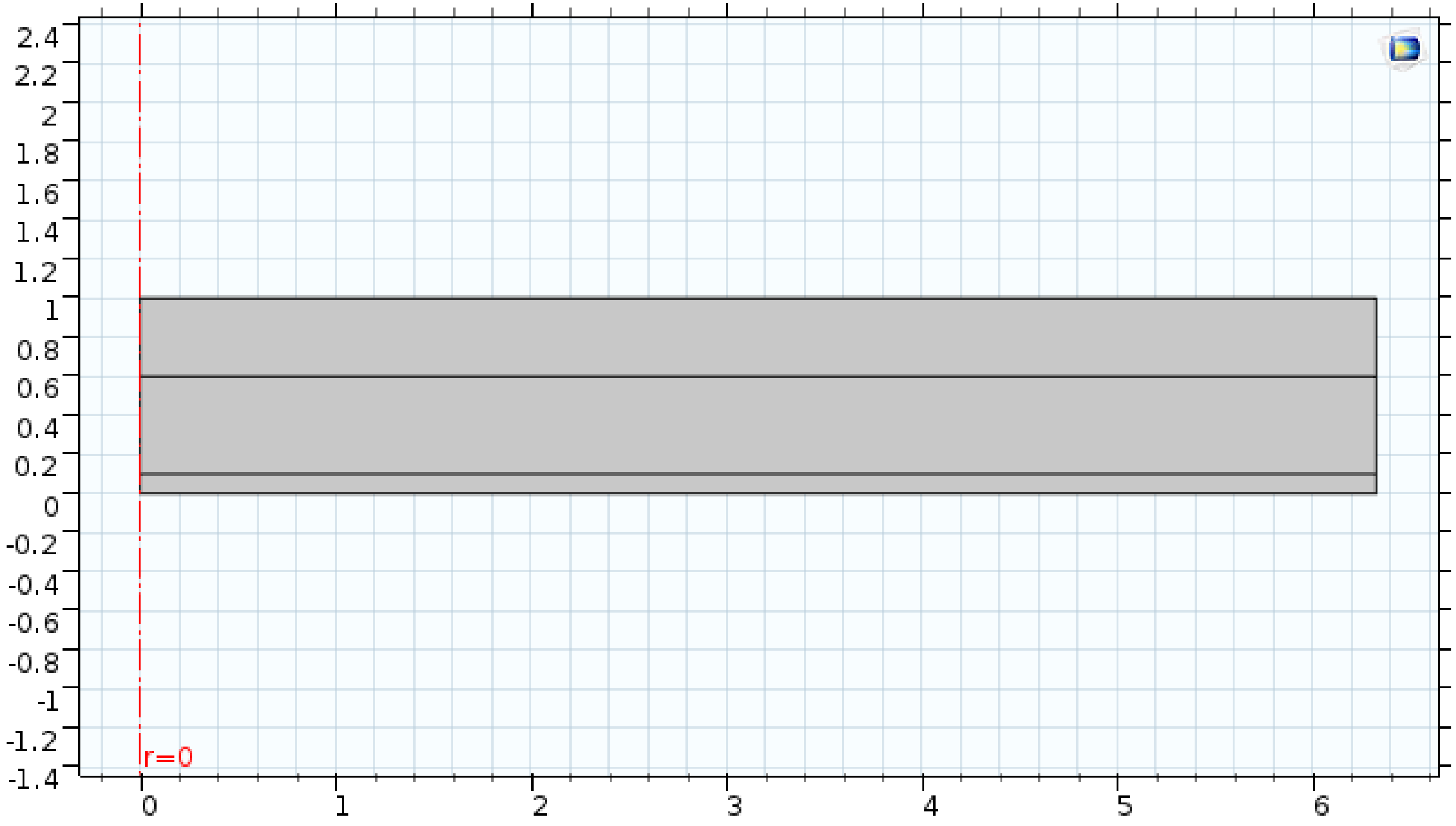
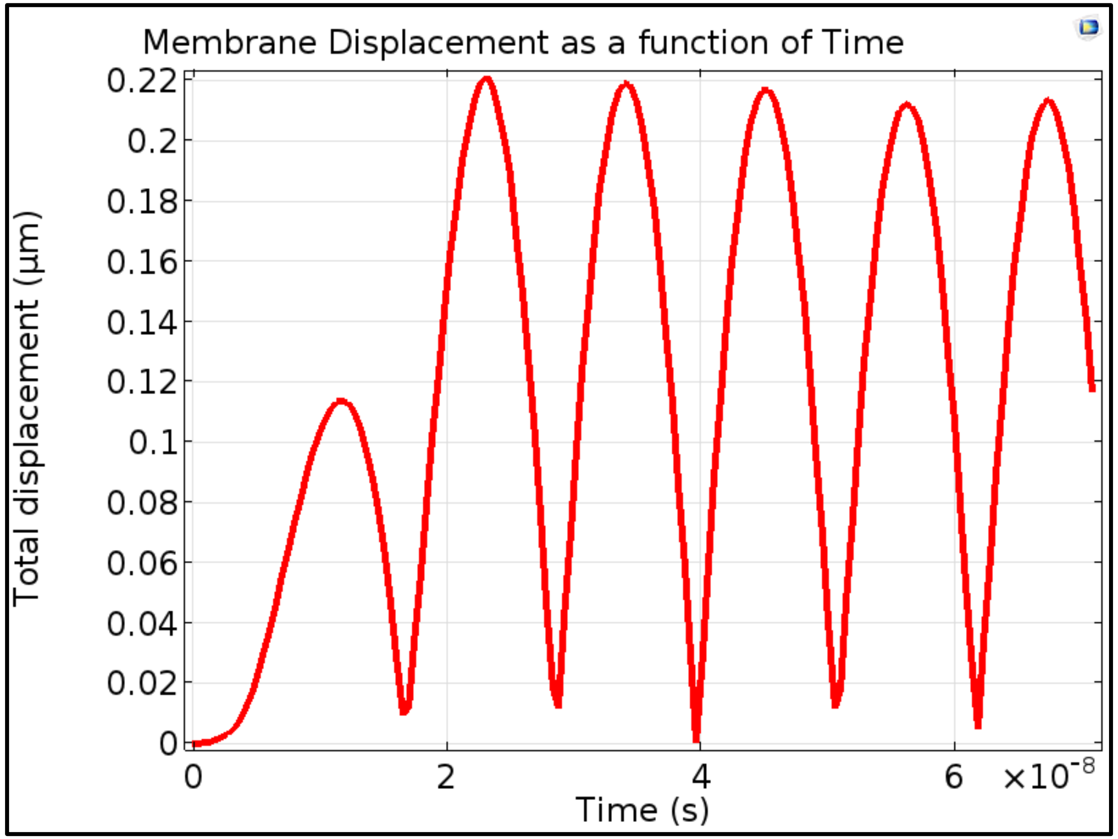


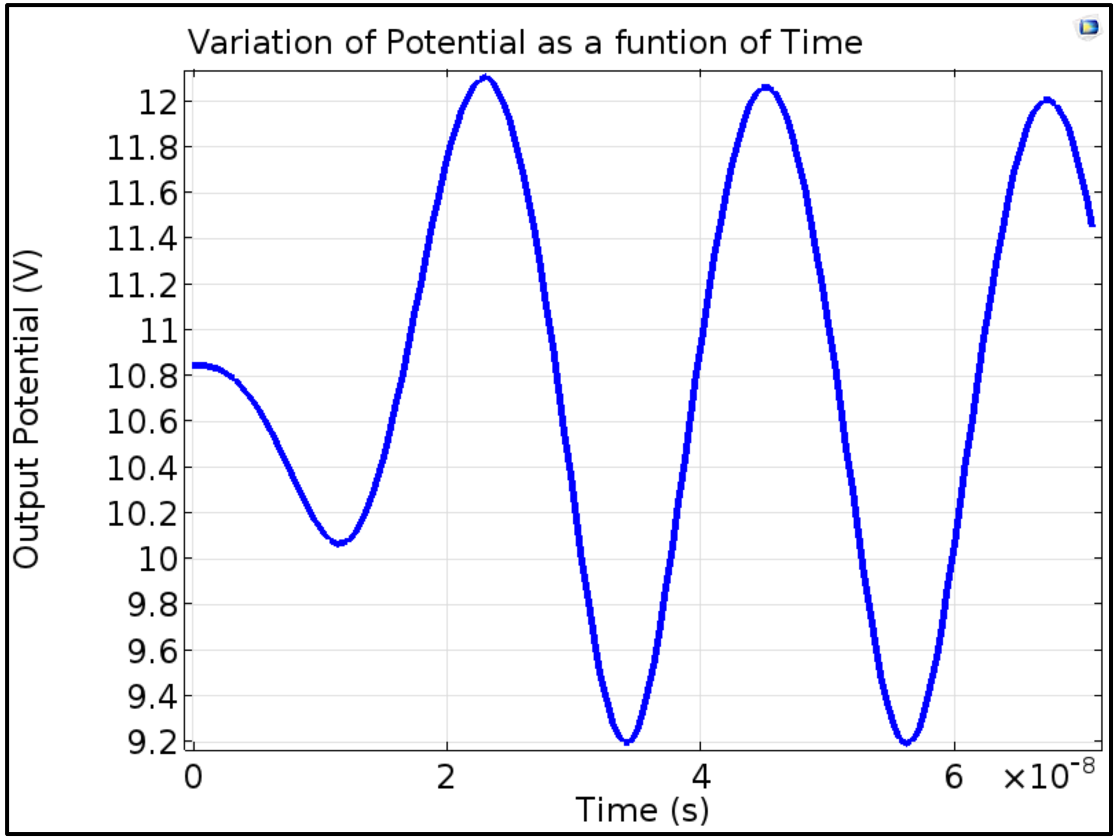
Boundary Load = $10^6 \cdot \sin(\pi F t) * \left(t < {}^{1}/_{F}\right)$

***PHYSICS USED: ELECTROMECHANICS**

VOLTAGE APPLIED	10 V
C AT STEADY POSITION	2.23 fF
CHARGE	22.3 fC

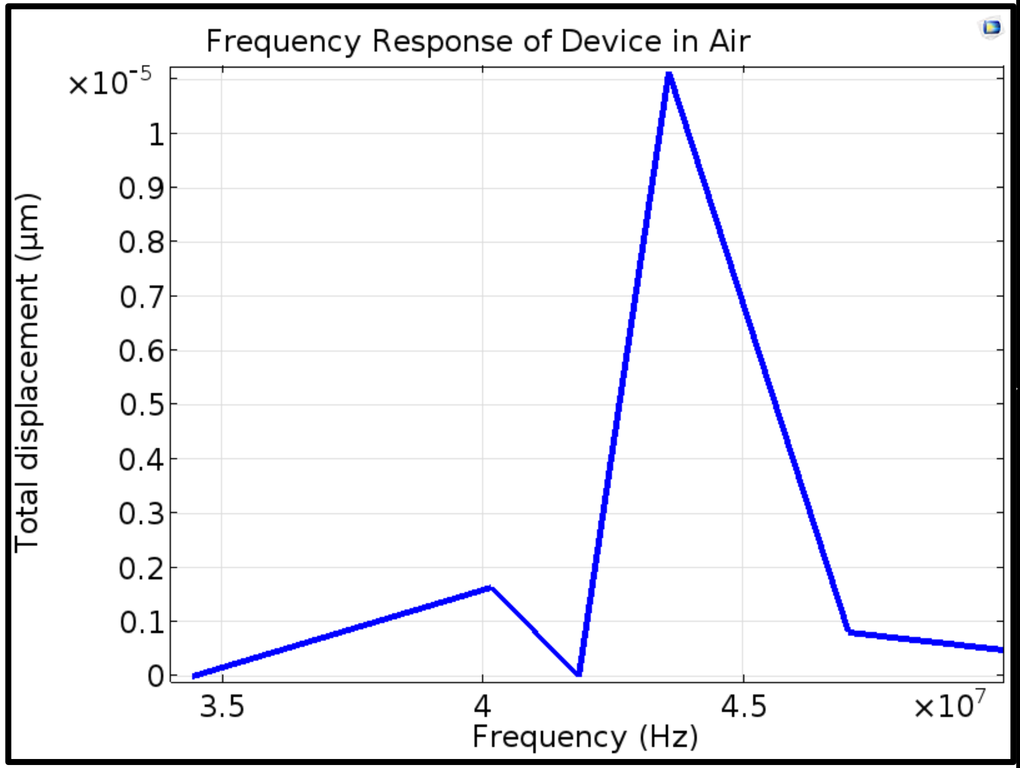
SENSING FROM Rx-CMUT

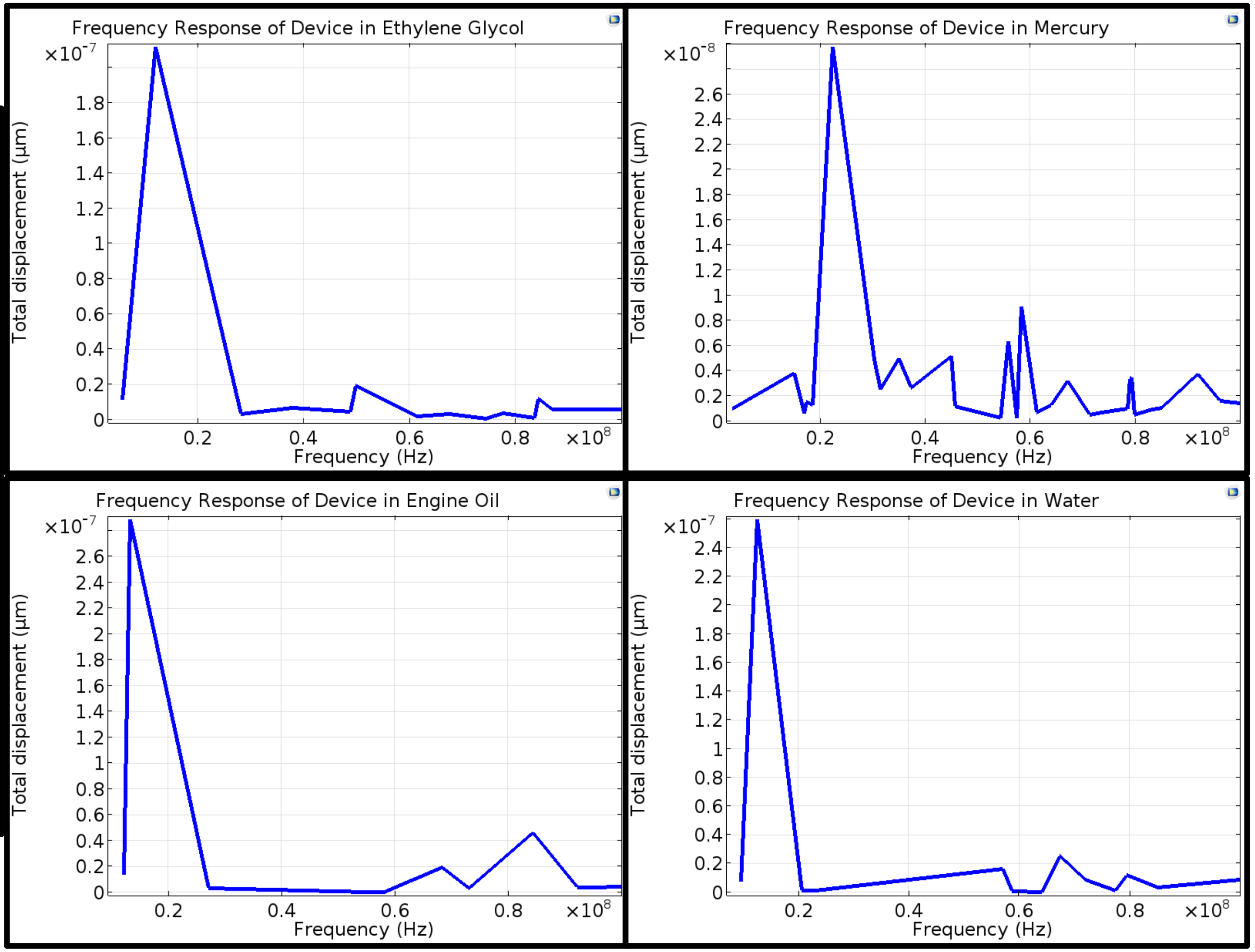




***PHYSICS USED: ELECTROMECHANICS**

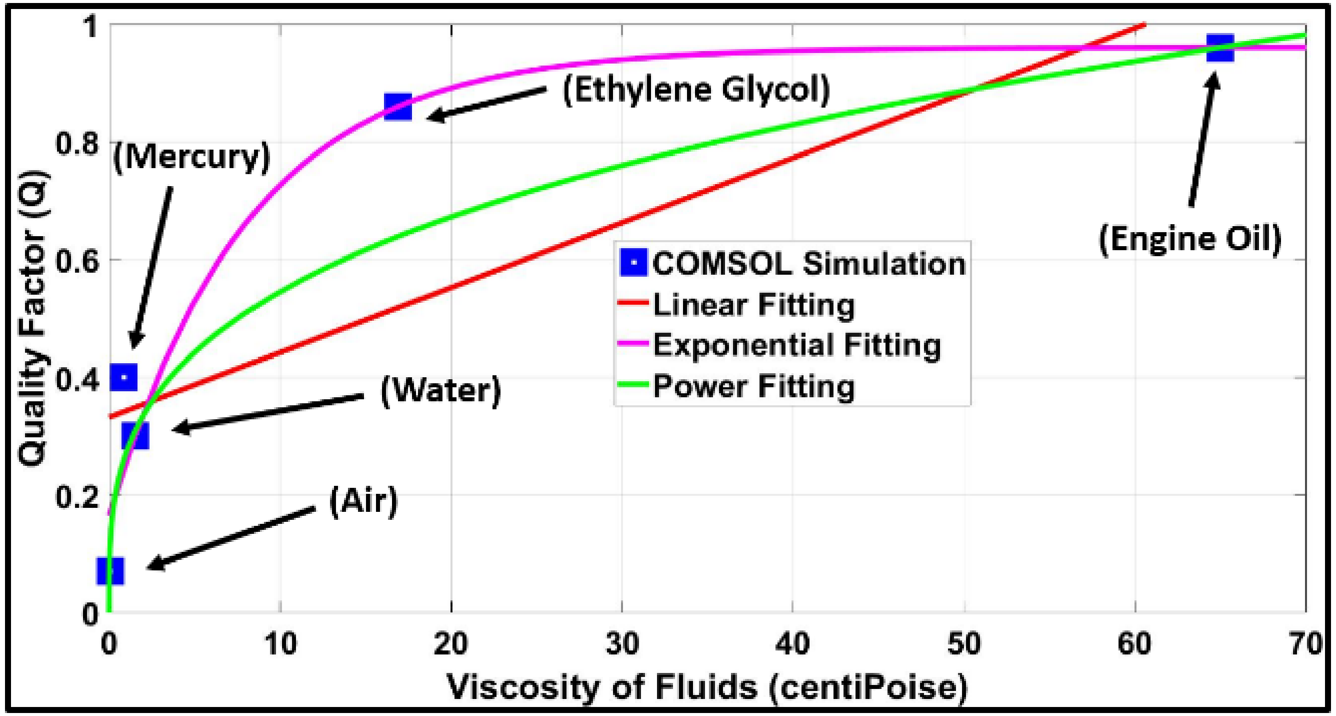
FREQUENCY RESPONSE OF THE RECEIVER CMUT IN DIFFERENT FLUIDS





***PHYSICS USED: SOLIDMECHANICS**

FITTING RESULTS



- Quality factor varies exponentially with the viscosity of fluids which provides efficient sensitivity below the viscosity of 50 cp.

- The method of viscosity sensing can further be improved by improving post processing of the electronic signal.

$$\text{Quality Factor} = \frac{\text{Bandwidth}}{\text{Resonant Frequency}}$$

THANK YOU