Design and Analysis of 3D Capacitive Accelerometer for Automotive Applications

Vijila G. ,Vijayakumar S,
Alagappan M. Anju Gupta

PSG College of Technology,
Coimbatore-641004

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Objective

- Accelerometers which detect rapid collisions.
- 3D Capacitive accelerometers which are less prone to noise and temperature variations.
- Checking out maximum stress device withstands.

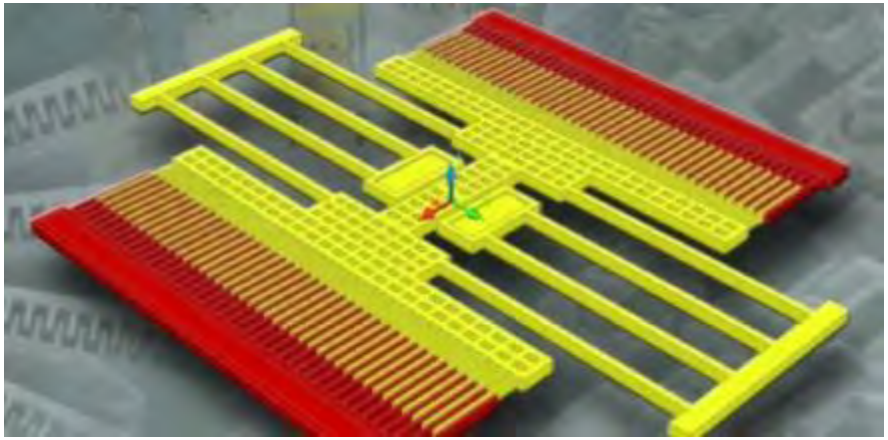
Air bag deployment

The driver and passenger front airbags, after having been deployed, in a Peugeot 306 car

- Vehicle safety device
- Airbag Control Unit(ACU)
- Accelerometers as inertia sensors in ACU

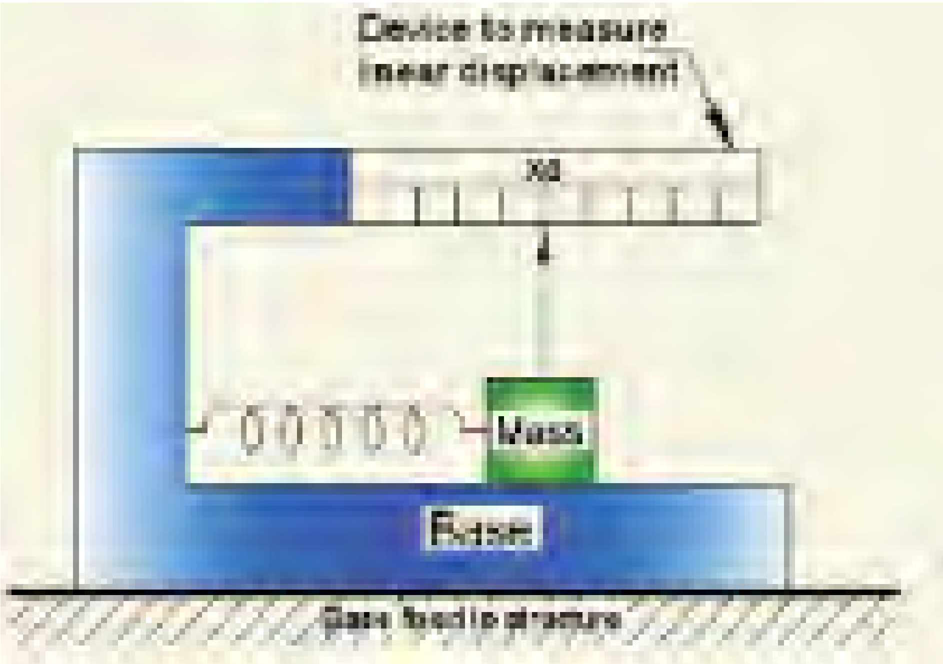
Accelerometers

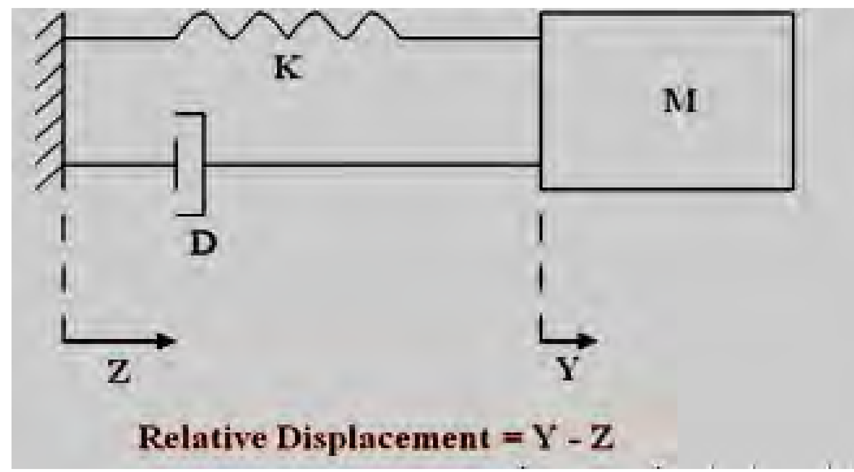
- An accelerometer thus measures **weight per unit of (test) mass**, a quantity also known as specific force , or g-force..
- Measuring is basically done by converting a mechanical signal in form of strain into an electrical signal



Courtesy:Sensors & Transducers Journal, Vol. 103, Issue 4, April 2009, pp. 52-64

Structure





Damped mass spring system

Types of accelerometers

- Accelerometers
  - Piezoelectric
  - Piezoresistive
  - Capacitive

Why Capacitive accelerometers?

- Higher sensitivity
- Lower temperature coefficients.
- Less Prone to noise
- Low power consumption
- Excellent Stability

Capacitive accelerometer

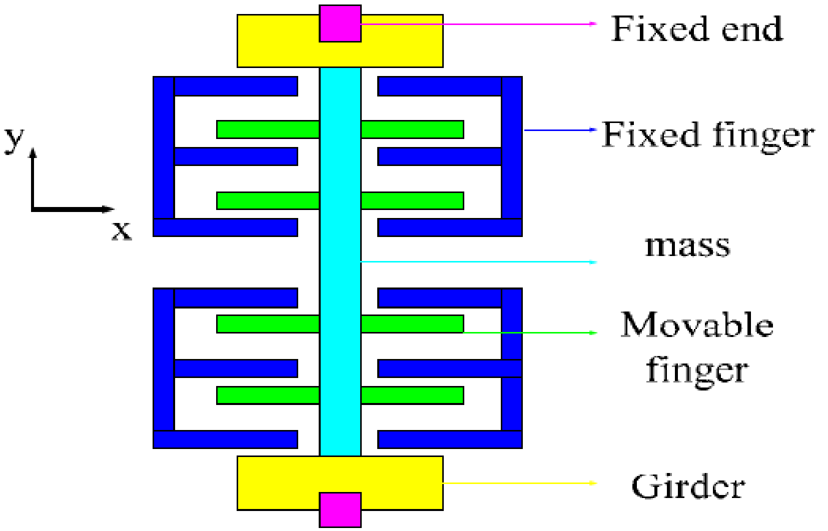
Acceleration

↓

Displacement

↓

Capacitance Change



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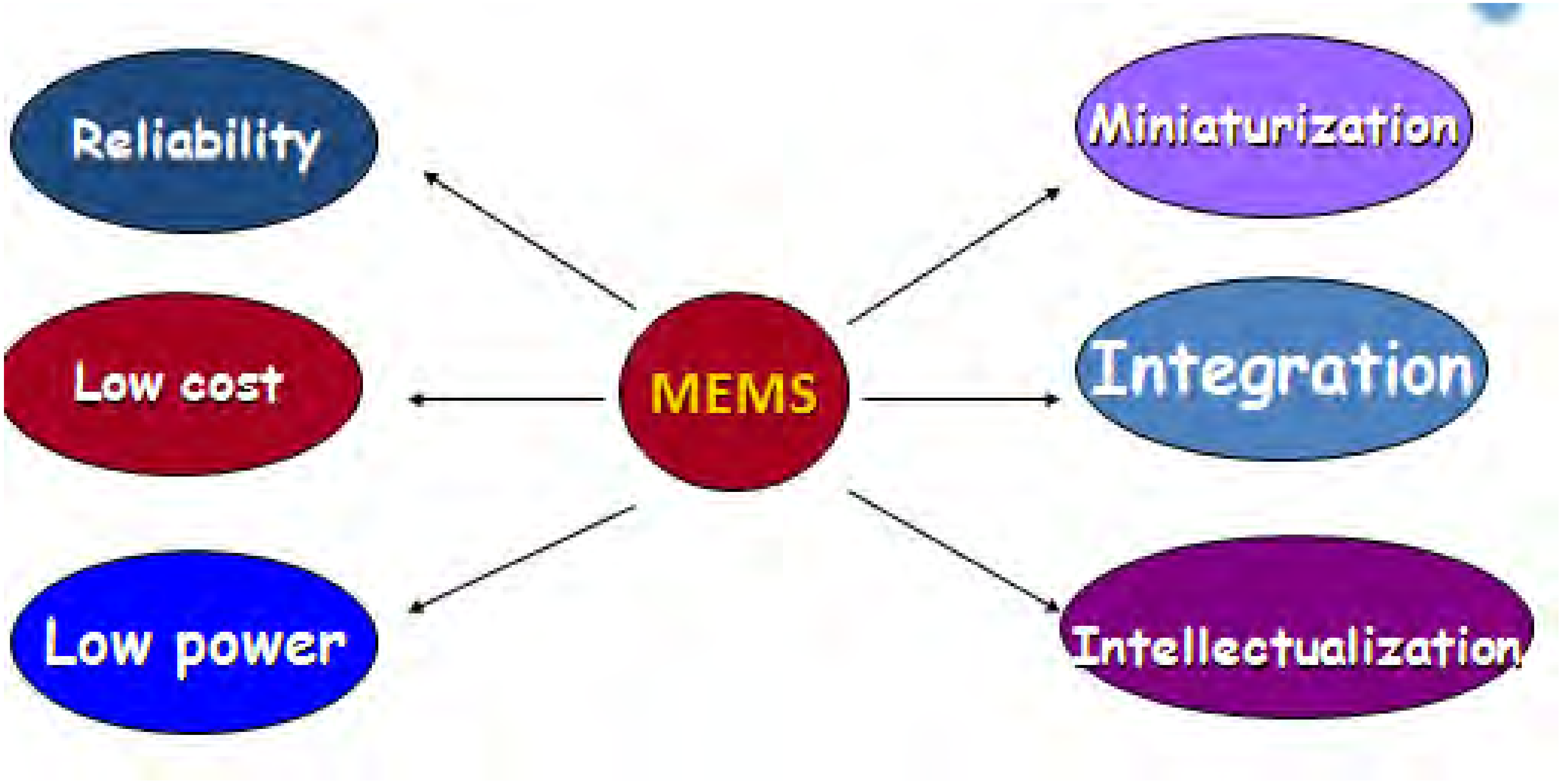
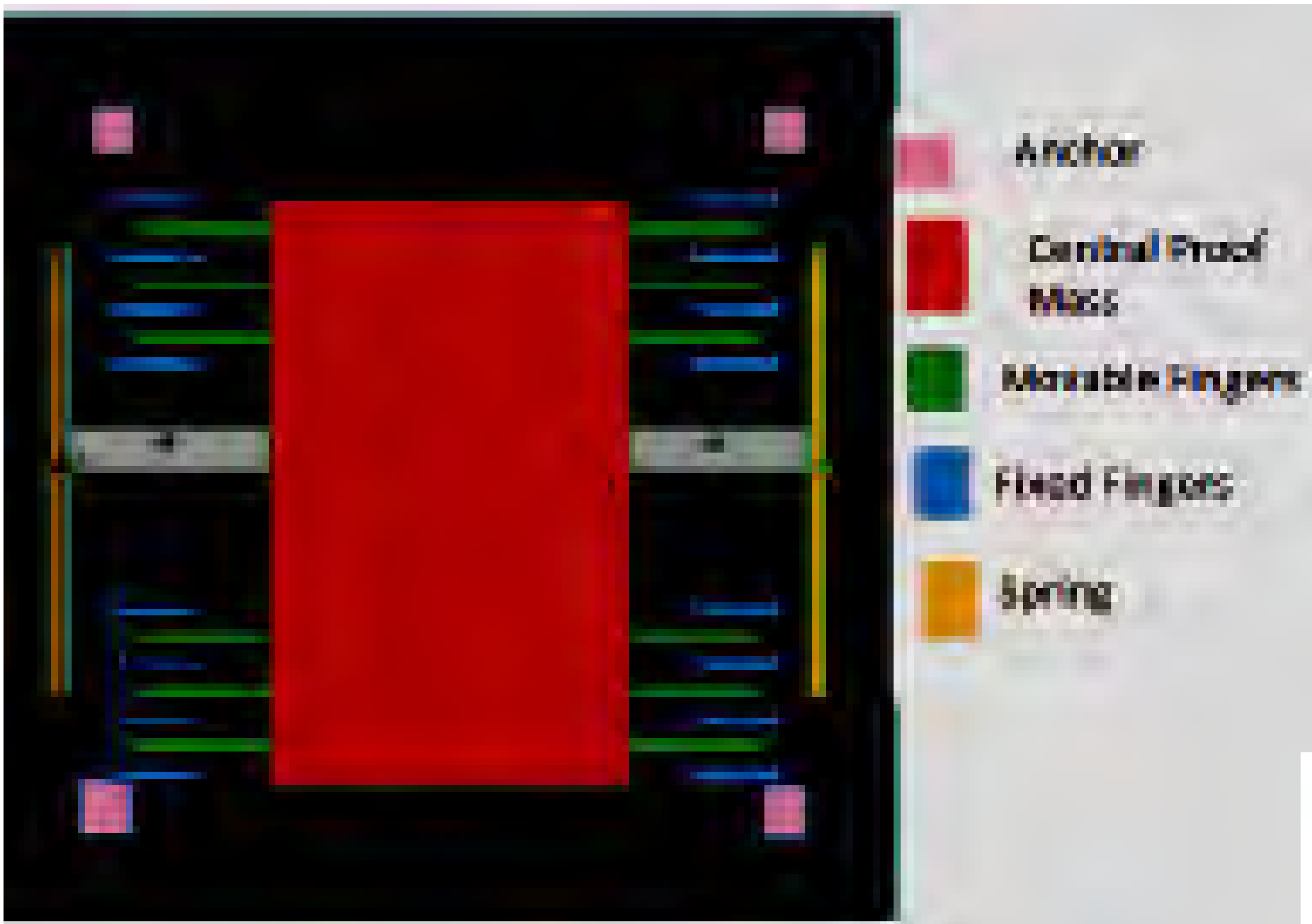
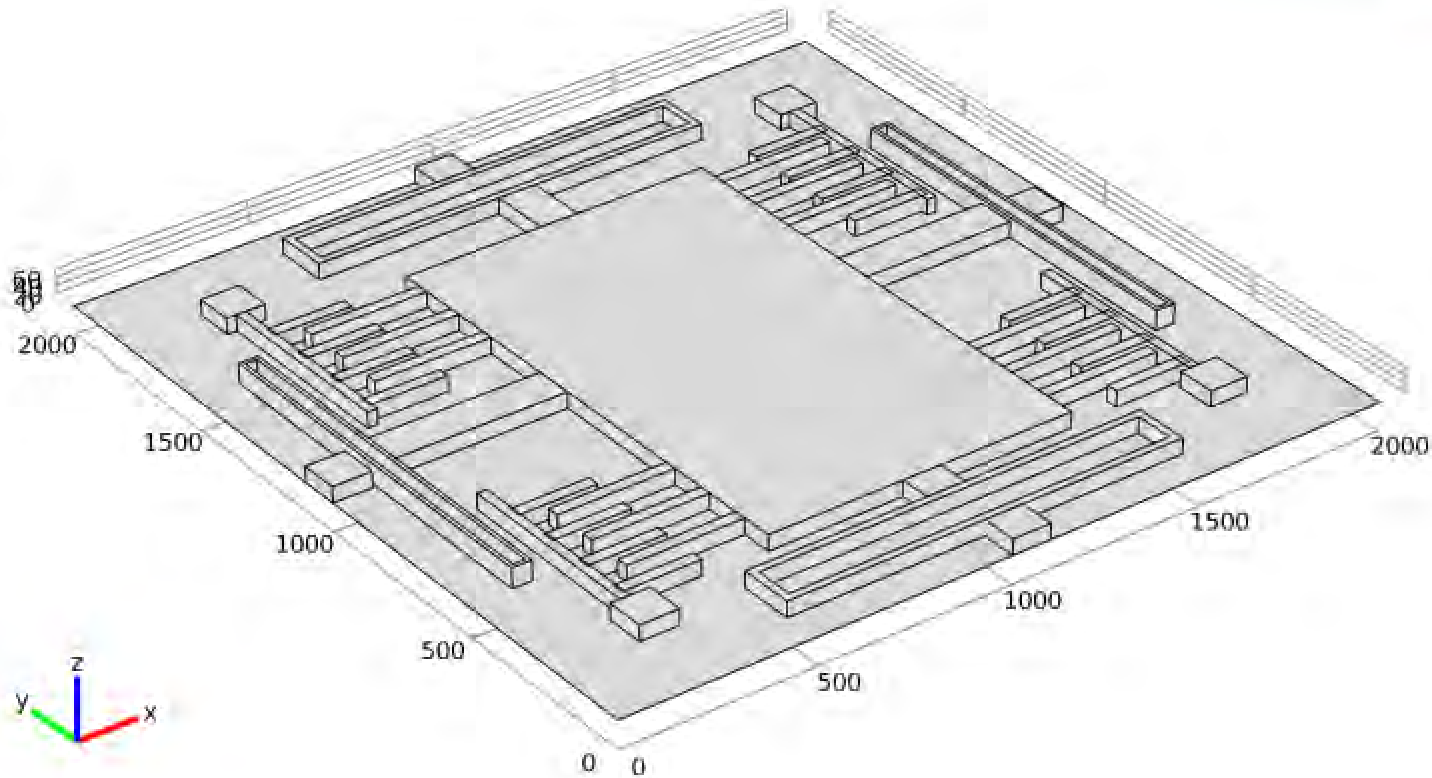
Why MEMS accelerometers?



Proposed Model



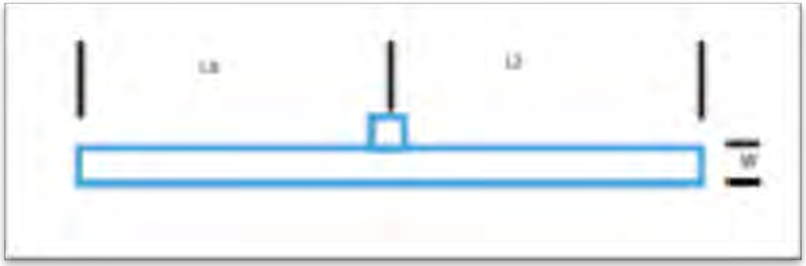
Schematic view of 3D model



Design Parameters

- Spring Constant

$$K = \left(\frac{\pi^4}{6}\right)\left[\frac{EWH^3}{(2L_1)^3 + (2L_2)^3}\right]$$



Folded spring structure

- Mass

$$m = \rho V$$

- Reasonant frequency

$$\omega_0 = 2\pi f = \sqrt{\frac{K}{m}} \text{ or, } m = \frac{K}{\omega_0^2}$$

Design Parameters

S.No	Parameter	Value
1	Spring constant (K) 2 spring	13.5829 N/m
	Spring constant (K) 4 spring	54.3364 N/m
2	Mass	12.5605×10^{-17} Kg

Spring Constant

$E = 131 \times 10^{9}$ Pa for silicon
W= 100nm
H=40 nm
L1=L2= 500 nm

Mass

Mass of central proof mass= 9.69×10^{-17} Kg
Mass of fixed and movable fingers = 2.8705×10^{-17} Kg

Total mass= 12.5605×10^{-17} Kg

Measurement Parameters

Capacitance

$$C = \in A/d$$

Voltage output

$$Vout = \frac{C1-C2}{C1+C2} \times Vs$$

$$Vout = \left(\frac{\Delta x}{d}\right) Vs$$

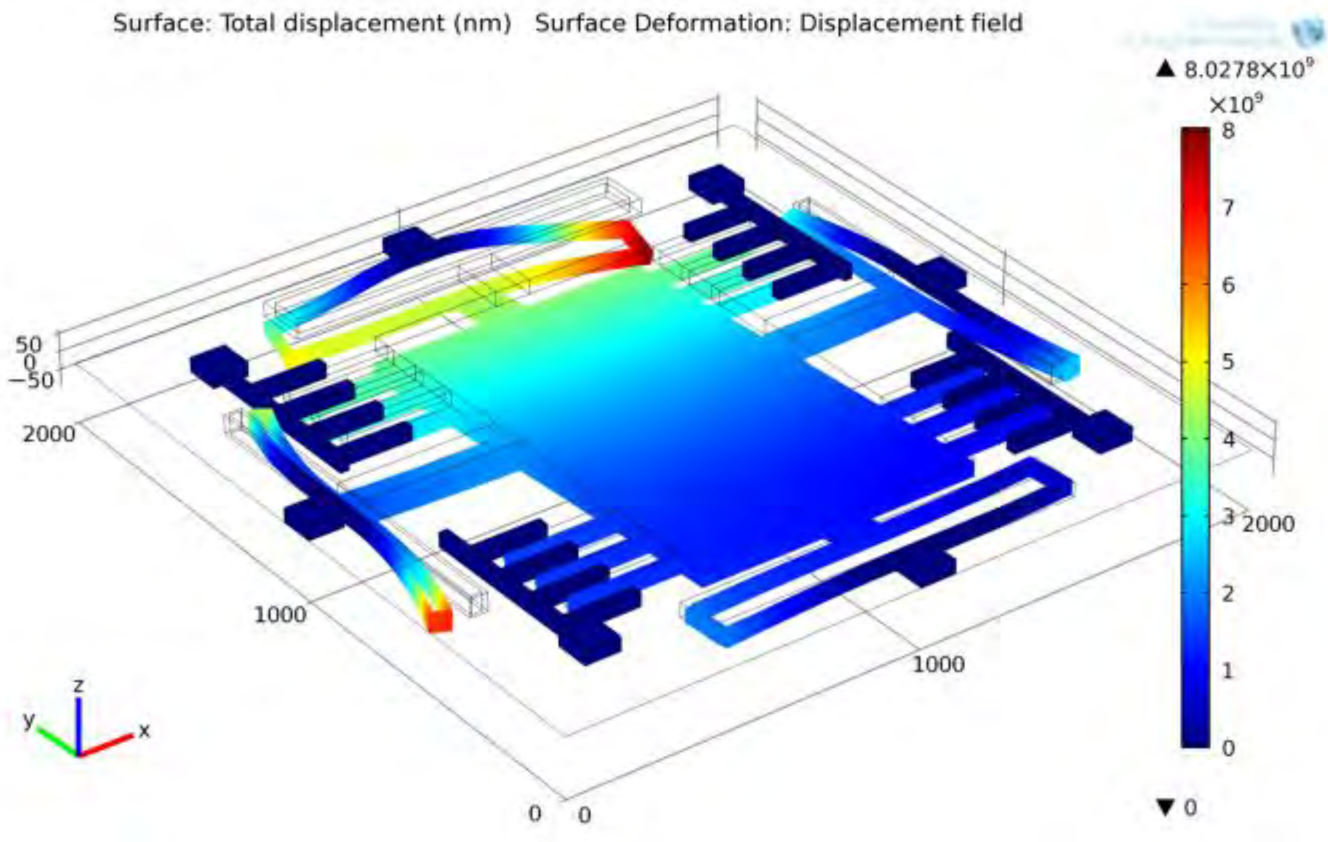
$$\Delta x = ma/k$$

Where
Δx
is displacement, Vs is input voltage, d
is original gap between electrodes.

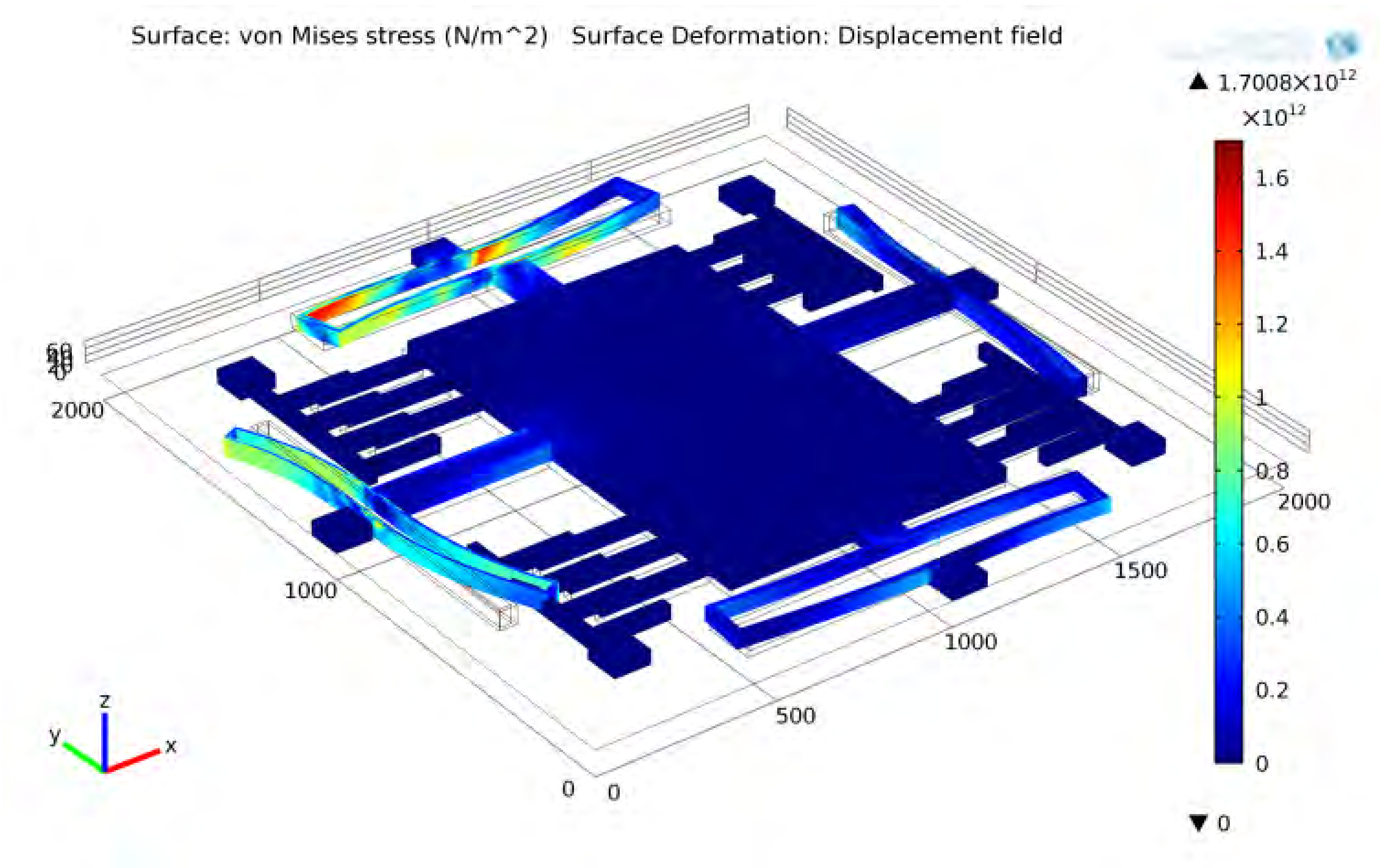
Simulation

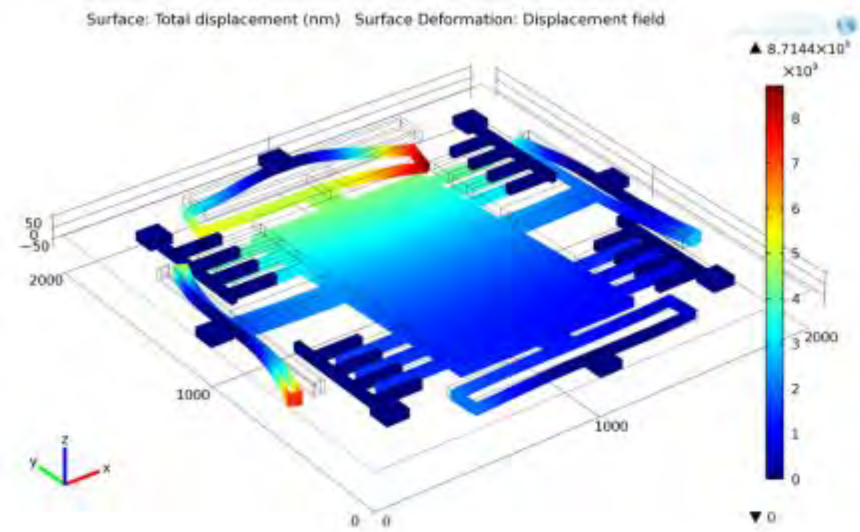
- **Software used** : COMSOL Multiphysics 4.1
- **Material**: Polysilicon
- **Physics**: Electrostatics & Solid mechanics
- **Mesh** : Free Tetrahedral

Simulation Results

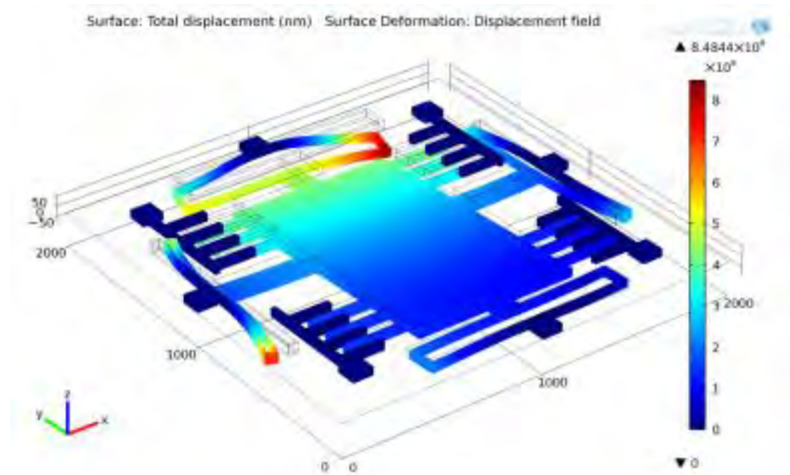


Maximum Stress device withstands…..

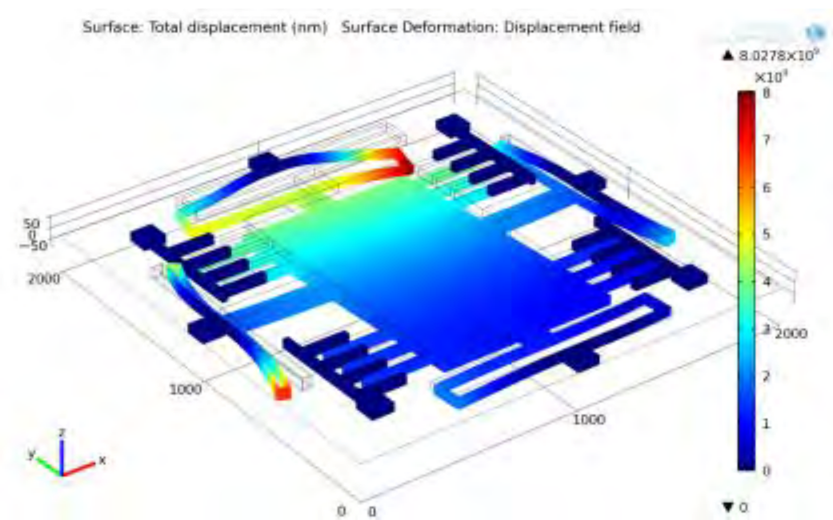




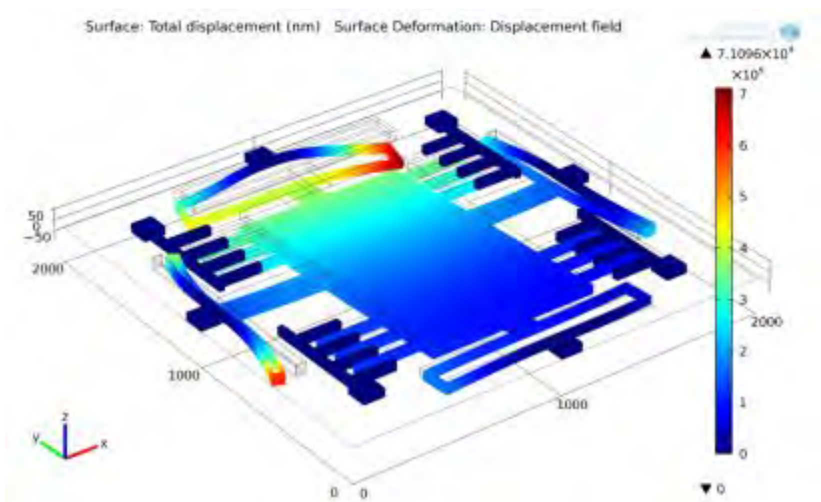
Acceleration: 25g



Acceleration: 50g

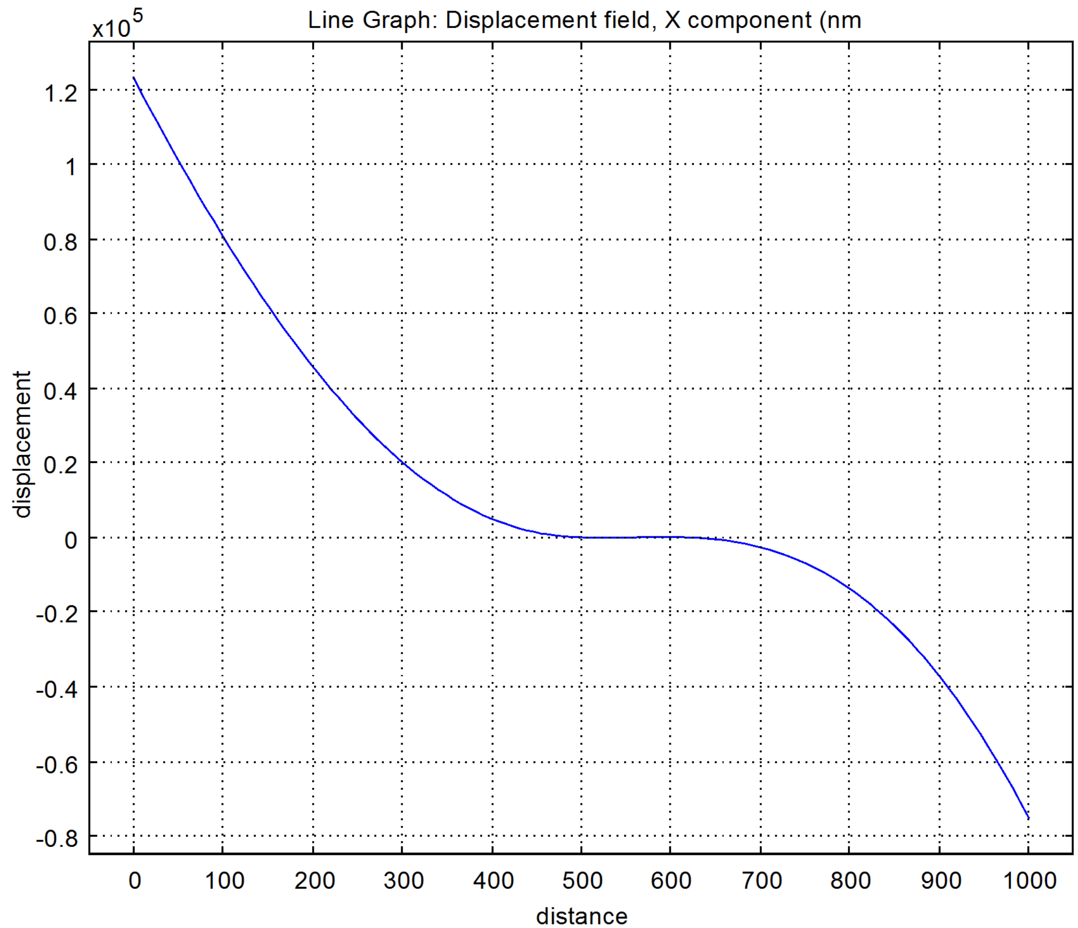


Acceleration: 100g



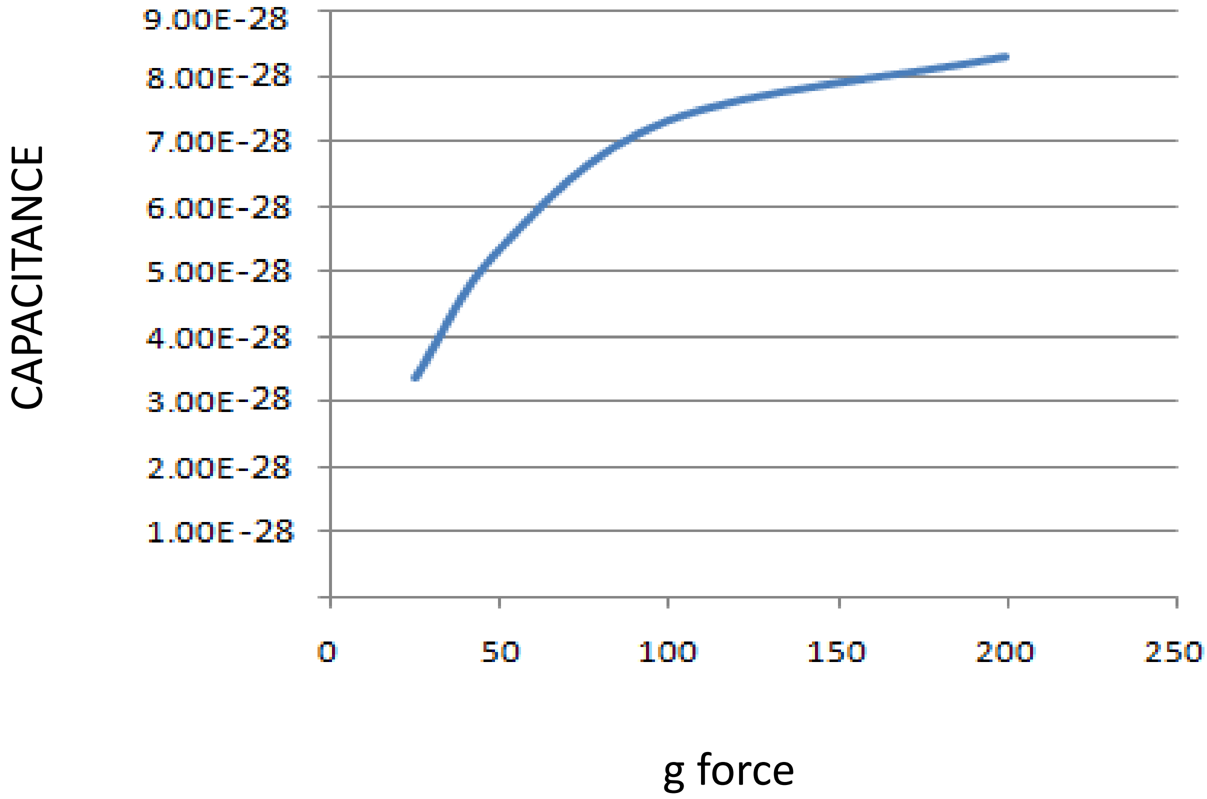
Acceleration: 200g

Displacement along the spring

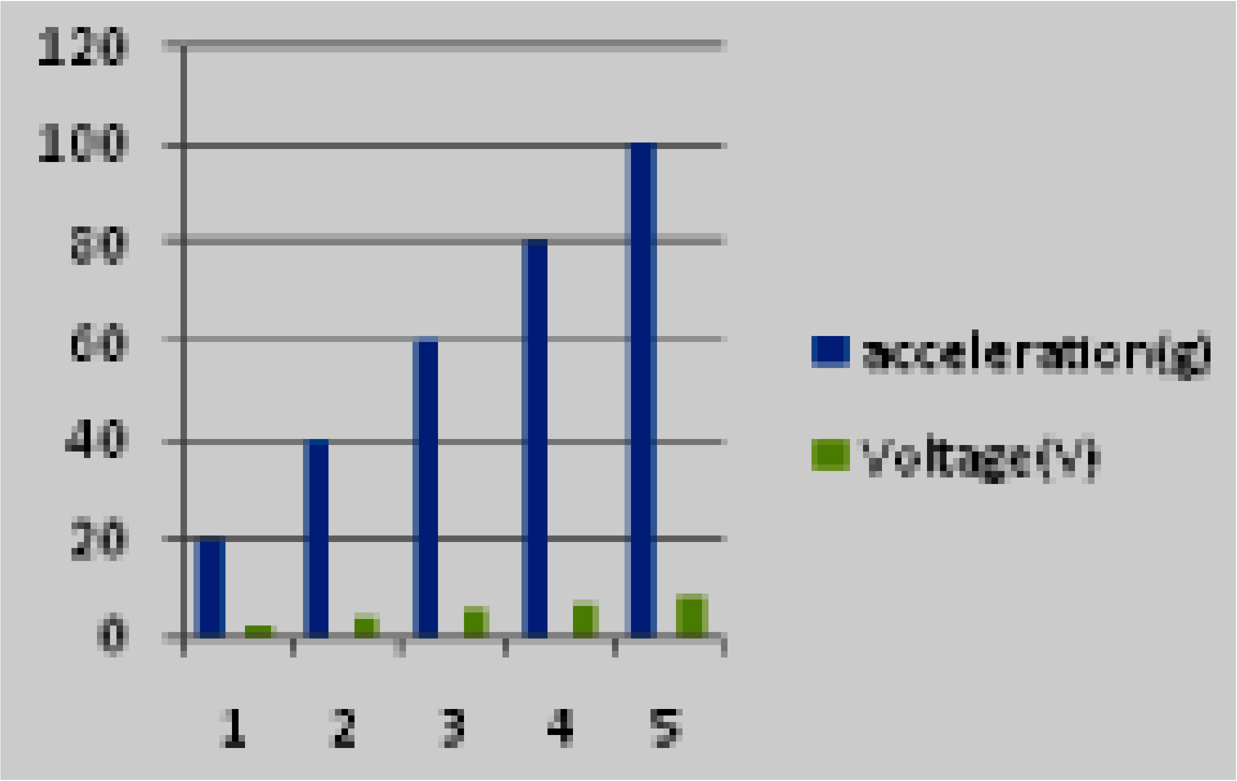


Displacement along the spring length

Capacitance Variation



Variation of acceleration with voltage



Relation between acceleration and voltage

Conclusion

- Accelerometers for airbag deployment applications designed
- Capacitance Studies done
- Nano dimensions

Future Work

Stability studies
Fabricating the accelerometer

References

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