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Analalysis and Modelling Of 2D Model Comb Drive For Folded Flexure Beam Using COMSOL 3.5

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***Abstract*— A new design of electrostatic comb drive actuator is presented in this paper by using different spring designs and with different folded beam lengths. An increased displacement of lateral comb drive actuator will subsequently be accomplished with the same actuation voltage. Stress distribution over different spring designs are simulated by COMSOL 3.5a using a standard comb drive with 4 movable comb fingers with respect 130V.**

***Index Terms*—MEMS, Electrostatic Comb Actuators, Flexure actuator, COMSOL 3.5**

I. LITERATURE SURVEY

Swati Kapoor et.al COMSOL Multiphysics 3.5a is used for the designing purpose as it offers Finite element analysis to prove the concept of controlled displacement of the movable comb fingers, achieved by prescribing the amount of electrostatic force generated by the device [1]. Shefali Gupta Stiffness produces a direct relationship between the applied voltage and the displacement covered by the finger the Comb-Drive due to its low stress, low stiffness, high sensitivity and low spring constant[2]. Tolga Kaya et al. modal analysis was also used to find the fundamental modes of vibration and frequencies, in order to avoid resonance and identify the device range of operation [3]. At the end, a series of three-dimensional electrostatic finite element analysis was conducted to calculate the mutual capacitance between the moving and [4] fixed fingers when the proof-mass is subjected to in-plane design acceleration.

II. METHODOLOGY

The comb drive actuator typically consists of a movable electrode consisting of one or more finger like features forming a interdigitated comb like pattern with a fixed electrode [5, 6, 7]. The inter digitated pattern ensures that the normal force between the electrodes in Y direction is cancelled out. When a voltage is applied between the movable electrode and one fixed electrode, based on which fixed electrode is activated, the movable electrode will move laterally in X direction towards it. This movement will continue till the tangential electrostatic force due to all the active fingers are balanced by the elastic force of the spring suspension. This position is the balanced displacement and the corresponding electrostatic force is the actuation force. Actuation force is independent of the overlapping distance. The spring suspension is not shown in the figure, but the comb drive is designed to move in X direction and should be prevented from moving in Y direction. So the spring constant should be calculated for Y axis and based on that the beam design should be done. The movable electrode in the picture has six fingers, only three of which on one side will be activated at one time. Using this design form, the balanced displacement, the actuation force and the minimum spring constant to prevent Y axis movement can be estimated. Assuming the supply voltage is the critical voltage that would force the fingers to move in Y direction, the minimum spring constant required in Y axis is calculated. If the spring constant is below this value, for the given voltage, the movable electrode will become unstable and move in Y axis till it hits the fixed electrode. Keeping the spring constant in Y above this value would ensure that the comb-drive is stable. The plot shows the relationship between the applied voltage and the lateral displacement for the given comb drive.

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III. MODAL ANALYSIS:

The comb-drive actuator works on the basis of electrostatic force acting between a pair of misaligned comb fingers. Consider two prismatic solids assume that they are misaligned in the longitudinal direction with voltage applied between them. Then, there will be an electrostatic force as indicated approximately by the field lines. If one of the fingers is held fixed, the other will then be moved so as to align them. This is how the motion is created in this device. The force of attraction between the fingers is given by the following formula. To see how the ratio of the stroke length to the overall size of the actuator scales for a fixed voltage, consider a simplified lumped-model of the comb-drive as a spring-mass system [8]. The mechanical stiffness of the suspension in the direction of the movement is denoted by *k* and has the form

$$C = \frac{2n\varepsilon_0 t(y_0 + y)}{g}$$

Where, t is the thickness of comb finger, y0 is the initial overlap, y is the comb displacement and g is the gap spacing between movable and fixed combs. The design parameters of comb drive are

$$F_e = \frac{\varepsilon_0 t V^2}{2g}$$

$$k = \frac{2Etw^3}{l^3}$$

Where *l* is the length of the suspension, *w* is its width, and *t* its thickness and *E* is the young's modulus of the material.

Assuming N force interactions between pairs of fingers, the Electrostatic force is given by[9]

$$F_e = \frac{N\varepsilon_0 t V^2}{2g}$$

Then, the displacement of the shuttle mass will be

$$\delta = \frac{F_e}{k}\left(\frac{N\varepsilon 0 V^2}{4E}\right)\frac{l^3}{gw^3}$$

From which we can write relative deflection taking the length of the suspension beams as the
Indicator of the overall size.

$$\frac{\delta}{l} = \left(\frac{N\varepsilon_0 V^2}{4E}\right)\frac{l^2}{gw^3}\alpha L^{-2}$$

It can be seen that for a fixed voltage, the relative deflection scales as $L-2$. This means that the
Stroke length dramatically increases with downsizing whereas it would be negligibly small when it is made at the large size scale. Another way to look at this is by looking at the voltage for a desired relative stroke length as shown below

$$V = \left(\sqrt{\left(\frac{\delta}{l}\right)}\left(\frac{4E}{N\varepsilon_0}\right)\left(\frac{gw^3}{l^2}\right)\right)\alpha L^{-2}$$

M

Properties of Polysilicon	
Property	**Parameters**
Young's Modulus	**170e9[Pa]**
Poisson's Ratio	**0.22**
Density	**2320[kg/m^3]**
Thermal Expansion	**2.6e-9[1/k]**
Relative Permittivity	**4.5**

IV. RESULTS:

The basic structure consists of 5 fixed and 4 movable combs attached to folded flexure spring having 6μm distance between the comb fingers. The fixed fingers are grounded and the voltage is applied on the movable combs as shown in figure.1and 2. Graph shows the variation of Comb drive displacement VS the driving voltage for several folded flexure spring designs is shown in figure 3. Figure 4 shows variation of Comb drive displacement VS Flexure length.

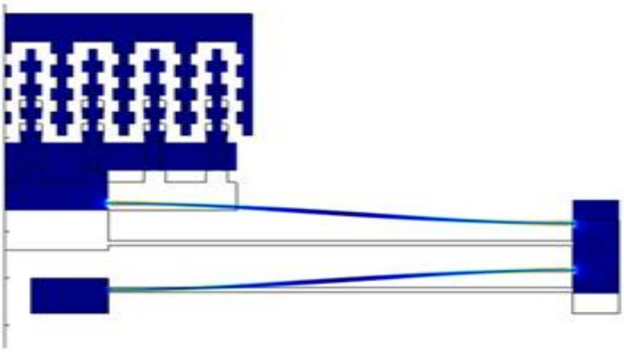

Figure1: Movable Comb for 50 Voltage

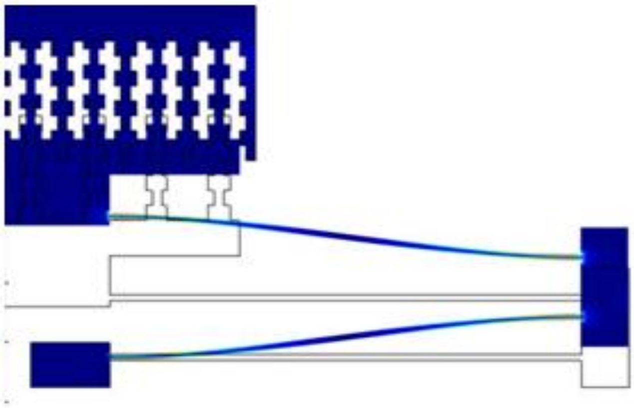

Figure2: Movable comb for 600 Voltage

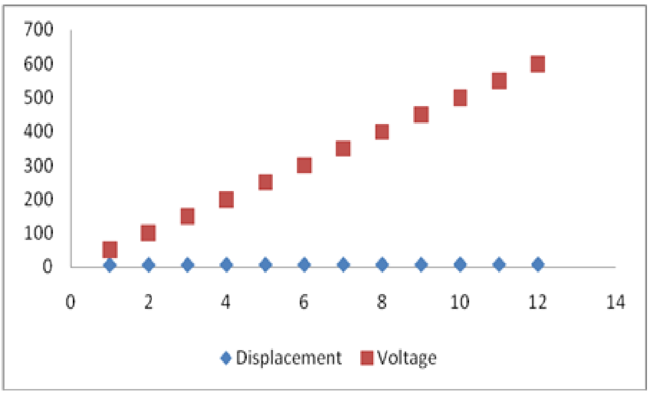

Figure.3 The variation of Comb drive displacement VS the driving voltage for several folded flexure spring designs

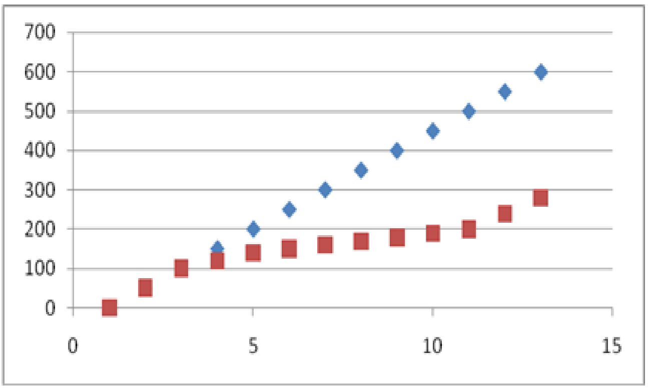

Figure.4 The variation of Comb drive displacement VS Flexure length

V. CONCLUSION

A large deflection, low-driving-voltage comb-drive actuator has been designed and fabricated by a one-mask fabrication process using boron doped polysilicon as the structural material and silicon dioxide as the sacrificial spacer. The lateral Young's modulus of the polysilicon layer has been obtained from static displacement-to-voltage measurements and is approximately 170 GPa. The spring stiffness in actuation direction is shown to decrease with the increase of the comb drive folded flexure length. From the results it can be concluded that folded flexure spring is a key factor for optimization of the Comb – Drive due to its low stress, low stiffness, high sensitivity and low spring constant.

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