Implementation of Time Based 3-Axis Capacitive Accelerometer using COMSOL Multiphysics

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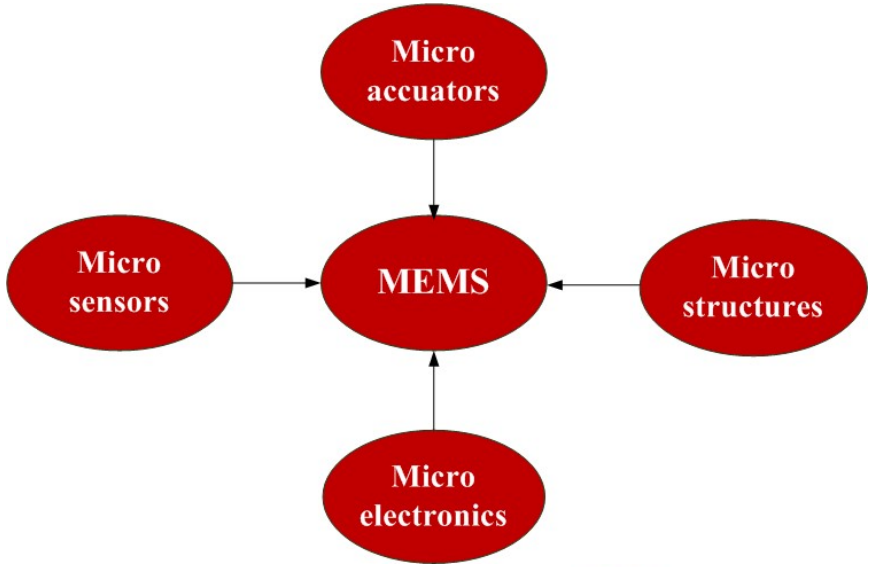
Introduction

- Accelerometer is an **electromechanical device** that measures **change in velocity or force of acceleration** caused by gravity or movement over time.
- Most of them are Micro-Electro-Mechanical-Sensors (**MEMS**) devices.
- Most commonly used capacitive sensing accelerometers have an edge over the piezoresistive accelerometers in terms of **less power, less temperature sensitivity and lower fundamental noise**.
- This model performs an analysis of a hypothetical sensor design using the **electromechanical interface of COMSOL**.

MEMS

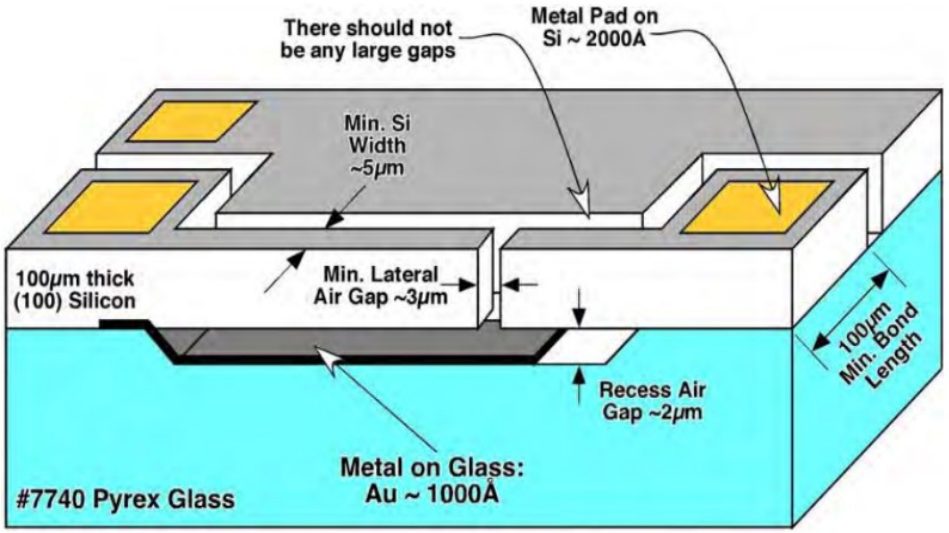
- Micro-electro-mechanical system (MEMS), simply can be understood as a miniature device or an array of devices combining electrical and mechanical components and fabricated with integrated circuit (IC) batch processing techniques.

  Eg: sensors, actuators, and micro electronics, that are made using various methods of fabrication.



MATERIALS REQUIRED

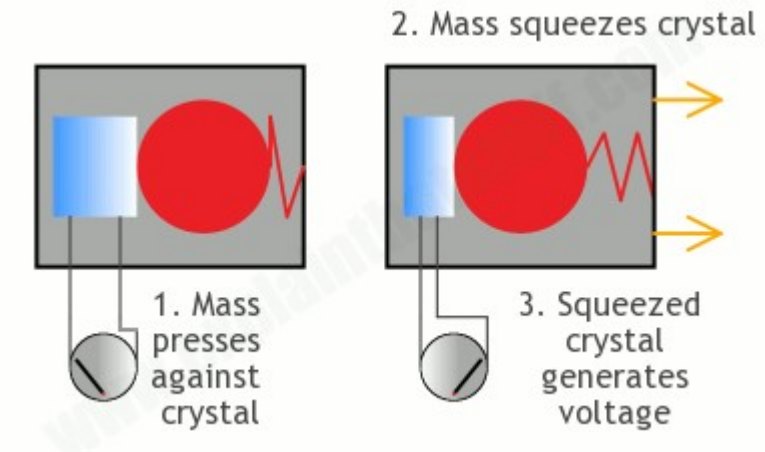
- The choice of good material is based on the **mechanical aspect**.
- This design of MEMS capacitive accelerometer mainly uses **silicon and silicon compounds.**
- It has **no elasticity limit** at room temperature.
- Silicon possesses some unique properties like Quartz crystal, glass, polymers, metals etc.



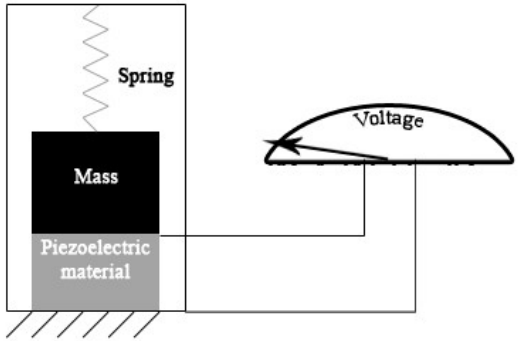
Accelerometer Fundamentals

Types of ACCELEROMETER

1. Piezoelectric Sensor
   - Acceleration applied on sensor deforms the crystal.
   - It is directly proportional to the force.



2. Piezoresistive Sensor
   - Change in mechanical stress results in change of material resistivity.



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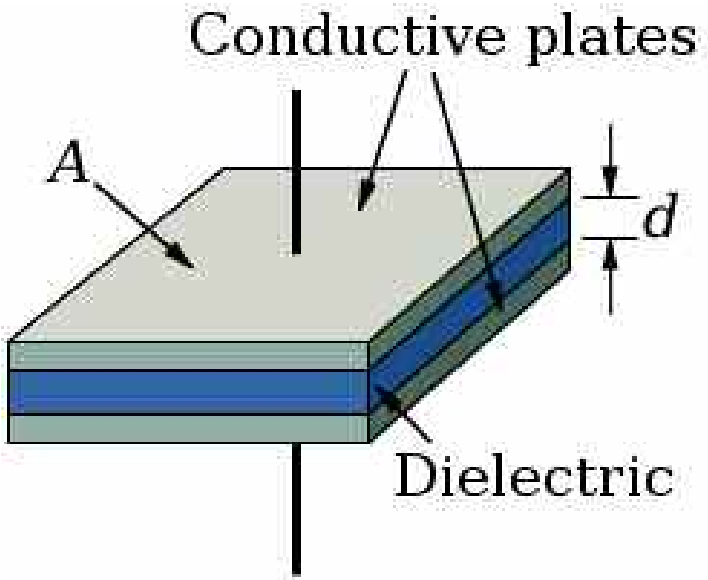
Accelerometer Fundamentals

3. Capacitive Sensor

- Senses the displacement of proof mass.
- Gives output voltage that is dependent on the distance between the two capacitive plates.
- Accuracy and stability are the important feature.



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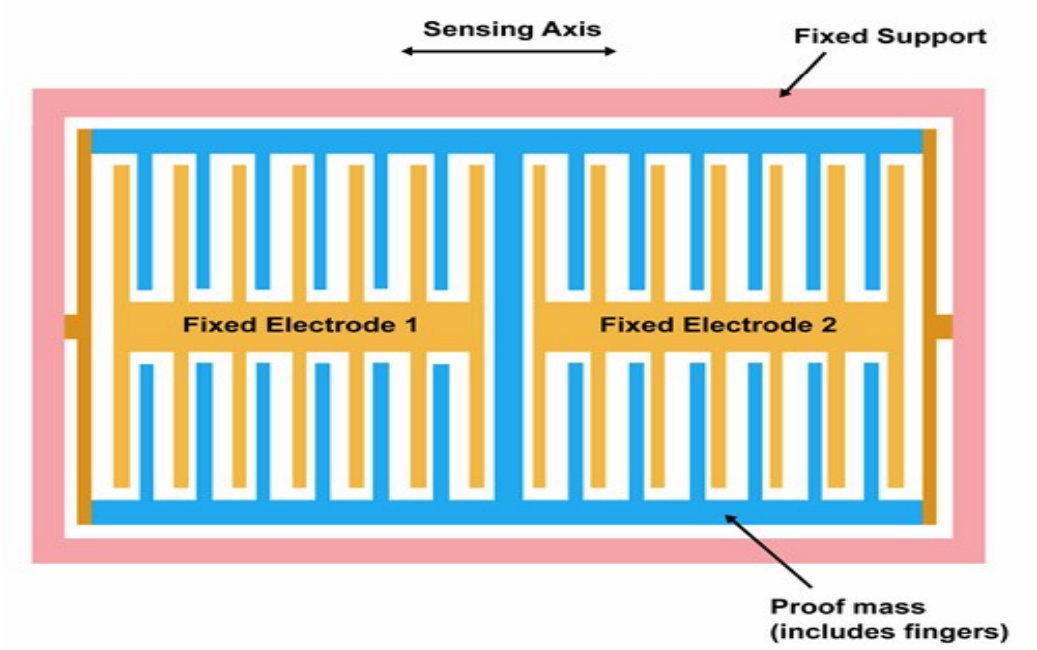
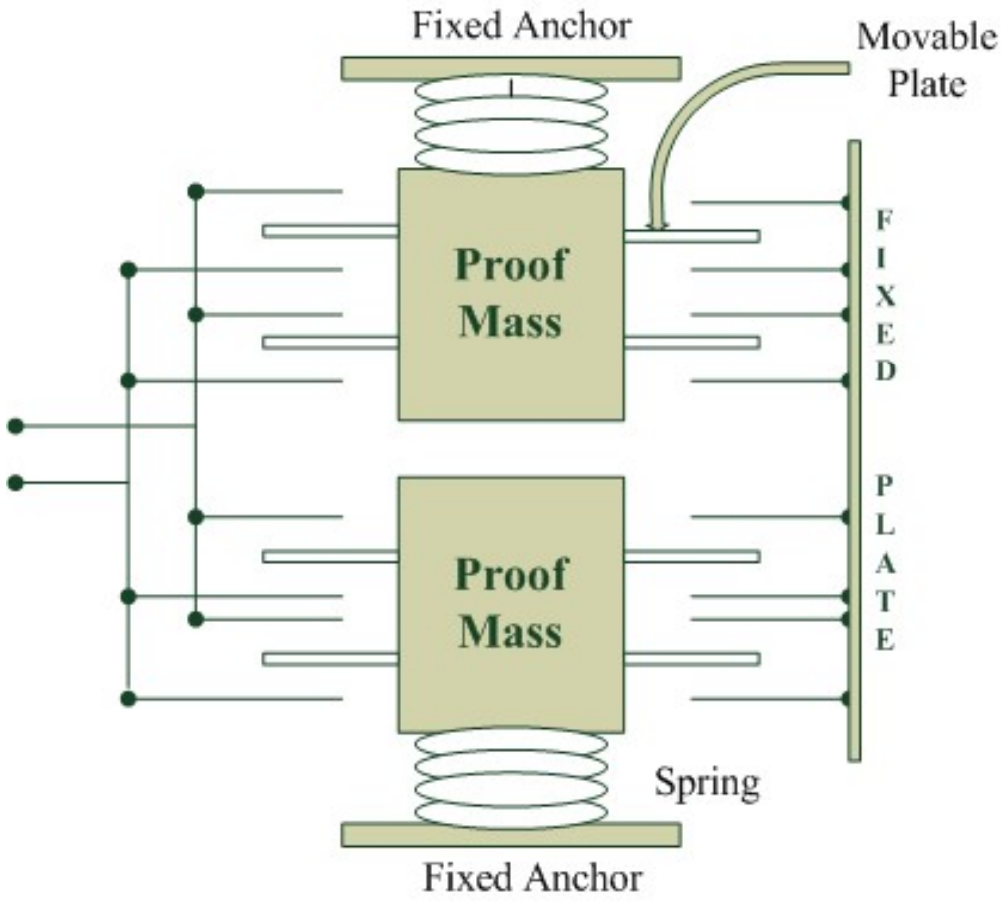
2-axis capacitive accelerometer

- It consists of a **proof mass** connected to a mechanical suspension system and to a **reference frame**.
- When acceleration is applied, the proof mass moves accordingly which **changes the distance between the capacitive plates**.
- The voltage sensed due to capacitance is used to **sense the acceleration.**

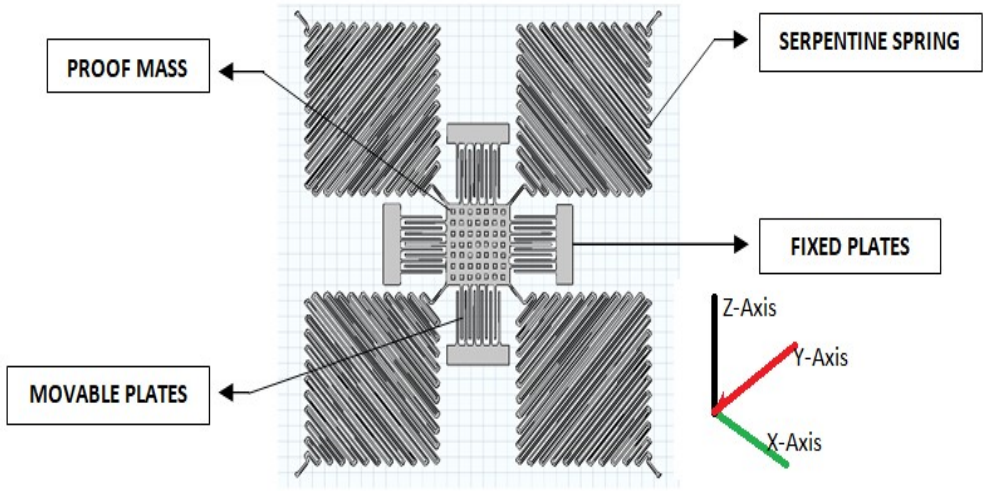


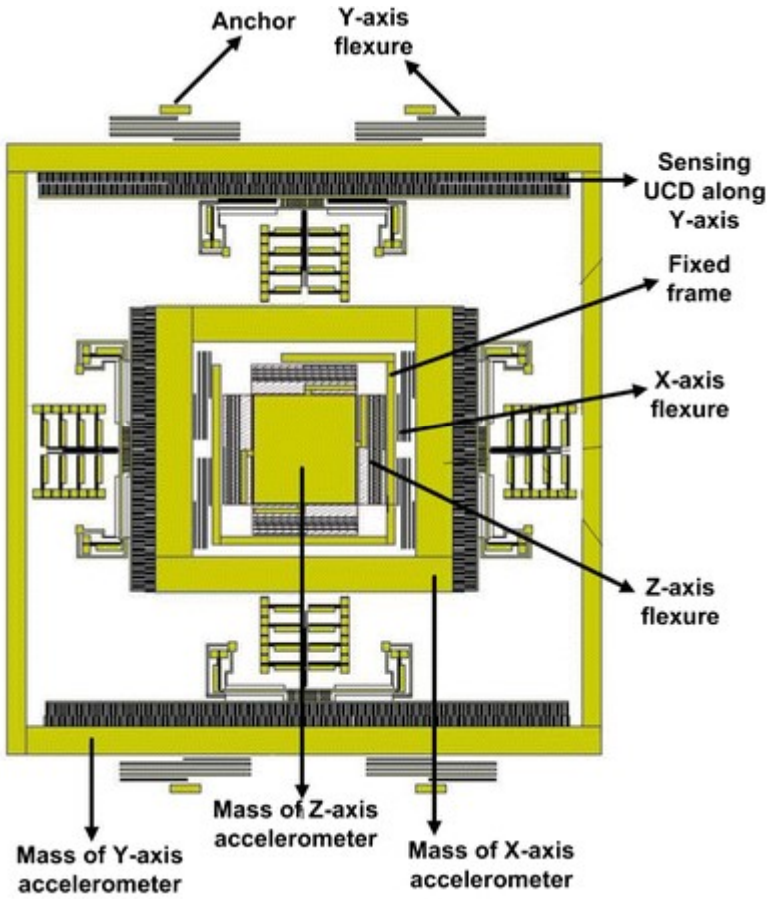
2-axis capacitive accelerometer



3-axis capacitive accelerometer

- It is constructed using **surface micromachining** process.
- Measurement of z-axis acceleration is using a differential **teeter-totter arrangement**.





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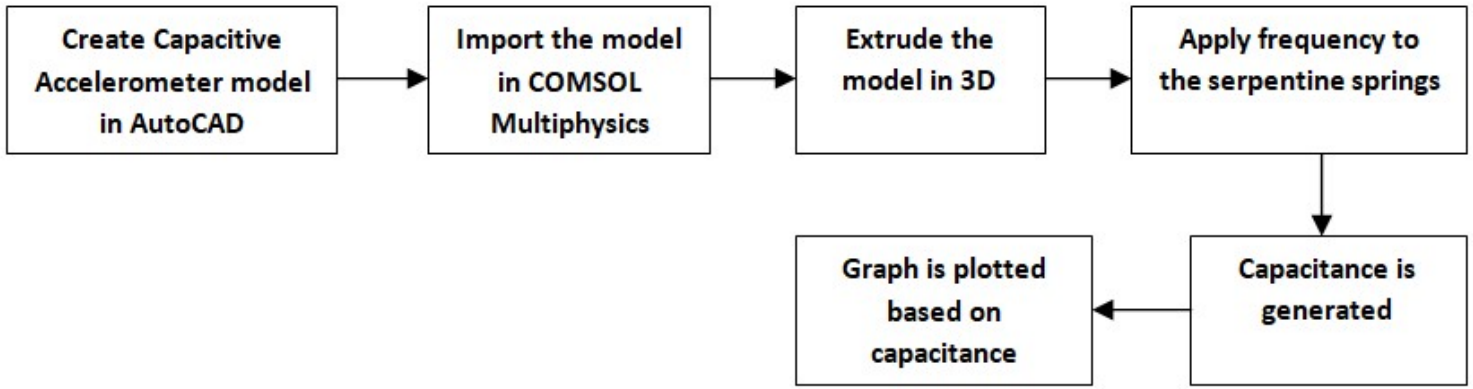
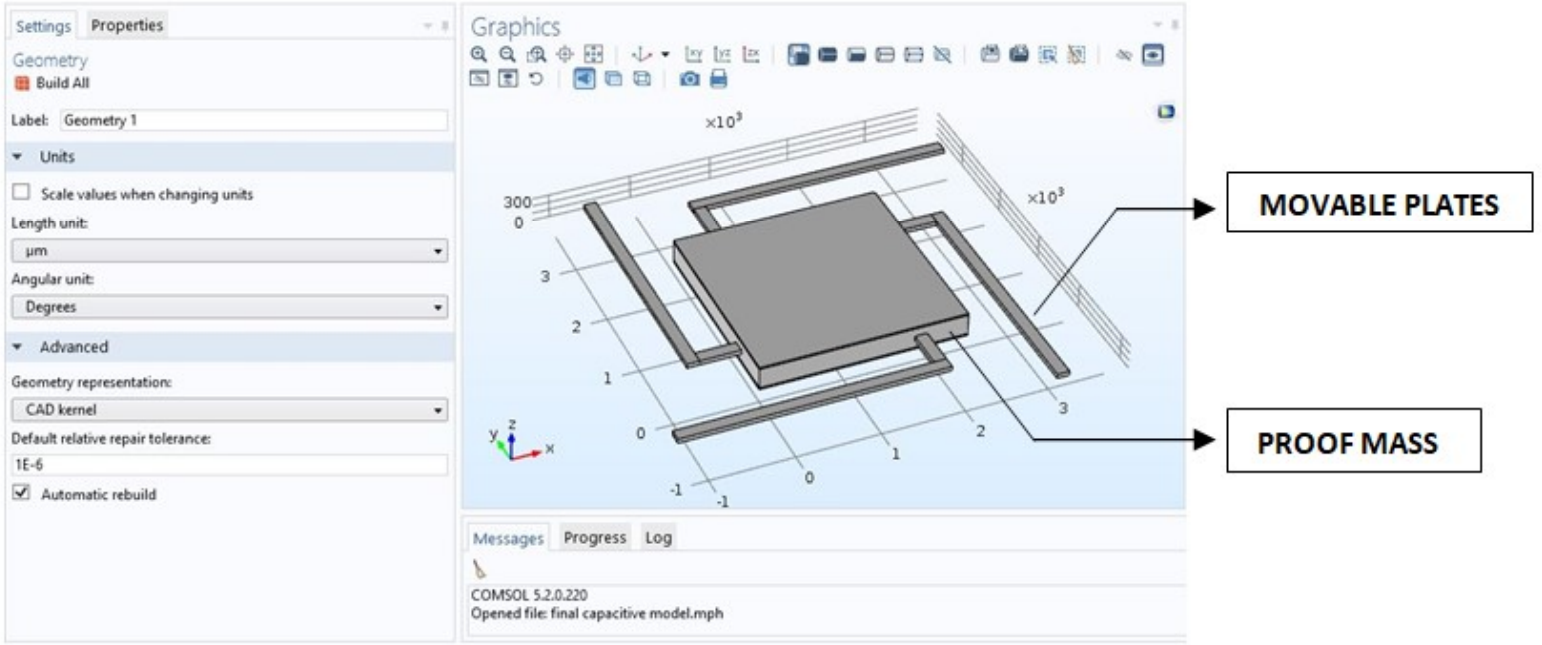
Implementation in COMSOL MULTIPHYSICS

- The system equipped with **COMSOL Multiphysics version 5.2** is used for the design.
- Software is based on advanced numerical methods for modeling and simulation.
- The mechanical model is designed in COMSOL. By using required materials The study is added with the feature of powerful meshing and the model is tested for the applied force using plot annotations.



Implementation of the Model in OMSOL Multiphysics

Step:1 Design 2D or 3D geometry, by constructing geometrical shapes as shown below.



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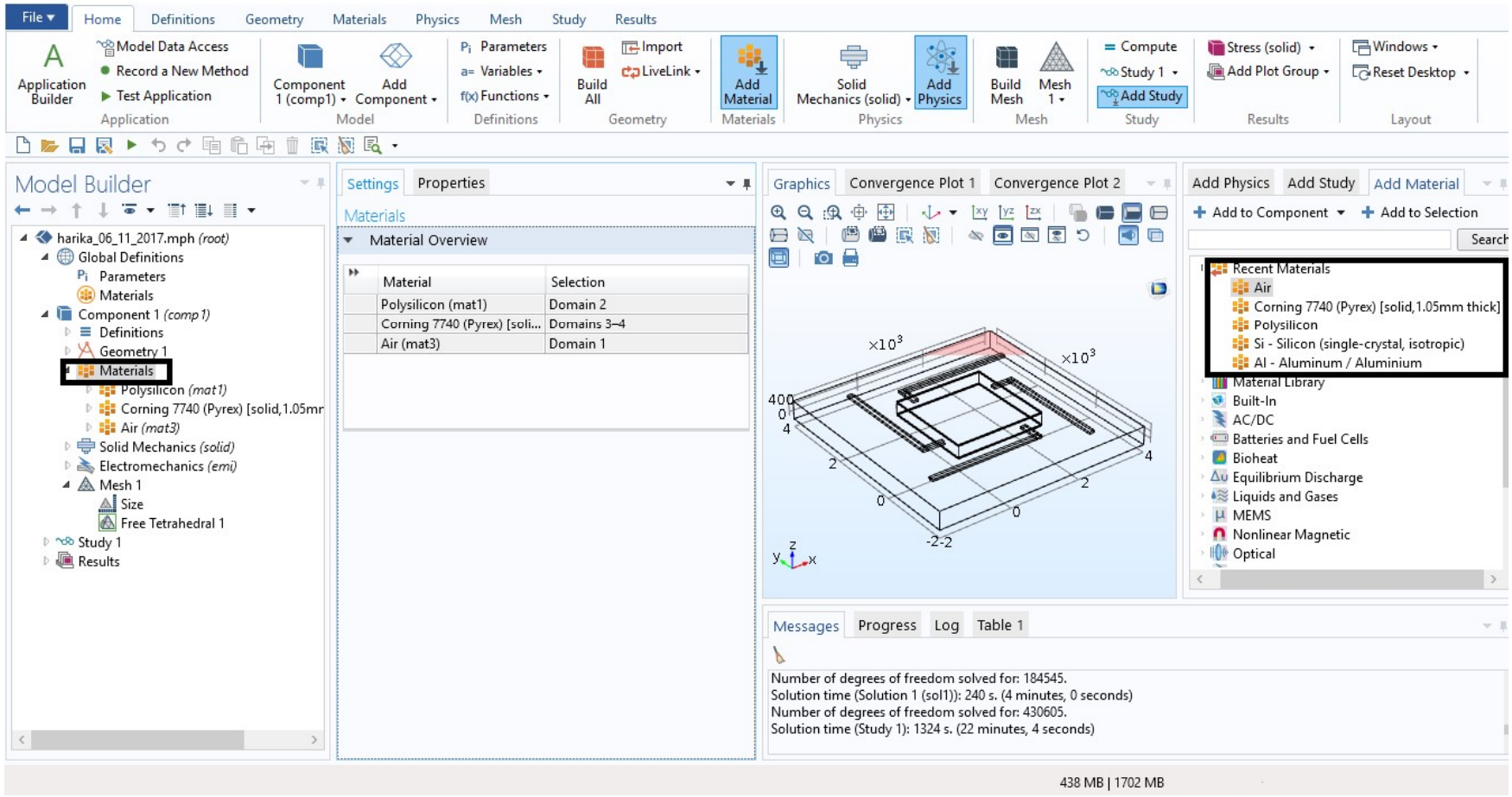
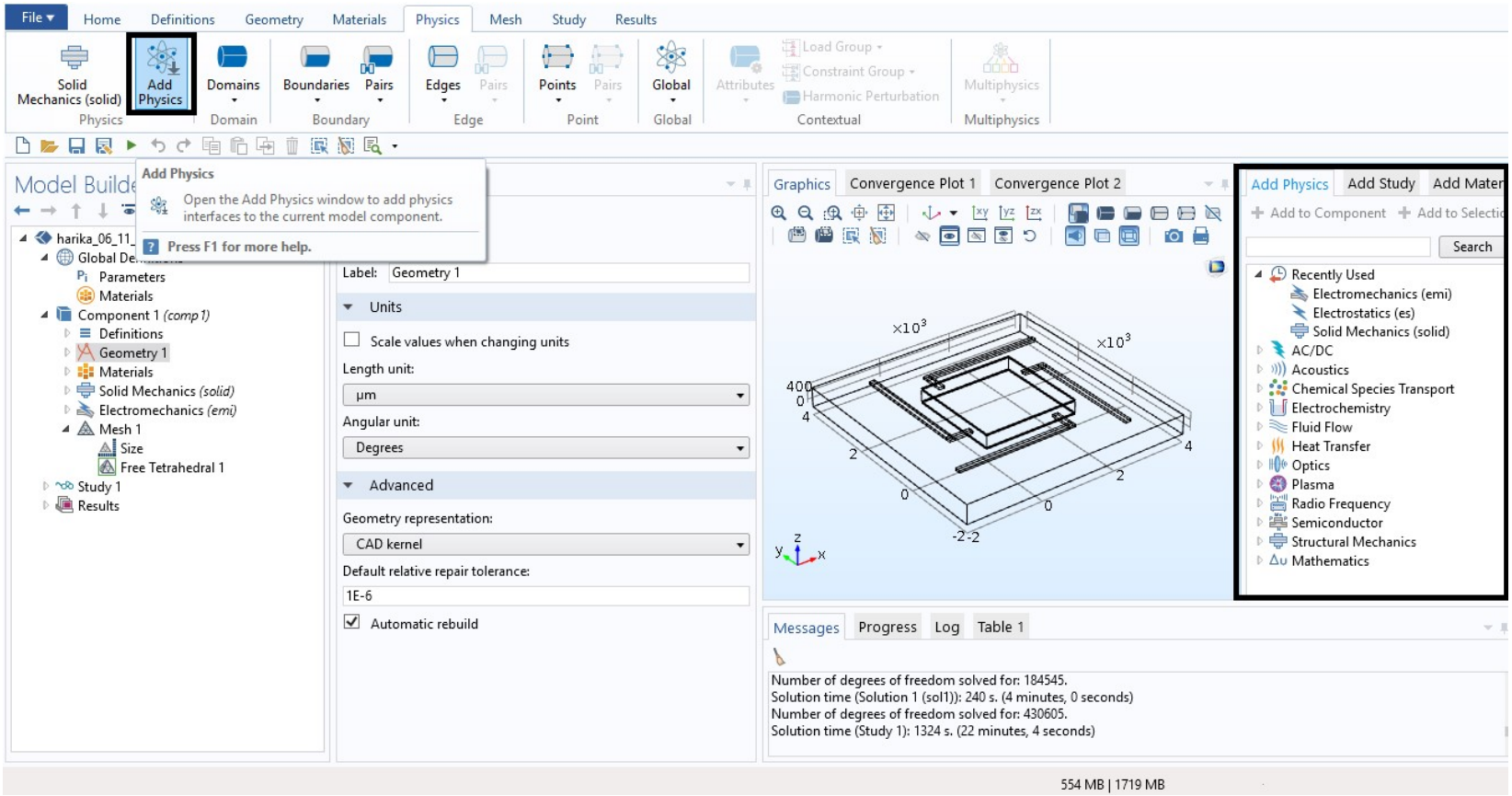
Implementation in COMSOL Multiphysics

Step:2 The material is selected for the model,



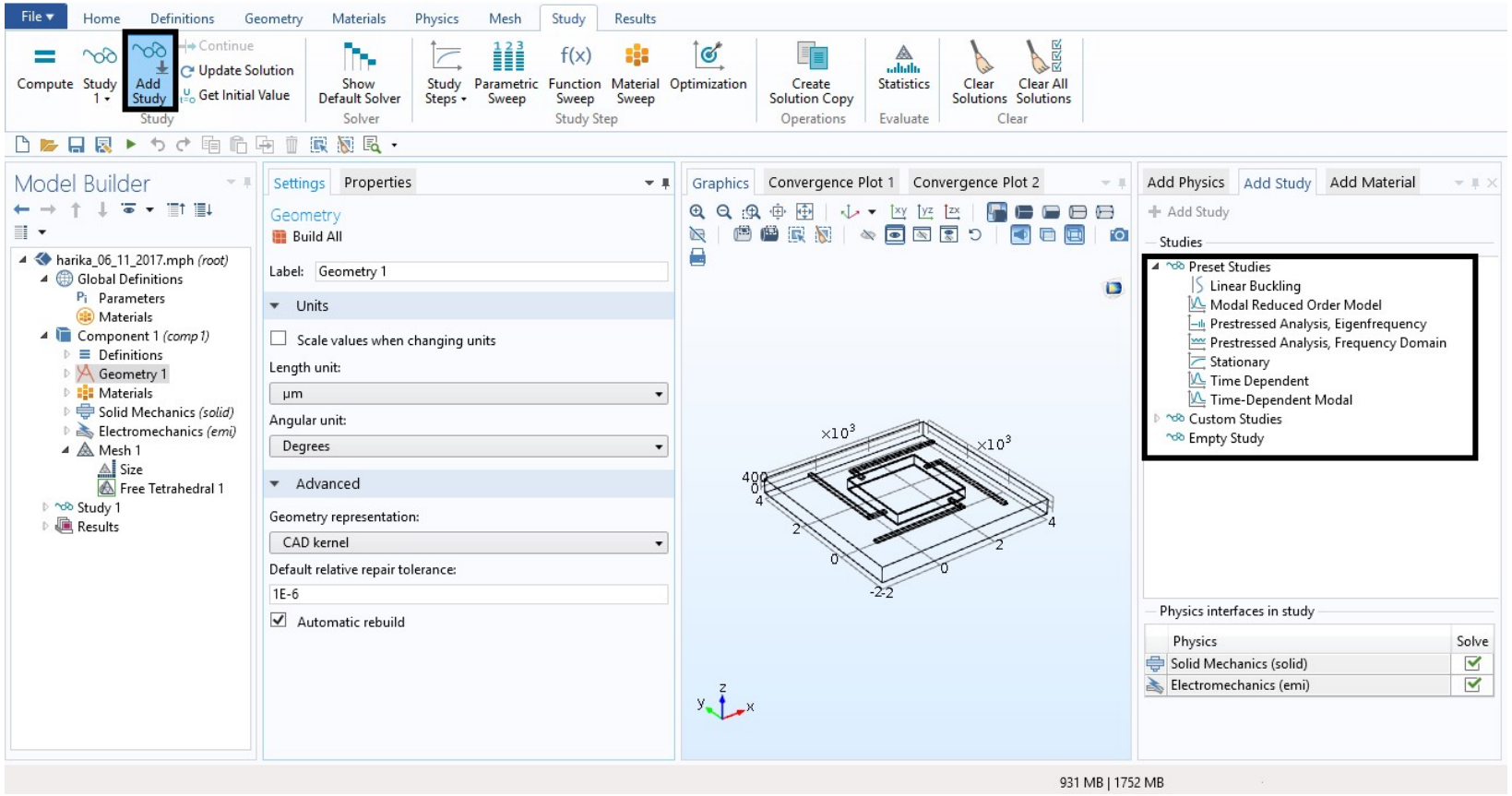
Implementation in COMSOL Multiphysics

Step:3 The physics for the model is selected.



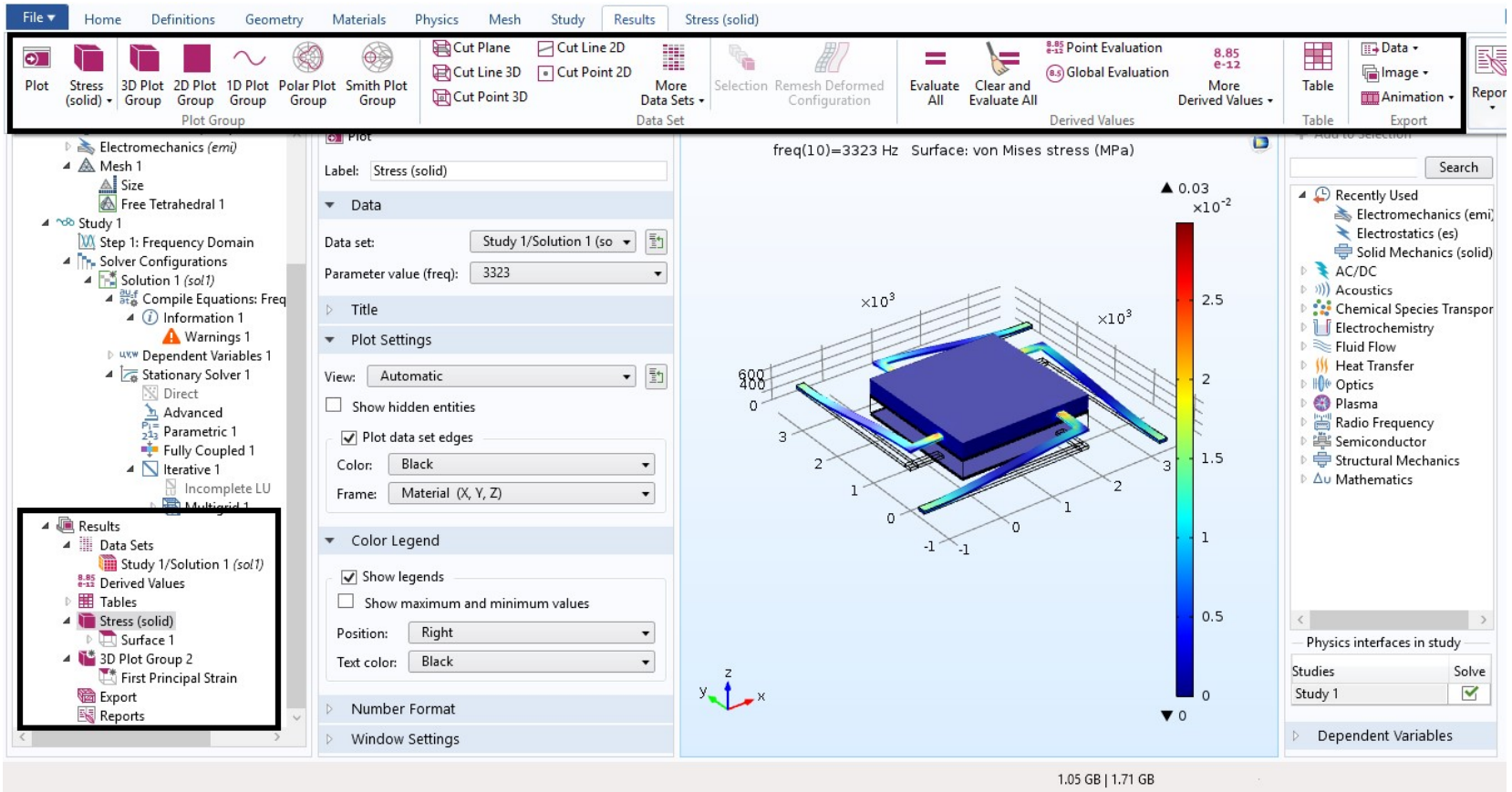
Implementation in COMSOL Multiphysics

Step:4 Meshing is carried out and solution for the model is obtained.



Implementation in COMSOL Multiphysics

Step:5 The displacement of proof mass is studied.



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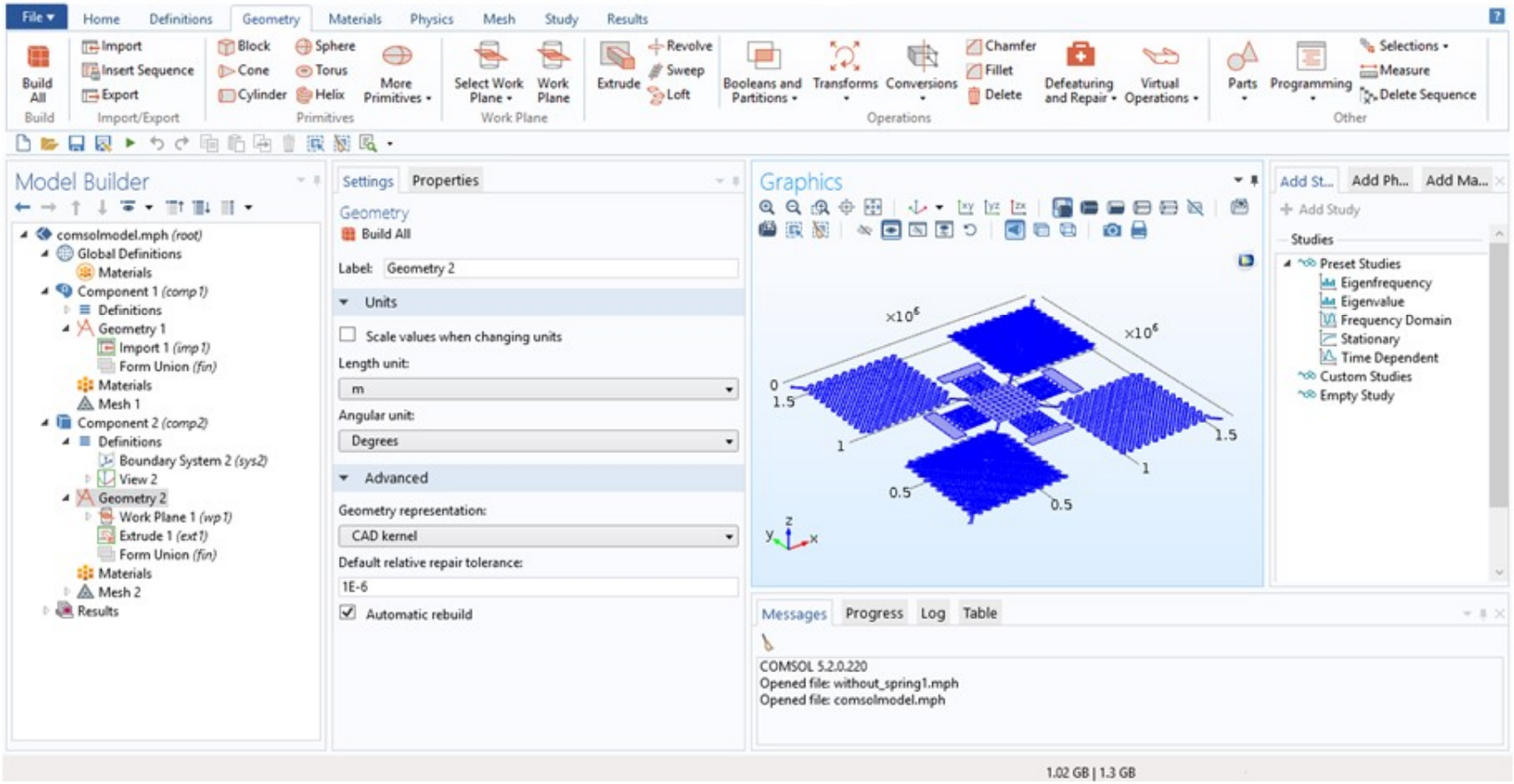
Implementation in COMSOL Multiphysics

Step:6 Proof mass designed for the displacement in X-Y direction



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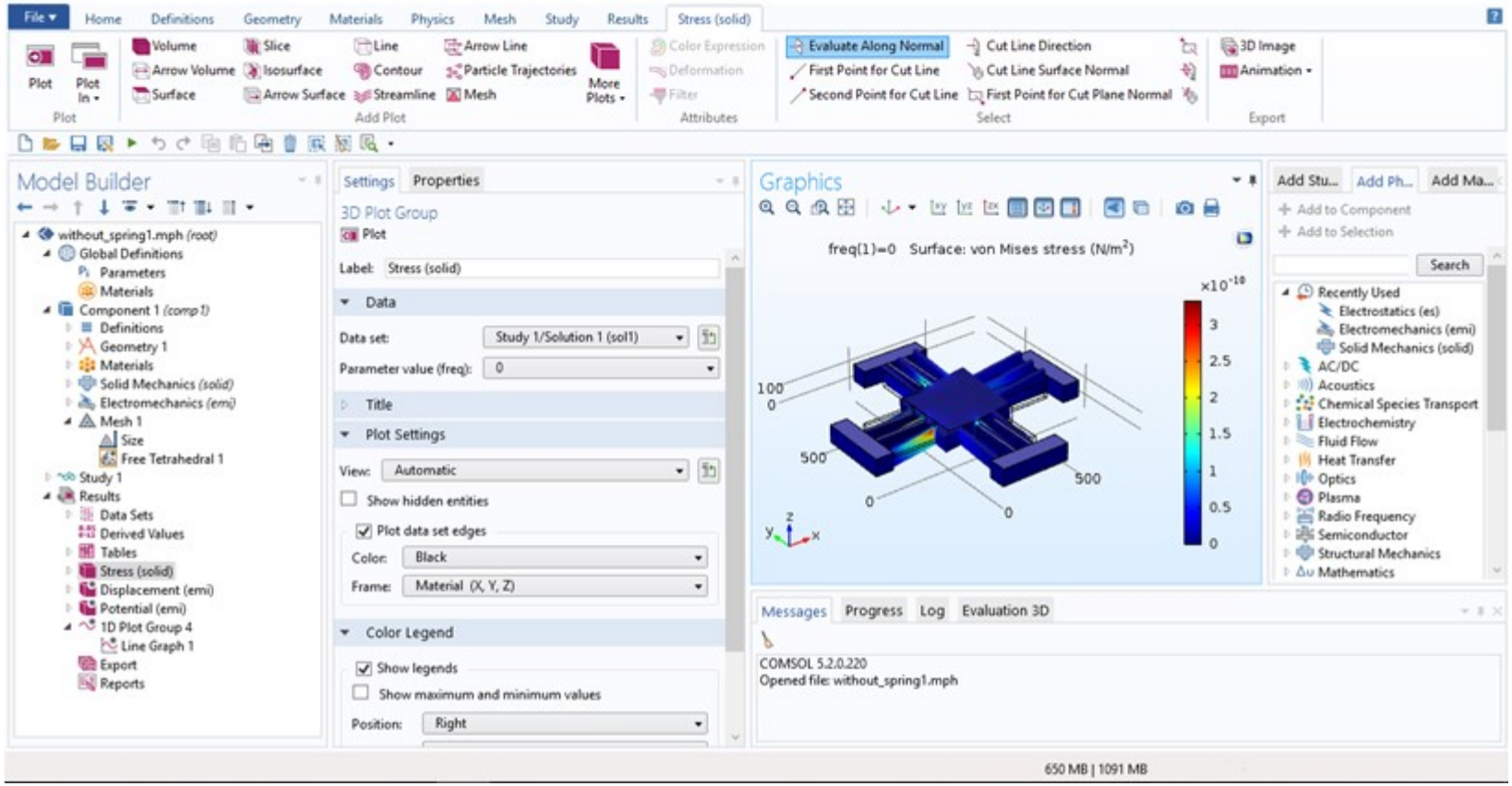
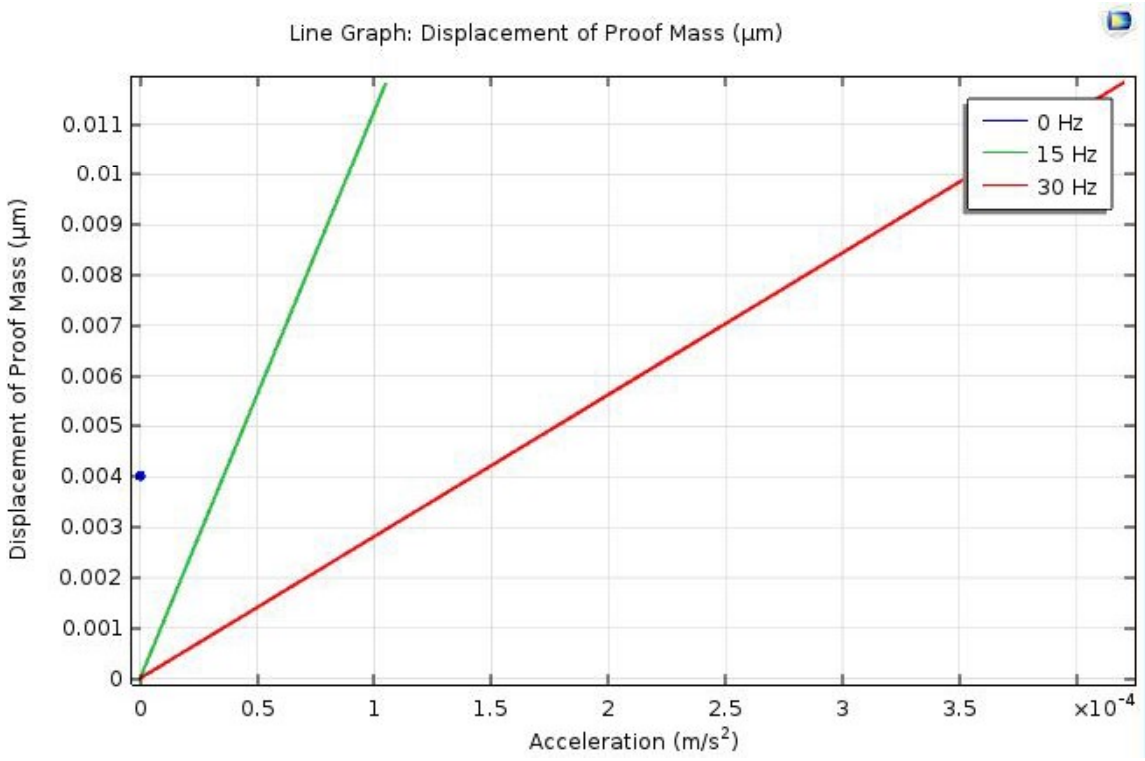
Implementation in COMSOL Multiphysics

Step:7 Study of X-Y direction displacement.



Results

- The 2-axis and 3-axis capacitive accelerometer using COMSOL Multiphysics.
- It is observed that acceleration is linearly proportional to the displacement.



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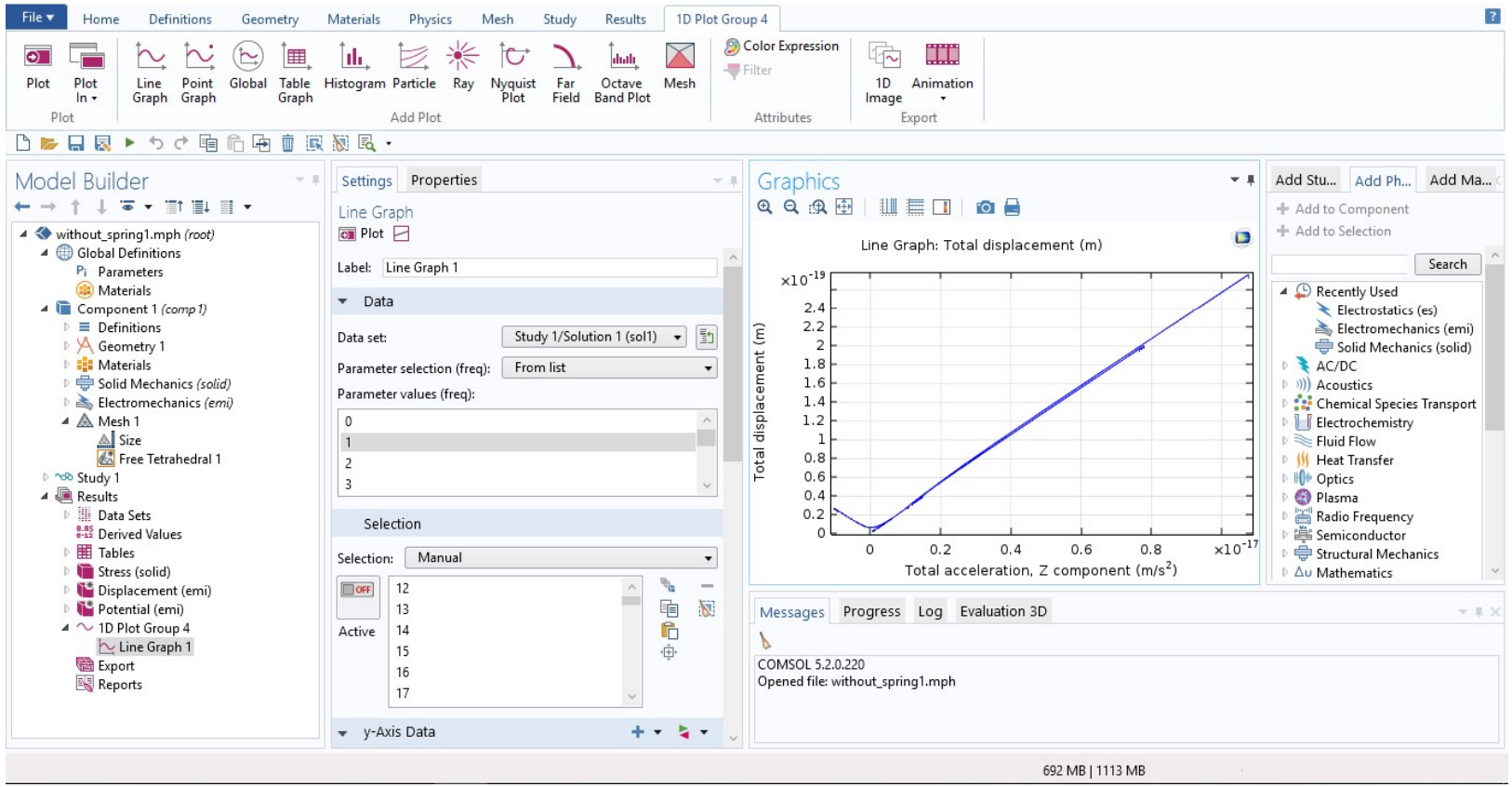
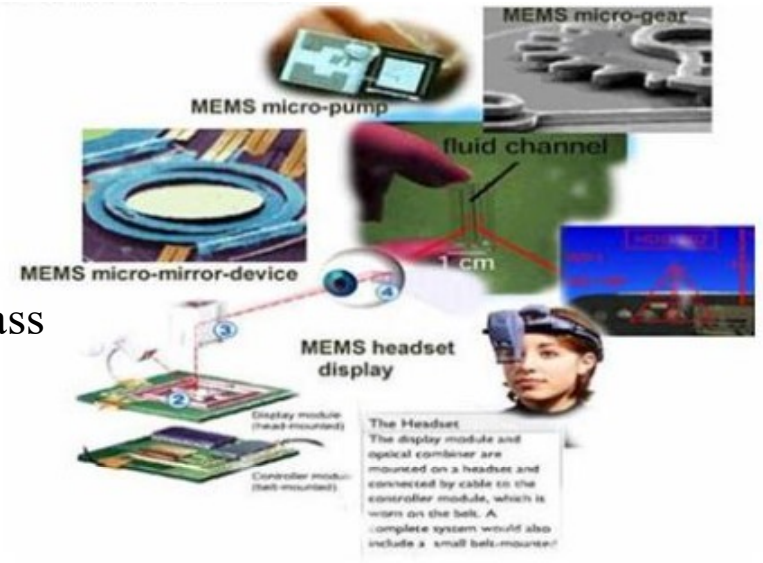
Results

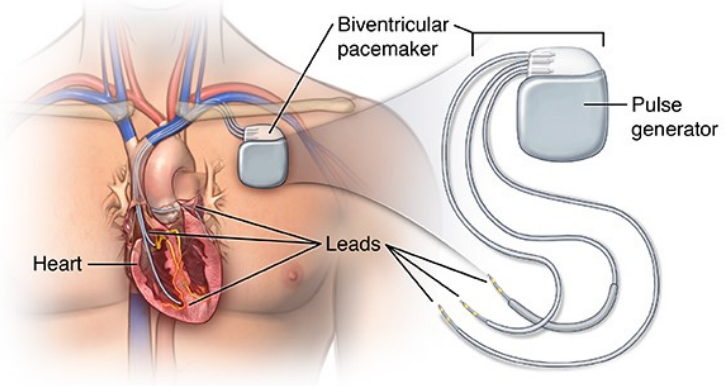
Displacement vs. Acceleration in Z direction

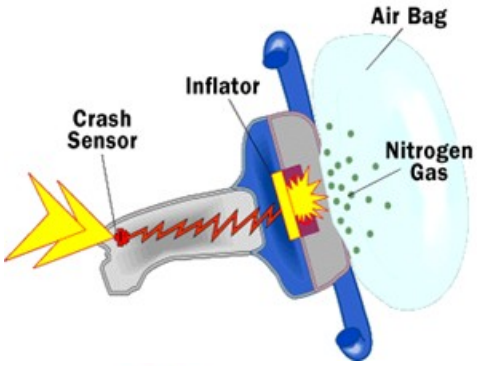


Applications

- **Automotive Application**
  - Airbags control
  - Crash detection
  - Navigation
  - GPS with E-Compass
- **Consumer Electronics**
  - Freefall detection
  - Image stabilization
  - Screen rotation
- **Biological Application**
  - Pacemaker







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Conclusion

The various types of accelerometers and the various materials required in its designing are studied thoroughly. A 3-axis MEMS capacitive accelerometer is implemented in COMSOL Multiphysics where we are applying the force in the positive z-direction. The results can be used to calculate the change in distance between the capacitive plates w.r.t change in capacitance which is linear in nature. This has its applications especially in the bio-medical industry where we can use this in pacemakers, eye surgery, kidney dialysis and much more other life-saving operations.

Thank You

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