NEW CONCEPTS IN WIDE BANDWIDTH FREQUENCY TUNABILITY IN MEMS ACCELEROMETERS

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ABSTRACT

MEMS (Micro Electromechanical Systems) accelerometers continue to make inroads in such applications as airbags, navigational systems, military applications and gaming devices. The application of MEMS accelerometers is expected to enter newer areas such as mobile devices like cell phones for both civilian and military applications and hand-held devices with navigational capabilities. However, these new applications pose aggressive performance requirements such as tunability of frequency range over a significantly wide bandwidth.

This research concentrates on developing an accelerometer capable of detecting a quick movement (0.5g – 2.5g) as well as zooming movement (0.1g – 0.5g). The MEMS accelerometer is named *WiBand*Accelero and is tunable from tens of kHz to hundreds of kHz. The range is selected to cover tilt needs in both digital map navigational as well as mobile gaming applications.

Tunability is achieved by varying the dimensions of the springs supporting the proof mass using different clamping mechanisms. The extension of the tunability by 2 orders (1000%) is certainly very significant progress with wide ranging implications. Further, we feel that this ongoing work in wide tunable accelerometers will open up new possibilities in personal mobile device applications by introducing much wider bandwidth tunability unavailable so far.

INTRODUCTION

Accelerometer is an electromechanical device that measures acceleration forces. These forces may be static, like the constant force of gravity or dynamic due to moving or vibrating parts where the accelerometer connected to. For example; just by measuring the amount of static acceleration due to gravity in navigation devices, it can be reached at the angle the device is tilted with respect to the earth. Likewise, by sensing the amount of dynamic acceleration, we can protect the machine, building or process control unit from damage.

Companies like, IBM and Apple have recently started using accelerometers in their laptops to protect hard drives from damage. If you accidentally drop the laptop, the accelerometer detects the sudden freefall, and switches the hard drive off so the heads don't crash on the platters. In a similar fashion, high gravity accelerometers are the industry standard way of detecting car crashes and deploying airbags at just the right time.

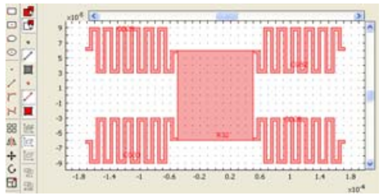
Governing equation from Stoney's formula [1]

$$\delta = \frac{3\sigma(1-\nu)}{E}\left(\frac{L}{t}\right)^2$$

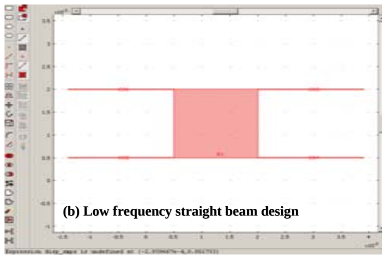
$$k = \frac{F}{\delta} = \frac{Ewt^3}{4L^3}$$

$$\omega_0 = \sqrt{k/m}$$

δ - beam deflection
σ - Stress
E - Young's modulus
ν – Poisson's ratio
L – spring length
t – Spring thickness
ω – Width of spring
K – Stiffness
m – Mass of spring
Ωo – Natural frequency



(a) High frequency crab leg mechanism design



(b) Low frequency straight beam design

Fig. 1 FEA Model of the two Wi Band accelerometer designs

Table 1. Classification of chemical vapor deposition process

Springs with uniform thickness		
Mode	Frequency (kHz)	
	Straight beam design	Crab leg design
1	0.11	98
2	0.125	101
3	0.155	107
4	0.206	114
5	0.270	122
6	0.444	131

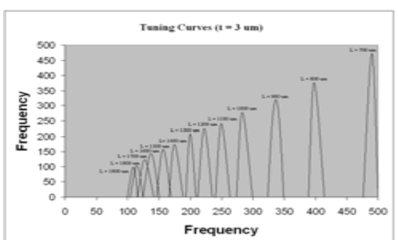


Fig. 2 Schematic diagram of frequency range detectable by the new straight beam accelerometer design

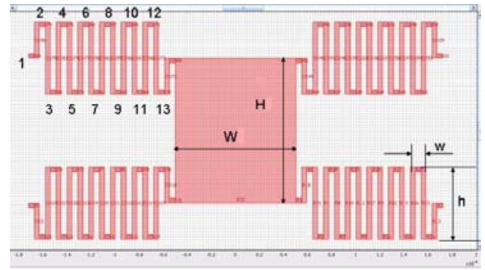


Fig. 3 Locations of clamping mechanism for the high frequency Wi band crab leg accelerometer design

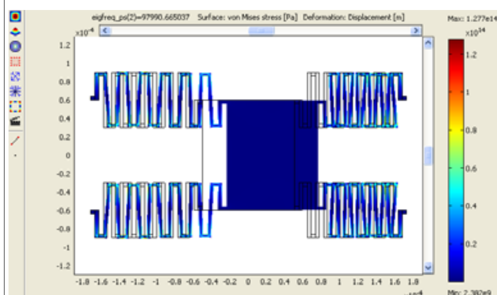


Fig. 4. Simulation result for the first mode six loop high frequency accelerometer design

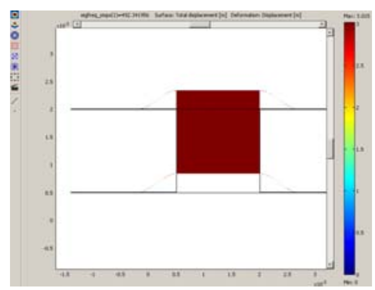


Fig. 5. Simulation result for the low frequency accelerometer design

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CONCLUSION

Generally, the natural frequency of any accelerometer design is optimized by specifying a proper value of seismic mass and respective spring dimensions for the required frequency specifications. As can be inferred from the governing equation derived from Stoney's cantilever beam formula, the natural frequency is a function of spring stiffness and proof mass; and in turn stiffness, K is defined by the spring dimensions and material properties as;

k = fun (E,L,w,t)

Therefore, we can design accelerometers for any frequency just by modifying the above variables. Tunability of accelerometers to a certain frequency range is inferred from the same argument that it is possible to detect more than one frequency modes by modifying the design for different stiffness and/or mass.

The FEA simulation results above for the two different accelerometer designs show this truth

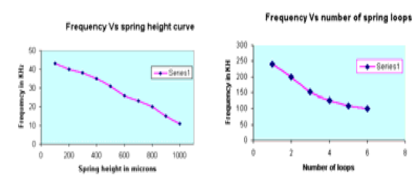

Fig. 6 Summary plot of FEA results showing frequency dependence on spring length and cross section

Future work involves determination of optimum spring dimension for tuning between 100 – 1000KHz frequency range specification for the crab leg mechanism and 0.100 – 1.00kHz for straight beam design. Also, DFM issue will be considered on the clamping mechanism designs for the feasibility of microfabrication (PolyMUMPs process).

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