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MEMS parallel plate beam actuator: Correlation study of pull-in voltage and dielectric layer beyond 1µm displacement

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Abstract: MEMS electrostatic parallel plate beam actuators can be comprehensive within pull-in with the existence of an intermediate dielectric layer, which has a major outcome on the performance of such actuators. In this research, .MEMS parallel plate actuator with intermediate dielectric layer was simulated to study the relationship between pull-in voltage and thickness of dielectric layer. Higher dielectric thickness gives more regular and predictable behavior, thus variable dielectric thickness was tested with a view to obtaining desired characteristic beyond pull-in. Many MEMS devices operate beyond pull-in, e.g., capacitive switches, zipper varactors, and coplanar waveguide (CPW) resonators. The actuator designed consists of two parallel plate electrodes with dielectric layer in between, and dielectric layer with varying thickness were simulated using Intellisuite in order to observe pull-in voltage beyond 1µm displacement required.

Keywords:MEMS parallel plate actuator; pull-in voltage; dielectric layer;

1. Introduction

In recent years, Micro Electro Mechanical System (MEMS) electrostatic actuators have been widely applied in many sectors such as communication and military. Most of these devices operate in the constant voltage drive mode [1]. However, the electrostatic force associated with the drive or bias voltage used in this mode is nonlinear and gives rise to the well-known phenomenon of ‘pull-in’ that causes a beam to collapse on the backplane if the bias voltage exceeds certain limit. Accurate determination of the pull-in voltage is critical in the sensor or actuator design process in order to determine the sensitivity, frequency response, distortion, and the dynamic range of the device [1]

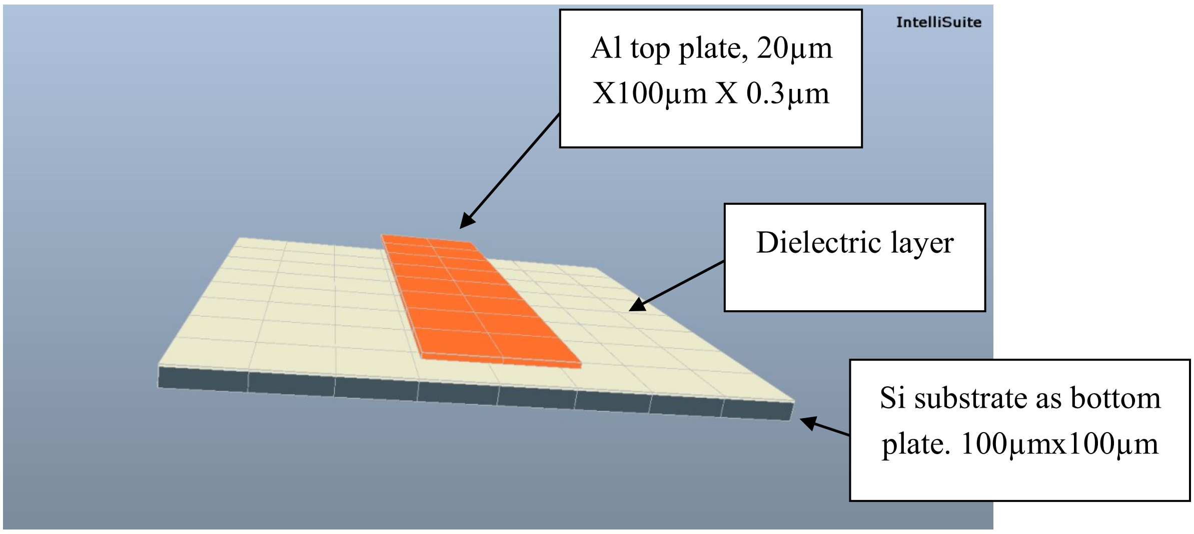
MEMS electrostatic parallel plate actuators can be extended beyond pull-in with the presence of an intermediate dielectric layer, which has a significant effect on the behavior of such actuators [2].

In this research, MEMS parallel plate beam actuator which consists of two parallel plate electrode insulated by a dielectric layer is designed, as shown in Fig. 1. The dielectric layer primarily serves to avoid the electric short circuit between two conducting plate electrode surfaces [3]. The variation of dielectric layer thickness was analyzed to see the pull-in voltage that will be generated within 1µm displacement of the beam. When voltage is applied between the movable plate electrode and the fixed bottom electrode, electrostatic charges are generated on both electrodes. This will caused electrostatic force to stir the top plate electrode towards the bottom electrode. Due to the application of voltage, the bending deformation of parallel plate takes place. The deformed electrode stores the elastic energy which will restore the parallel state when voltage is removed [4].

2. Experimental Section

The MEMS parallel plate actuators system in this work is design as fixed beam of two parallel plates as shown in Fig. 1. One plate is fixed electrode which is silicon substrate and the moveable top plate is formed using Aluminium (Al) thin film. Silicon nitride (Si_3N_4) was used as dielectric layer because of its high dielectric constant. The gap between the top and the bottom plate is 1µm. Simulations were done using TEM analysis in Intellisuite software where different thickness were experimented to analyze the relationship toward pull-in voltage.

Figure. 1: The structure model of MEMS parallel plate a top view.



3. Results and Discussion

The changes in the pull-in voltage are calculated for different dielectric layer thicknesses. Consider a parallel plate capacitor of area A_p, K is the spring constant, d is the geometric factor of the system, ε_a is permittivity of air medium, and ε_o is relative permittivity. The equation of d is:

$$d = G - T_d \frac{1-\varepsilon_o}{\varepsilon_d} \tag{1}$$

Where, G is the initial gap between the electrodes, T_d is the thickness of the dielectric layer in contact with the bottom electrode, ε_a and ε_d are the relative permittivity of air and the dielectric layer, respectively. The equation of pull-in voltage is derived by [3]:

$$X_{pull-in} = \sqrt{\frac{8Kd^3}{27\varepsilon_o\varepsilon_a A_p}} \tag{2}$$

The results below show that changes of silicon nitride thickness have some impact toward pull-in voltage. For the dielectric thickness of 0.05µm, the generated pull- in voltage is 9.3V.

Figure 2(a). The displacement of beam within 1µm (**b**).The graph result between pull-in voltage and dielectric layer thickness.

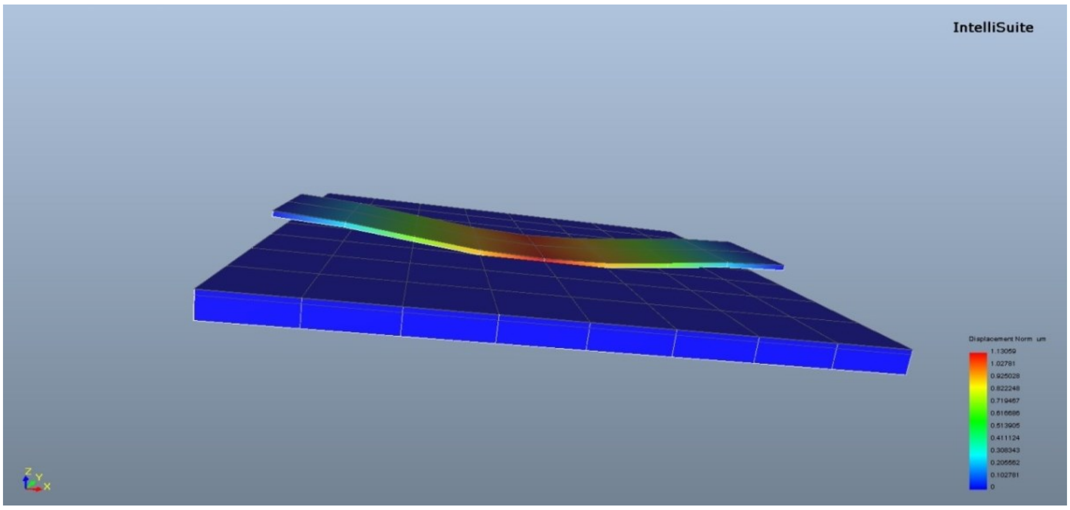


Figure 2(a)

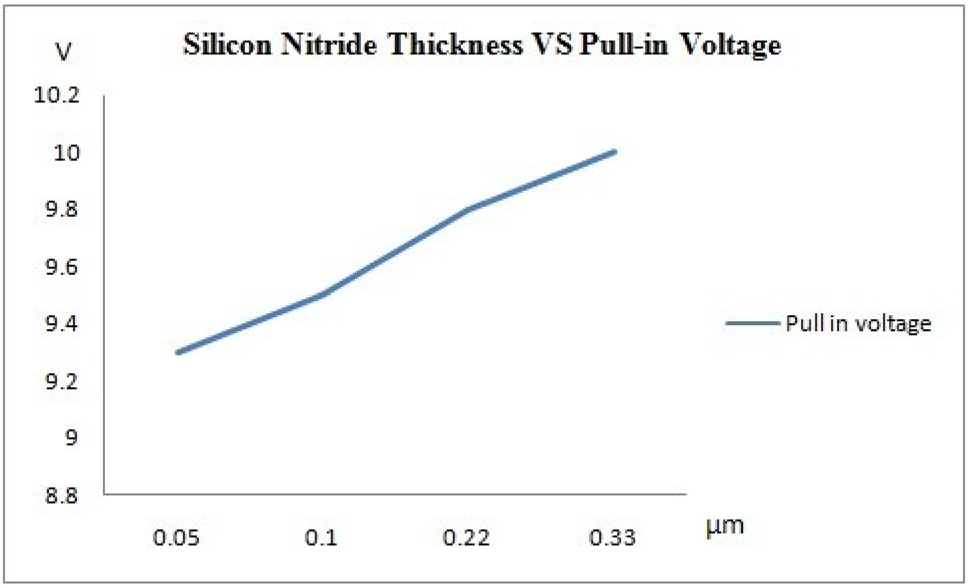


Figure 2(b)

4. Conclusions/Outlook

The MEMS parallel plate actuator beam was design and simulated using Intellisuite software. As shows in the result, the changes in pull-in voltage are calculated for different dielectric layer thickness. Higher dialectric thickness generated more pull-in voltage in this MEMS system. This preliminary finding can be used as a reference point in the design of MEMS parallel plate beam actuator.

Acknowledgments

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Conflicts of Interest

The authors declare no conflict of interest.

References and Notes

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