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Modeling and Simulation of H and T Shape Capacitive Comb Accelerometer

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Abstract

The paper Presents the modeling and simulation of a highly sensitive three axis Micro Electro Mechanical Systems (MEMS) based H and T shape Capacitive Accelerometer . The MEMS Capacitive Accelerometer Sensor which both capacitance and displacement are the primary sensing characteristics. The differential capacitive accelerometer produces displacement and capacitance due to applied acceleration. The main focus of the work has to improve the displacement sensitivity by changing the diaphragm dimensions with applied input acceleration from 1g to 10g.The H and T shape accelerometers has simulated with the parameterized thickness, length, width of the proof mass for better sensitivity.

Keywords

Accelerometer, COMSOL Multiphysics, Displacement, H and T Shape, Sensitivity

Introduction

The market is growing with different applications, MEMS acceleration sensors have many essential part of systems like smartphones, air bag deployment, navigation and aerospace applications. MEMS based Sensors mostly working on either piezo resistive, piezo electric, capacitive sensing [1]. Piezo resistive sensing type accelerometer works on the principle of change in resistance due to applied pressure. This was the primary sensing mechanism technique .The main drawback of this technique is bounded range of working and high reactions to changing temperature [2].Piezo electric sensors have better displacement but the working changes as surrounding temperature is changed [3].Due to this major limitations capacitive sensing type has the better chance with good sensitivity. It can be applied to a wide range of sensors for detecting change of acceleration, pressure and displacement etc. [4]. Capacitive accelerometer has found the low mechanical sensitivity for square and rectangle is 0.00275nm/g and 0.022nm/g respectively [6].Accelerometer is the one of main sensor being developed and use heavily in biomedical and automotive fields for various purpose like health monitoring, air bag control respectively [7]. The accelerometer shows good linearity but low sensitivity in the operating range [8]. In this paper the capacitive accelerometer has simulated with the combination of H and T shape Proof mass and these two accelerometers has compared to found which is given the better sensitivity.

Accelerometer Design

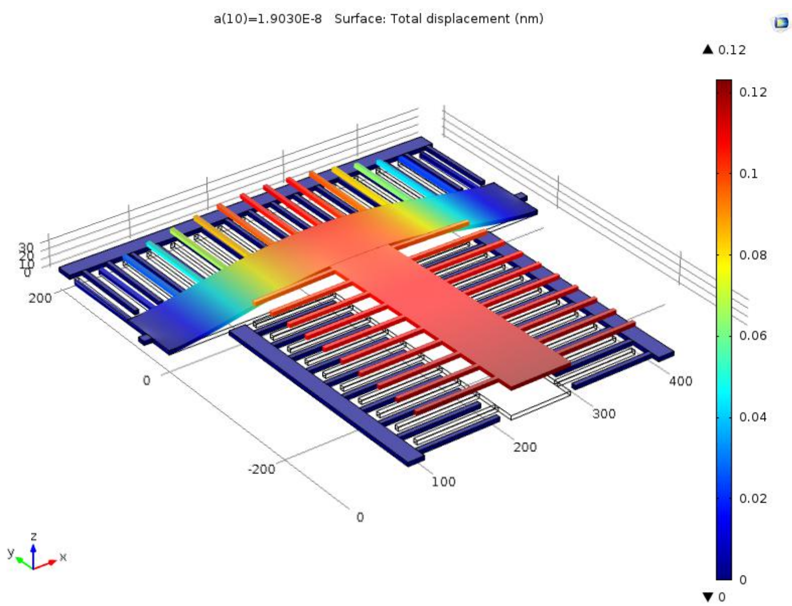
The Capacitive accelerometer type is proposed here having a comb structure. The movable proof mass is suspended via springs connected to the anchors. The H and T shaped proof mass structures are presented to analyze the mechanical properties of the accelerometer. The H and T shapes structures have different spring constants with respect to the dimensions. The two dimensional structure of H and T shape is shown in below Fig.1(a) and (b) respectively. The comb accelerometer has a fixed part which is connected to moving part of accelerometer. Initially at zero acceleration is applied on the proof mass, the zero displacement is occurred and equal capacitances C1, C2 has formed with fixed electrodes. When acceleration is applied on the proof mass the displacement is occurred and differential capacitance is formed in between every three electrodes. Higher sensitivity will be formed by the lower spring constant, spring which is connected to proof mass both sides. The dimensions of the H and T shape accelerometers are given below. The width of the proof mass is 70µm, length is 475 µm , width of the beam and capacitance gap is 10 µm, Length of the beams are 220 µm ,Devices Thickness 5 µm, width of the finger 7 µm, Length of the fingers 100 µm, Number of sensing fingers for T shape and H shape is 72 and 48 respectively. The density of the polycrystalline silicon which is used as a material for proof mass is 5316kg/m3,Proof mass is 7.69x 10^{-10} ,the spring constant for T shape is $1.72x10^{12}$ and H shape is $1.28x10^{8}$,The proof mass for H shape is $8772x10^{-13}$Kg and T shape is $1993x10^{-13}$Kg.

Results and Discussion

The acceleration applied on the proof mass from 1g to 10g , the corresponding displacement for H and T shape is shown in below Table1.The corresponding simulation outputs are shown in figure3(a)and (b).

Acceleration(g)	T-Shape	H-Shape
	Displacement(nm)	
1	0.0001	4e-4
2	0.0002	0.08
3	0.0004	0.12
4	0.0005	0.16
5	0.06	0.2
6	0.07	0.24
7	0.08	0.28
8	0.1	0.32
9	0.11	0.36
10	0.12	0.4

Table1: Acceleration Vs Displacement



(a)

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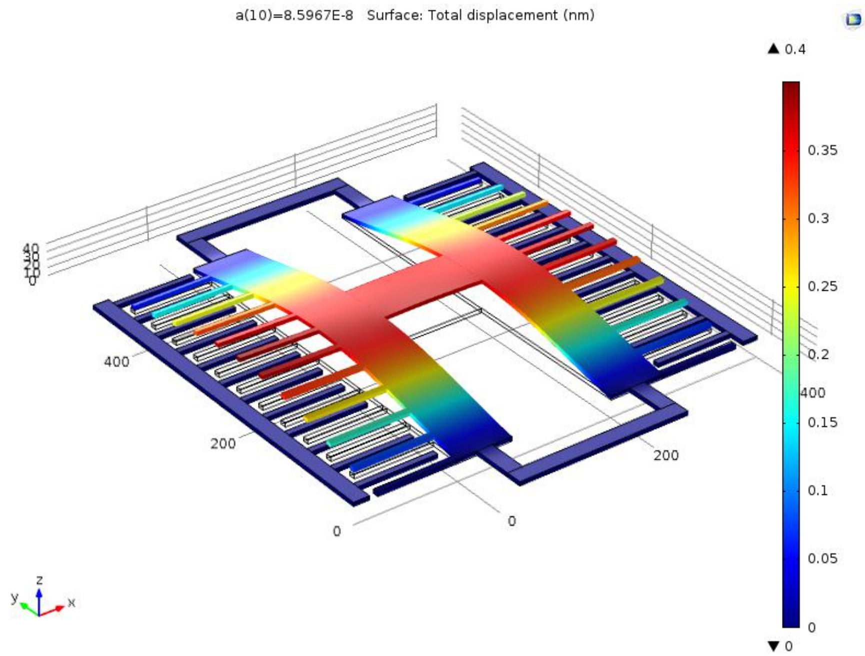
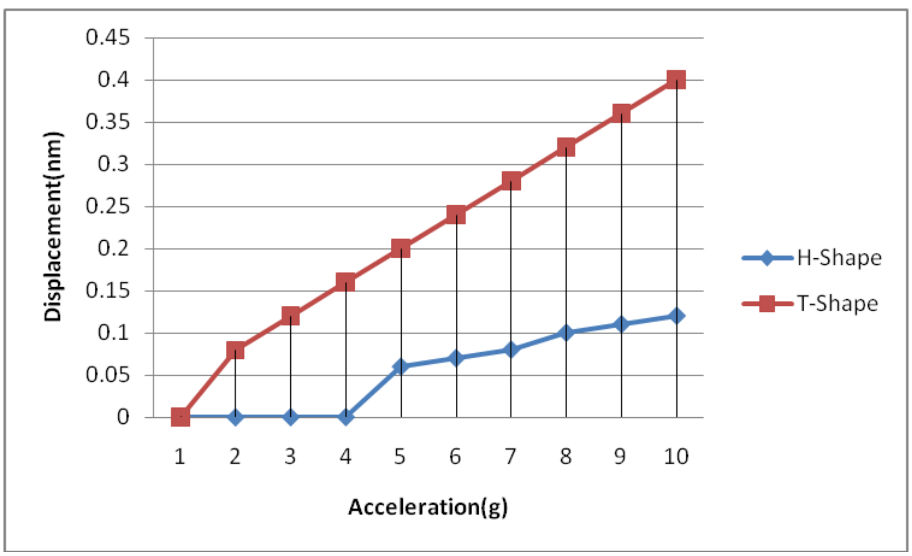


(b)

Fig. 2: (a) & (b) Displacement at 10g T-shape and H-shape respectively.

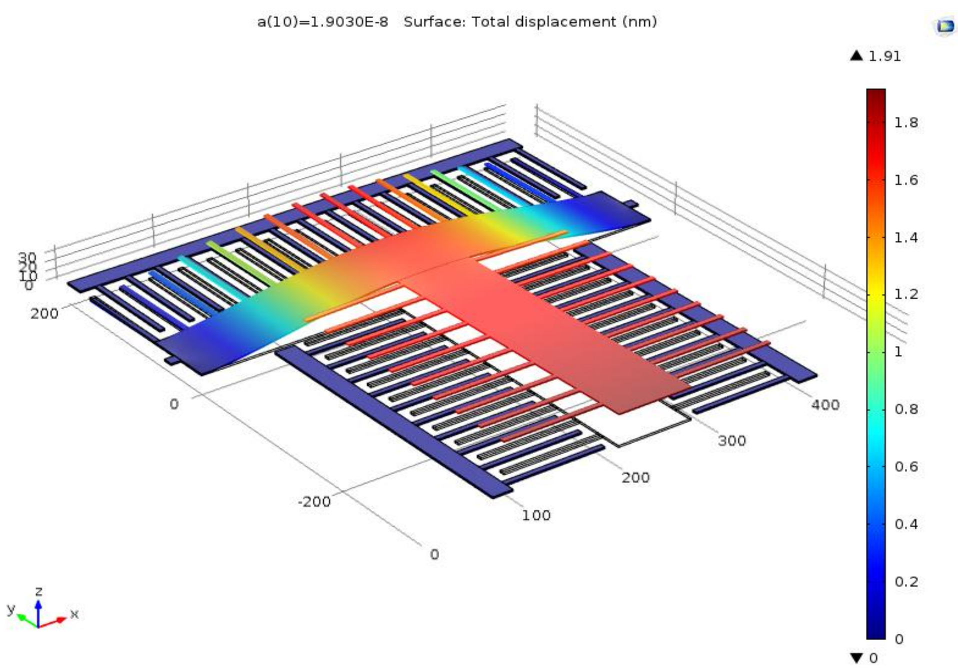


Graph 1: Acceleration (1g to 10g)Vs Displacement

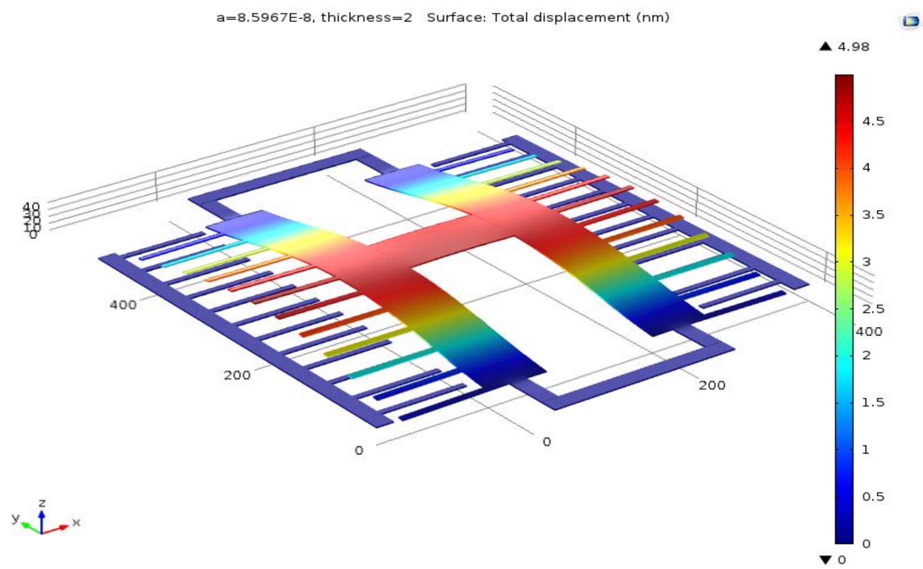
The displacement has found with respect to the thickness at acceleration 10g as shown in below table2.The Thickness of the entire model has varied from 10 to 2 µm .The displacement is varied from 0.0002 to 1.91nm for T-shape,0.06 to 4.98 nm for H- shape w.r.t the thickness 10 to 2 µm respectively. The maximum capacitance at 10g acceleration with 2 µm for H- shape is 7.03e-14 fF and T-Shape is 2.28e-13 fF.

Thickness(µm)	T-Shape	H-Shape	T-Shape	H-Shape
	Displacement(nm)		Sensitivity(nm/g)	
10	0.0002	0.06	0.00002	0.006
9	0.0002	0.1	0.00002	0.01
8	0.0003	0.12	0.00003	0.012
7	0.0005	0.16	0.00005	0.016
6	0.08	0.25	0.008	0.025
5	0.12	0.4	0.012	0.04
4	0.23	0.74	0.023	0.074
3	0.54	1.63	0.054	0.163
2	1.91	4.98	0.191	0.498

Table 2: Thickness Vs Displacement

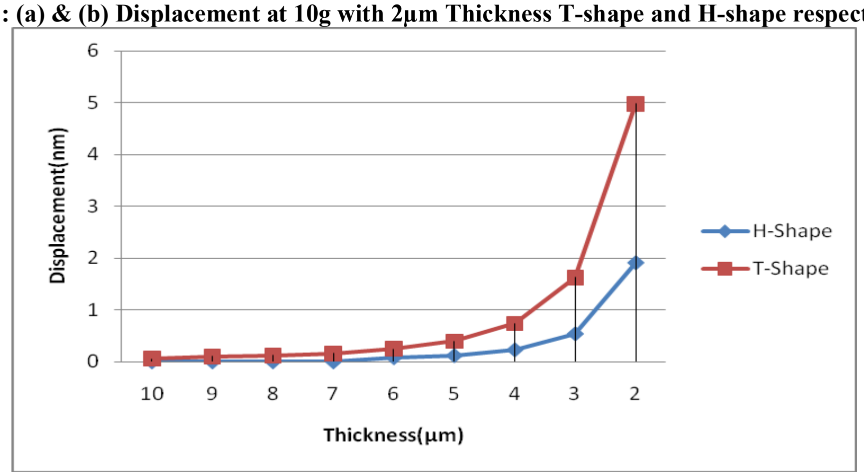


(a)



(b)

Fig. 3: (a) & (b) Displacement at 10g with 2µm Thickness T-shape and H-shape respectively.



Graph 2: Thickness Vs Displacement at 10g Acceleration

Length of the Proof mass (µm)	T Shape	H Shape	T Shape	H Shape
	Displacement (nm)		Sensitivity (nm/g)	
500	1.7	4.55	0.17	0.455
600	1.41	3.96	0.141	0.396
700	1.85	7.3	0.185	0.73
800	7.43	15.1	0.743	0.151
900	19.8	23.8	0.198	0.238
1000	42.2	57.2	0.422	0.572

Table 3: Length of the Proof mass Vs Displacement

Width of the Proof mass (µm)	T Shape	H Shape	T Shape	H Shape
	Displacement(nm)		Sensitivity(nm/g)	
100	1.33	3.96	0.133	0.396
90	1.56	4.3	0.156	0.43
80	1.69	4.68	0.16	0.468
70	1.91	4.98	0.191	0.498
60	2.3	5.23	0.23	0.523
50	2.82	15.8	0.282	0.158
40	3.79	21.5	0.379	0.215
30	7.45	35.8	0.745	3.58

Table 4: Width of the Proof mass Vs Displacement

Conclusion

Most of the parameters in differential capacitive accelerometer like the finger dimensions, the beam dimensions and length of the sensor need to be chosen attentive. The results obtained by varying certain dimensions for better displacement sensitivity and capacitive sensitivity. The dimensions of the differential capacitive accelerometer have one of the major advantage to improve the sensitivity. It is observed that the displacement sensitivity has been improved by changing the beam length, width and thickness. As observed, by decreasing the thickness , width and increasing length practically achieved high sensitivity for a device.

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