MEMS II FEM Project 2020 Spring

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Answer the following questions:

- **What does FBAR stand for?**

  Ans) FBAR Stands for Film Bulk Acoustic Resonator.

- **What acoustic wave is FBAR using?**

  Ans) An acoustic wave is a movement in an elastic medium that travels in space and time, thus transmitting the energy provided by an excitation source to the medium in the form of oscillation or vibration. FBAR uses Longitudinal acoustic wave.

- **How is resonance frequency determined in FBAR?**

  Ans) We can find the resonance frequency by looking at the frequency vs impedance graph at the end of the simulation. The place where impedance is minimum is our resonance frequency. The one more method in finding resonance frequency is by hand calculations. By a formula F=v/2h where h is thickness of piezo film, V is acoustic velocity in longitudinal direction and f is mechanical resonance frequency.

- **What is figure of merit of a resonator in general?**

  Ans) A figure of merit is a quantity used to characterize the performance of a device, system or method, relative to its alternatives. Figure of merit considers different characteristics like RF Loses, Surface resistances and quality factor etc. FBAR resonator has several FOMs of interest for filter design like resistance at parallel resonant frequency Rp, resistance at series resonant frequency Rs, ratio of Rp/Rs and Q as in quality factor.

- **What happens to impedance (Z-parameters) or admittance network (Y-parameters) at series resonance and parallel resonance?**

  Ans) As a parallel resonance circuit only functions on resonant frequency. At resonance, the impedance of the circuit is at its highest and hence suppresses or excludes the current whose frequency is equivalent to its resonant value. At resonance the admittance of the circuit is at its minimum and is equal to the conductance of the circuit.

In Series resonance, impedance is at its minimum at resonance then consequently, the circuits admittance must be at its maximum and one of the characteristics of a series resonance circuit is that admittance is very high.

- **What would the S-parameter look over the frequency?**

Ans) Also called as Scattering Matrix Parameters. S-parameters are complex matrix that show Reflection or Transmission characteristics (Amplitude/Phase) in frequency domain. With knowledge on amplitude and phase, we can measure system's reflection and transmission characteristics.

- **What would the resonator behave like (i.e. resistor, capacitor, inductor) when it is out-band (away from the resonance)? And Why?**

Ans) A resonator is a device that experiences resonance. That is, it oscillates spontaneously at certain frequencies, called resonant frequencies, with a larger amplitude than at other frequencies. Oscillations are limited by the inclusion of resistance, either via a specific resistor component, or due to resistance of the inductor windings. So, when it's out of band a resonator acts as a Resistor by limiting its oscillations.

- **What would change if the area of the FBAR increase?**

Ans) Changing the area changes the resonant frequency, magnitude and few other parameters. Ex. Change in the area of PZE layer either increases or decreases the resonant frequency and impedance changes occur in the device.

- **What is relationship between resonators and filters?**

Ans) A filter is built by resonators. E.g. a combination of filters can contain several resonators. A resonator resonates at certain frequencies related to a wavelength. A filter is a circuit capable of passing (or amplifying) certain frequencies while attenuating other frequencies.

- **In your simulation, what is the purpose to set the "material damping" in "volume BC"?**

Ans) Material damping includes stiffness proportional and mass proportion which depends on material stiffness, young's modulus, damping coefficient and resonance frequency of the structure. Damping materials reduce or eliminate the damaging forces caused by mechanical or electrical energy (i.e., vibrations, movement, or noise). The performance of a damping material depends on the combined characteristics of the material and the environment in which it is used. It is important to choose the best damping material for a specific environment to maximize its performance.

FBAR PROJECT

Read literatures and study basics about FBAR and develop FEM simulations with assigned frequencies following the FBAR tutorial on Canvas. Generate a lab report containing necessary screenshots of important steps and simulated results similar to the tutorial.

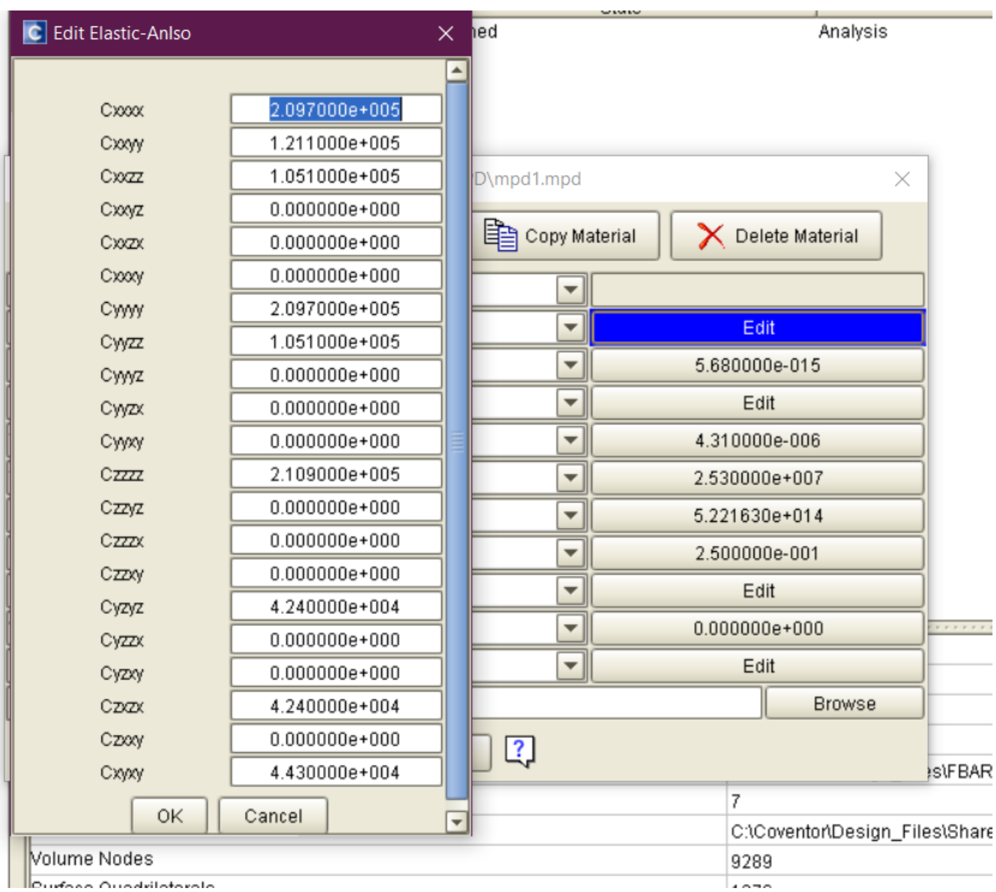
Student Name	Assigned Resonance Frequency
Preetham Ganesh Kamisetty	1.5 GHz

Important Process Steps and Results:

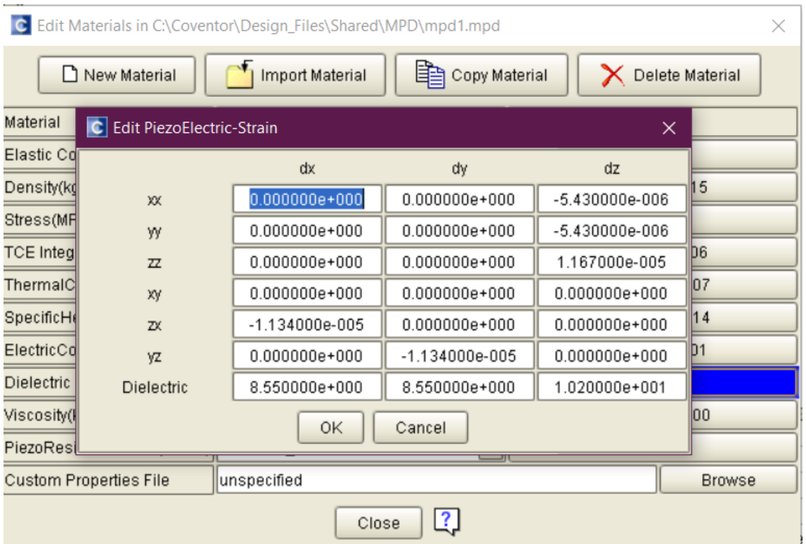
Note: Not all steps are included. Only important and relevant data is provided. PZE layer Used is 1.735microns.

1. Checking 'Zno' properties in MPD Editor.

   A) Elastic Constants



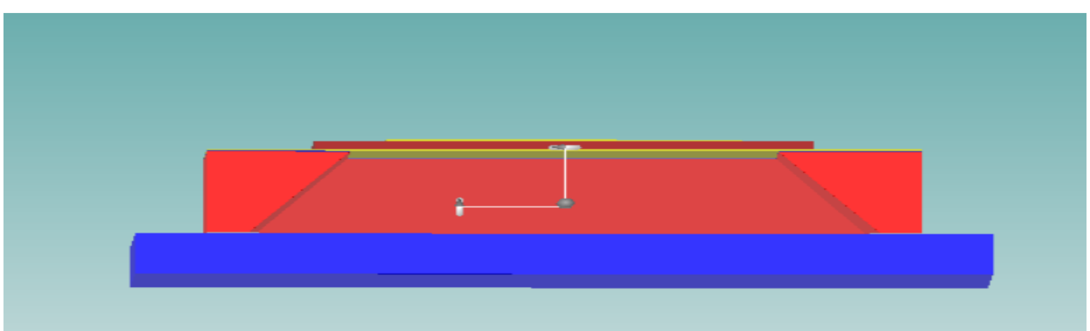
2. B) Piezo Electric- Strain



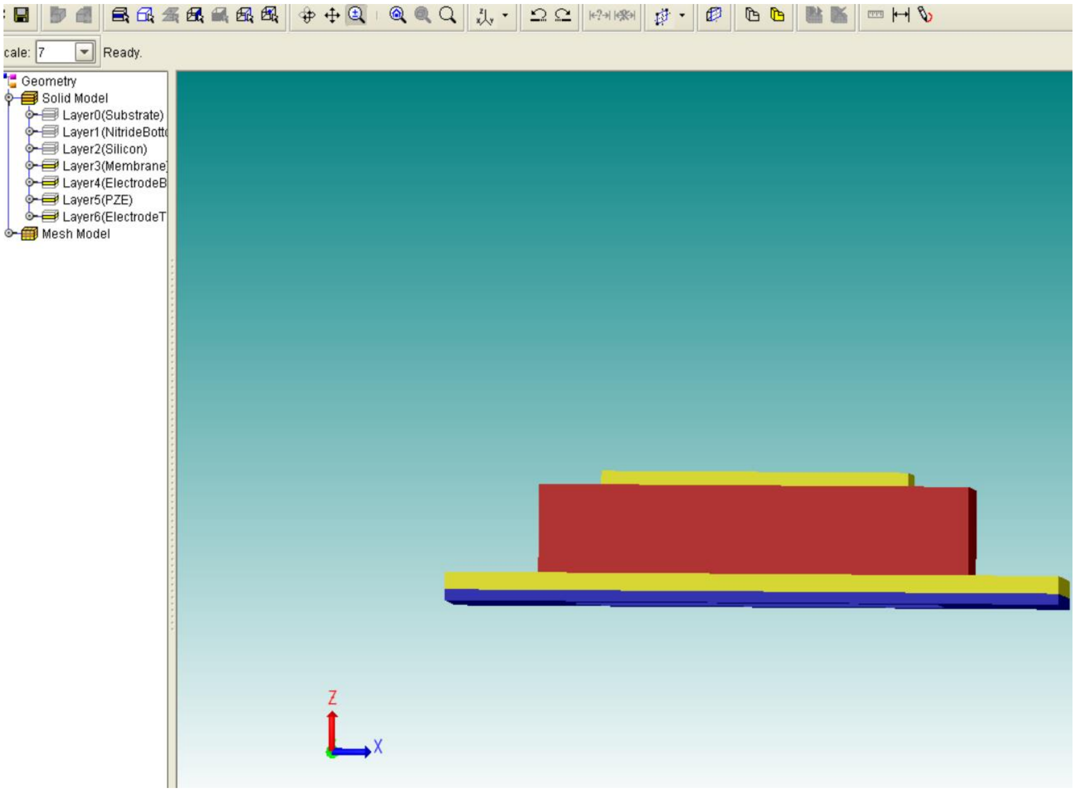
3. Process Steps used to build the Solid Model. As the assigned Frequency is 1.5GHz, the thickness of PZE layer used in 1.735 microns. Build the solid model using the provided layout file.

Number	Step Name	Layer Name	Material Name	Thickness	Mask Name	Photoresist	Depth	Mask Offset	Sidewall Angle
0	Substrate	Substrate	SILICON_100	10	SubstrateMask				
1	Stack Material	NitrideBottom	SIN	0.25					
2	Straight Cut				Nitride	-		0	0
3	Stack Material	Silicon	SILICON_100	20					
4	Straight Cut				KOH_Etch	-		0	35.3
5	Stack Material	Membrane	SIN	0.25					
6	Straight Cut				KOH_Etch	-		0	0
7	Stack Material	ElectrodeBottom	ALUMINUM_FILM	0.4					
8	Straight Cut				ElectrodeBot	+	20.9	0	0
9	Stack Material	PZE	ZnO	1.735					
10	Straight Cut				PZE	+		0	0
11	Stack Material	ElectrodeTop	ALUMINUM_FILM	0.32					
12	Straight Cut				ElectrodeTop	+		0	0

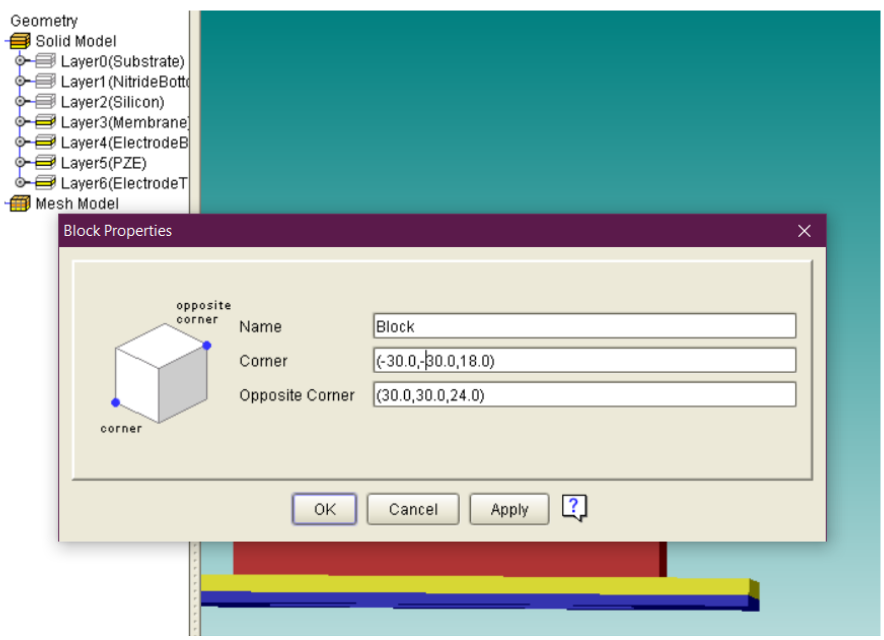
4. The cross-section of the 3d-Model constructed using the above process steps.



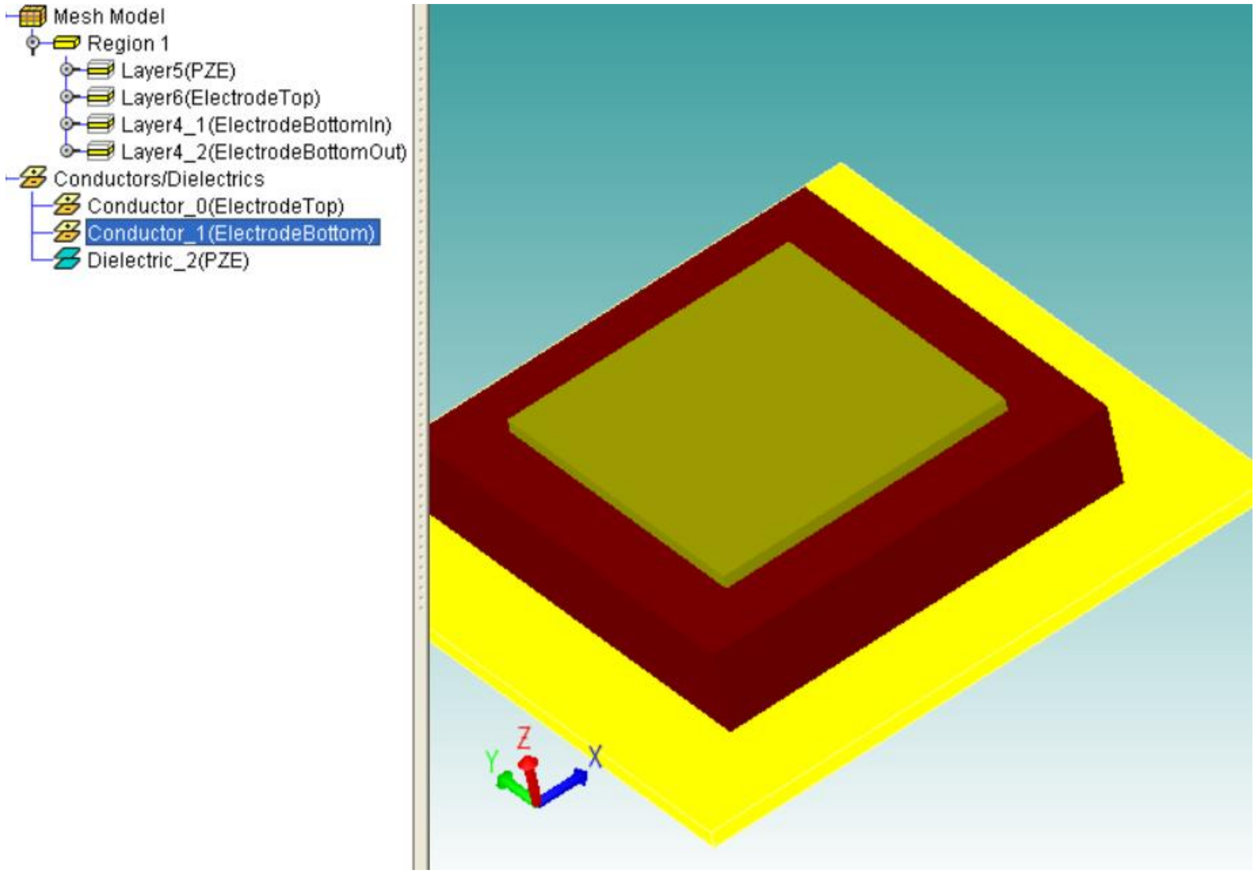
5. Hide the Nitride Bottom, Substrate and Silicon Layers.
   Set the Z scale to 7.



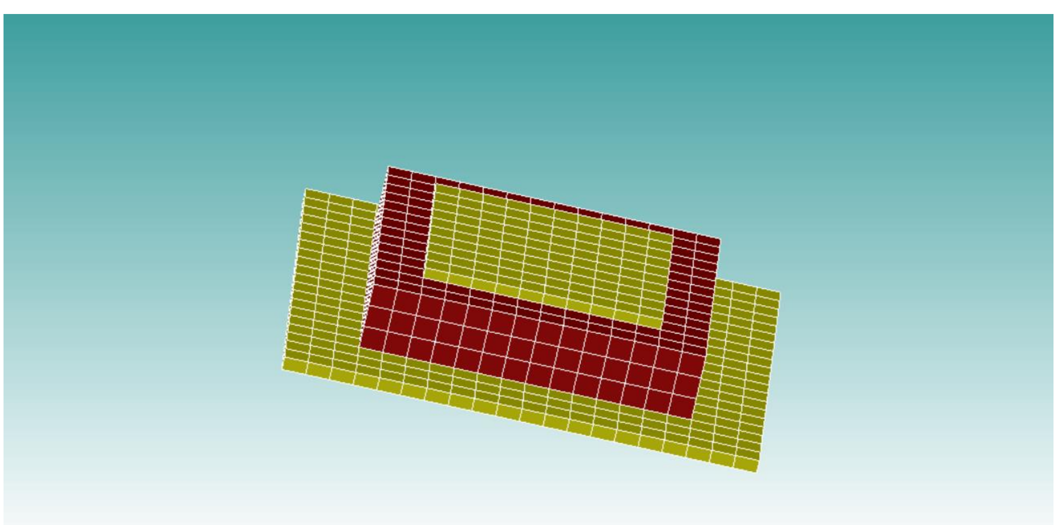
6. Create a Block with the below given coordinates.



7. Select the block and Electrode layer and partition them. After Partition, delete the block and Assign the names as below.

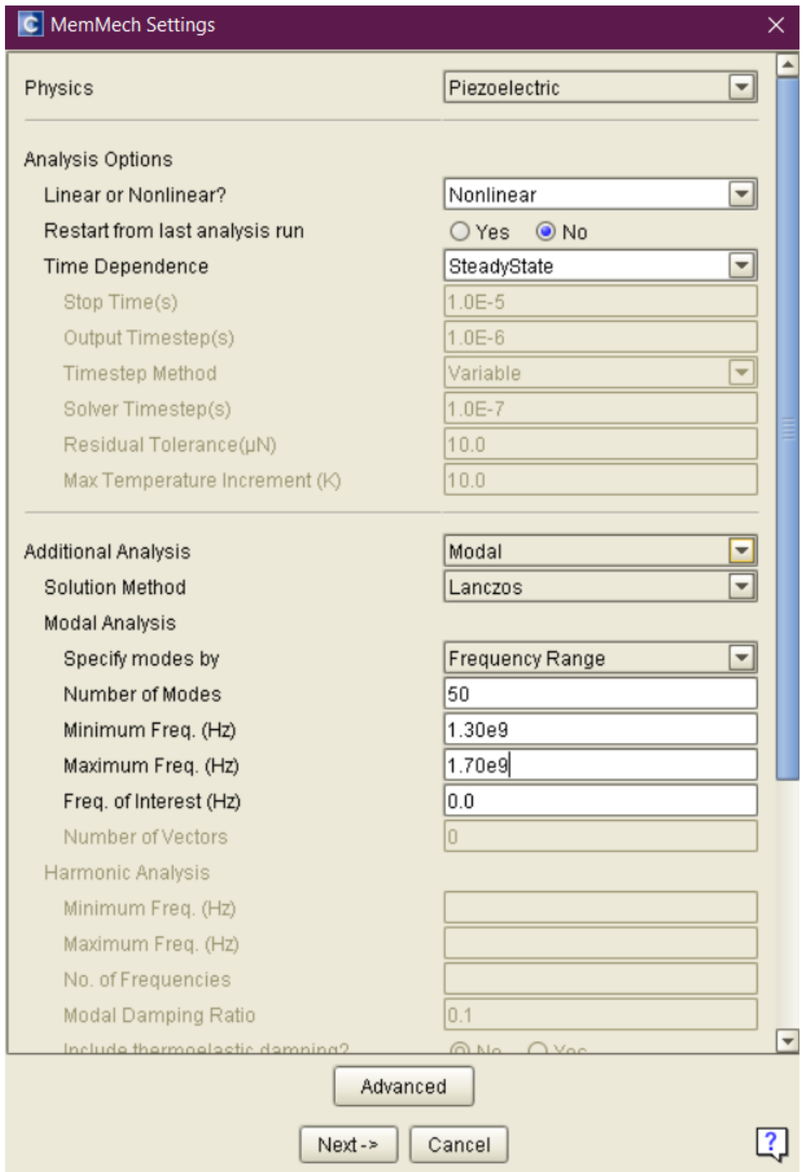


8. Open Mesher settings and put 5,5,0.6 values in X,Y and Z directions. Generate the Mesh. Below is the meshed 3d- Model.

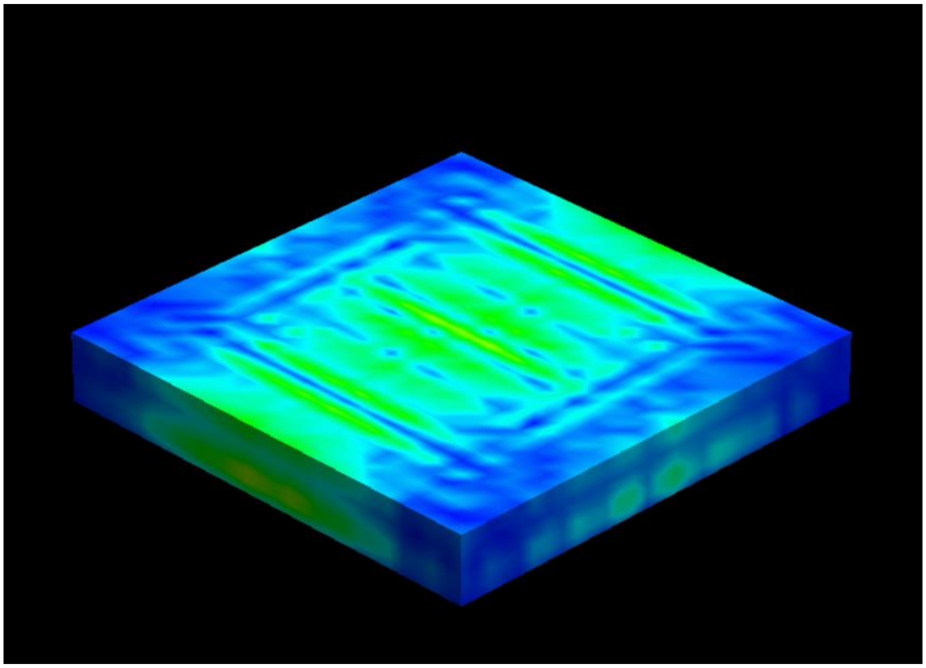


Analysis on the created Model:

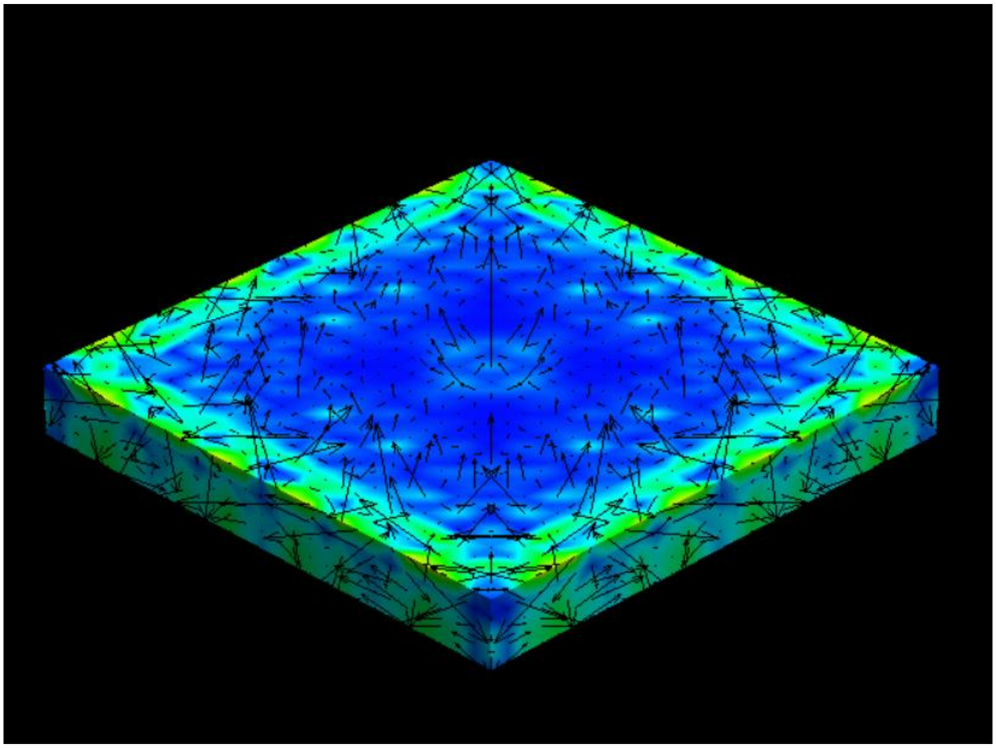
1. Use MEMMECH and apply the ranges as shown below.



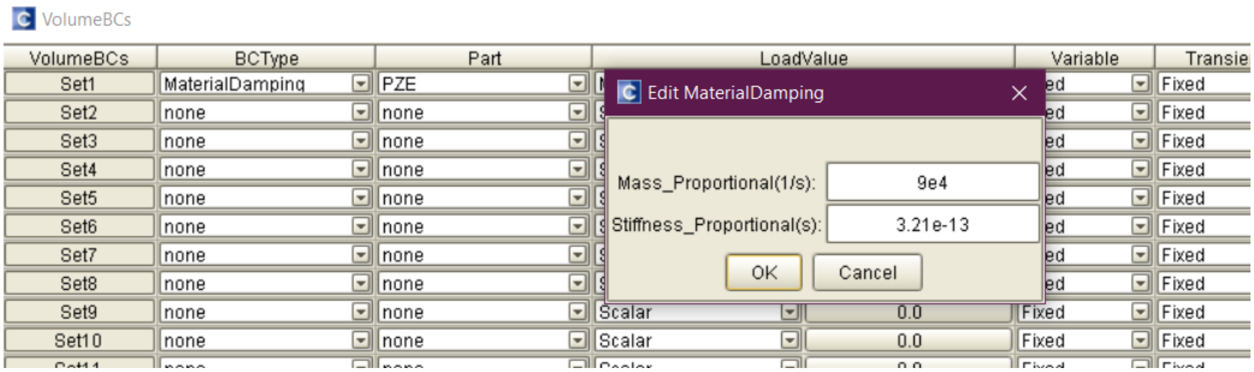
2. In surface BC's, fix all the Fix part of the Model and apply Potential fix type to pzbot and pztop patches. Run the analysis. After completion, view the 3d results. Below shown figure is displayed after hiding all the parts except PZE layer.

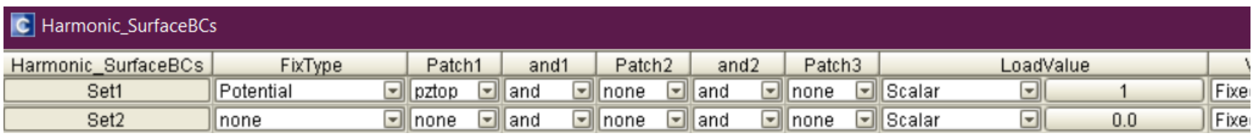


3. Model Shape results after applying Vectors to the above model.

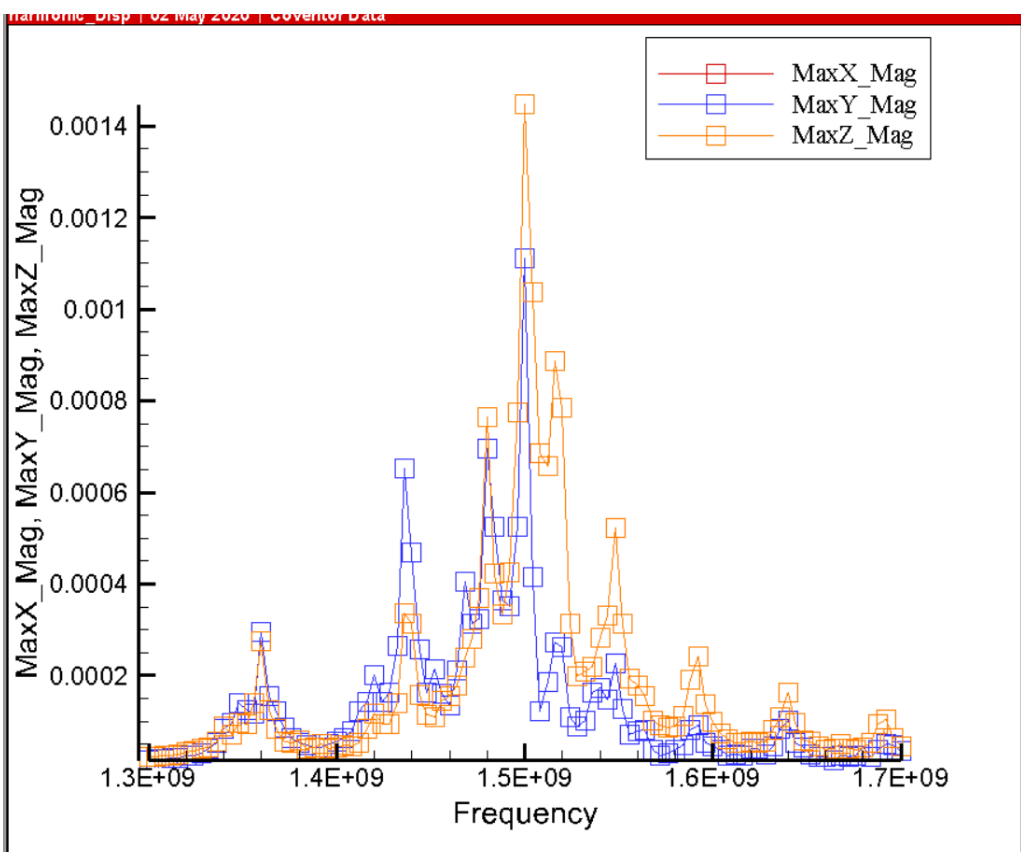


4. The final step in analysis is estimating the displacement and impedance variation with signal frequency. Click on the solver setting and changing the analysis to " Direct Harmonic" and apply the below conditions.





5. Run the simulation and check the "harmonic Displacement" graph. In the visibility, just make the below lines visible.



6. Open “Harmonic Patch Charge” graph. In the Data settings, Specify the below equation

   {Omega}=2*PI*{Frequency}
   {Q_Re}={pztop_Q_Mag}*Cos({pztop_Q_Phase}*PI/180)
   {Q_Im}={pztop_Q_Mag}*Sin({pztop_Q_Phase}*PI/180)
   {Z_Re}= -1e12/{Omega}*{Q_Im}/({Q_Re}**2+{Q_Im}**2)
   {Z_Im}=-1e12/{Omega}*{Q_Re}/({Q_Re}**2+{Q_Im}**2)
   {Z_Mag}=sqrt({Z_Re}**2+{Z_Im}**2)
   {Z_Phase}=180/PI*atan2({Z_Im},{Z_Re})

   Click on compute and close the dialogue box.

7. Now just make one of the line visible and change the Y axis variable to Z_mag. Now in the axis settings make the Y-axis use LOG Scale. Which thus gives us the final result.