

Sensitivity Analysis of MEMS Flexure FET with Multiple Gates

K.Spandana ^{*1}, N.Nagendra Reddy ^{*2}, N.Siddaiah ^{#3}

^{#1} PG Student Department of ECE in K.L.University Green fields-522502, AP, India

^{#2} PG Student Department of ECE in K.L.University Green fields-522502, AP, India

^{#3} Professor Department of MEMS in K.L.University Green fields-522502, AP, India

¹ spandana.kolakaluri@gmail.com

² nelaturinnagendra@gmail.com

³ nalluri.siddu@gmail.com

Abstract—This paper deals with the design and modelling of Flexure FET and the FETs are the one of the important fundamental devices in electronic devices.. In this paper we are going analyse one of the MEMS Flexure Gate Field Effect Transistors. Here we will design gate of the FLEXURE FET with different type of materials and with different structure and we made the comparison between all the structures. We apply pull-in voltage to the Gate with respect to the change in the gate voltage the respective displacement of the gate changes which reflect the change in the drain current and sensitivity.

Keyword- flexure FET, MEMS, single gate, double gate, triple gate

I. INTRODUCTION

Present day technology is improving in way to give the exact and accurate results to the human beings. This improved technology made the things easier and faster with small efforts of humans. MEMS is kind of modern technology which give high sensitivity and less power consumption to the classical devices. For the general classical devices the sensitivity is having the certain limitations in detecting the target molecules, but MEMS devices are having the boundary which is lesser then the existing devices.

MEMS technology made the devices in a micro size so there by using the less power and having the high sensitivity [1]. In this Flexure FET is having the advantage over then the traditional sensors [2]. In the construction of the device we take a unique substrate for the source and the drain and the channel and the gate is isolated direct contact to the substrate by using the dielectric layer. The dielectric layer act as a separation layer between the substrate and the gate and the gate is suspended over the two edges of the gate which is located over the dielectric layer. The gate is act as a simple cantilever but which is fixed at the both the ends.

We apply the relative target molecule on the top of the gate layer with the detection of the respective target molecule on the top of the gate the spring constant of the gate material changes which results in the relative change in the displacement of the gate of the FET. This change in relative shift in the gate material alters the respective channel current from drain to source. For measuring the sensitivity of the design we plot graph between applied pressure and the displacement in the gate and also plot drawn for applied voltage and the drain current.

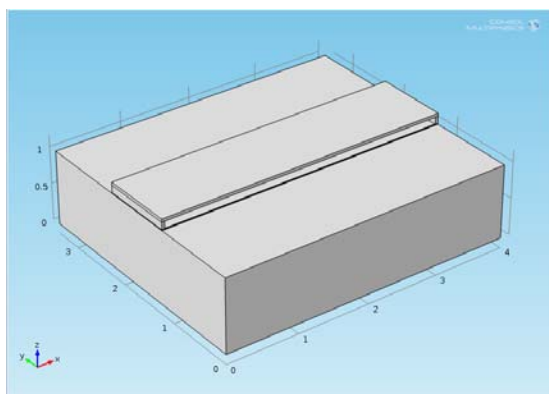


Fig 1: Single gate Flexure FET

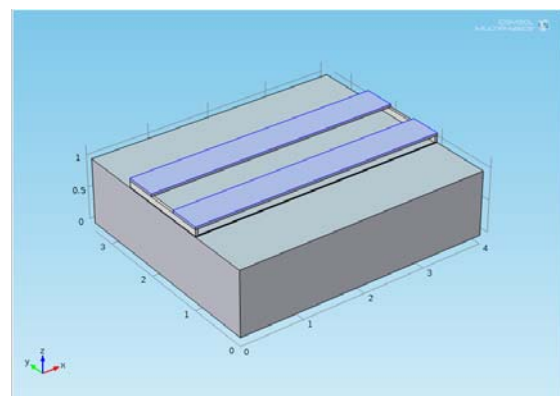


Fig 2: multiple gate Flexure FET

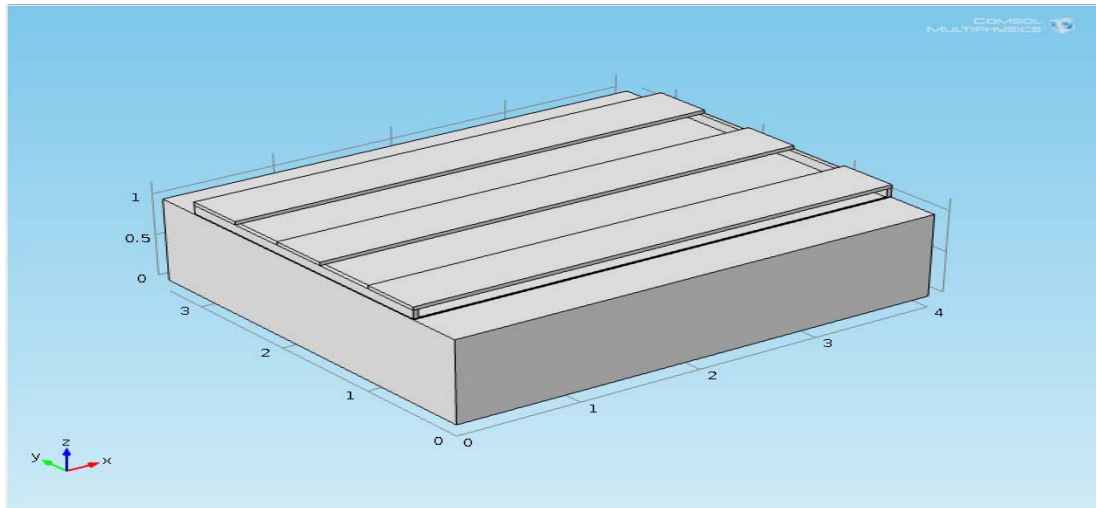


Fig 3: multiple gates Flexure work

The numbers in the above describes 1 is the gate metal 2 for dielectric layer and 3 for the substrate.

II. STRUCTION AND MATERIAL OF THE PROPOSED DESIGN

The structure of the intended design is the substrate is separated from the gate by using the dielectric layer. The gate is suspended on the top of the dielectric stratum below is the channel and the above is a metal gate. We are using different metals and we have given one table below to specify the properties of metals that we are using in model. We have shown two different structures one is a single gate and another is a multiple gate Flexure FET. The gate dimensions for both designs are unique but differ number only [3][4].

For single gate as well as for the multiple gates we are going to use the single metal. The dimension for the both the designs are described in the table 2. We are using SiO₂ is as the insulator between the channel and the gate, the space between the suspended gate and the sio₂ layer is filled with air which is act as a dielectric layer

TABLE I. Specifications of the intended FLEXURE FET design

| Design parameters | Design parameter | | |
|-------------------|------------------|------------------|-----------|
| | Gate | Dielectric layer | Substrate |
| Length (um) | 1 | 1 | 3.4 |
| Width (um) | 4 | 4 | 4 |
| Thickness(um) | 40 | 10 | 1 |

TABLE 2. Gate material and their properties

| Design parameter | | |
|------------------|-----------------|-------------------------|
| Metal | Property | Value |
| Gold | Density | 193000kg/m ³ |
| | Young's modulus | 70*10 ⁹ pa |
| | Poisson's ratio | 44 |
| Poly silicon | Density | 2023 kg/m ³ |
| | Young's modulus | 160*10 ⁹ pa |
| | Poisson's ratio | 22 |
| Germanium | Density | 5223 kg/m ³ |
| | Young's modulus | 103e ⁹ pa |
| | Poisson's ratio | 0.2 |

III. WORKING PRINCIPLE OF THE FLEXURE FET

In the design of the Flexure FET we are using a metal gate which is suspended over the dielectric layer with the help of supporting hands at the two edges. The entire structure is having a uniform dimension for the gate source and drain. The gate act as a two side fixed cantilever. When we are applying the voltage to the metal gate then there occurs a mechanical effect which displaces the gate from its centre point of its original rest position vertically.

This mechanical effect shift the gate towards substrate direction as a result thickness of the dielectric layer is reduces (the air gap), because of decrement in the air gap capacitance of the device is changes. This change in the capacitance will form an inversion channel in the substrate form drain to source and existence of current takes place because of the inversion charge. For measuring the sensitivity of the device we fix the gate voltage at a certain voltage and we alter the voltage between source and drain. The vertical displacement is measured with reference to the length of the gate and also with respect to capacitance is recorded for measuring the sensitivity [5].

The formula how the mechanical effect in the gate metal changes the inversion charge of the channel is given by equalizing the spring constant of gate and the electrostatic forces. Because of solitary and flexibility of this device we can use this for ultrasensitive application in bio sensing as well as current switch and for memory applications[6][7]. Then below graph shows the displacement of the gate with respect to the applied different gate voltages. We have shown both single gate as well as the multiple gates Flexure FET..

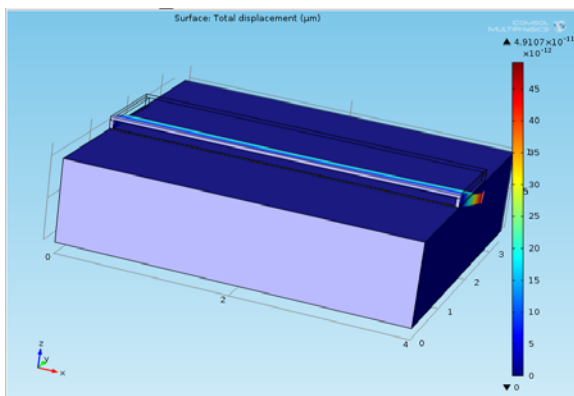


Fig 4: Displacement of single gate

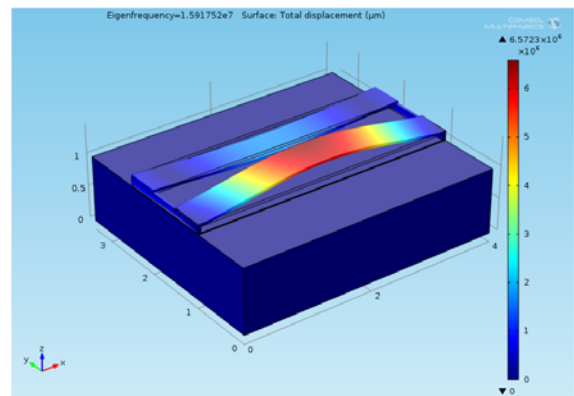


Fig 5: Displacement of double gates

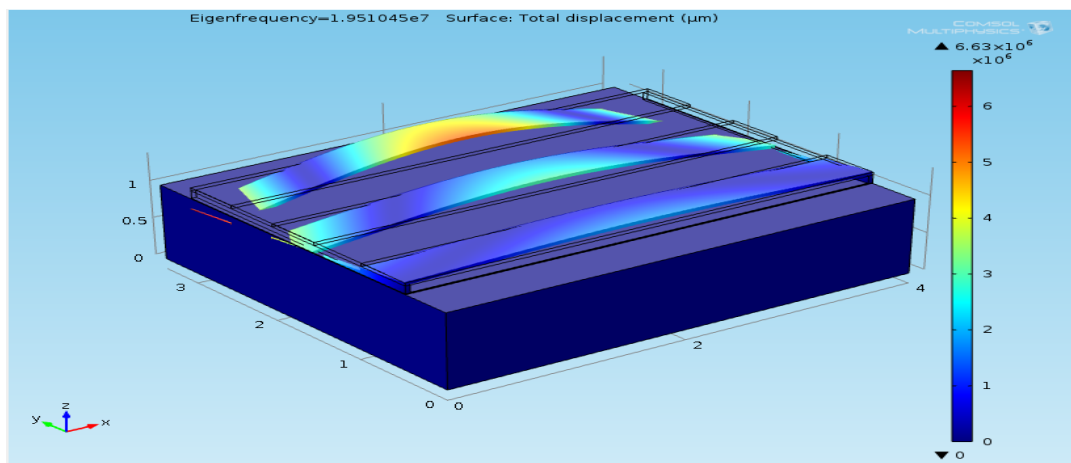


Fig 6: Displacement of multiple gates

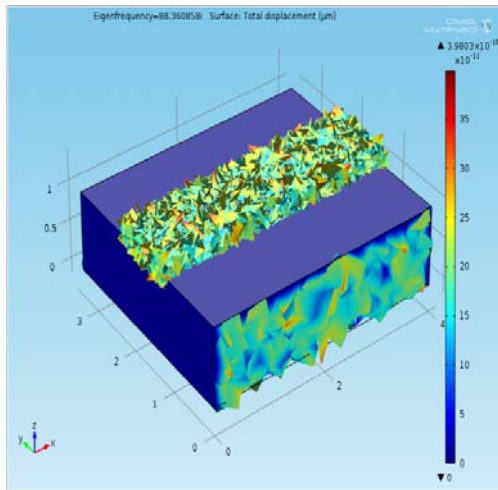


Fig7: Stress of Single gate

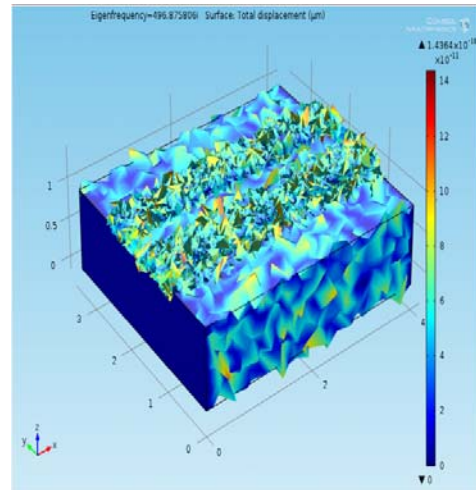


Fig8: Stress of Double gate

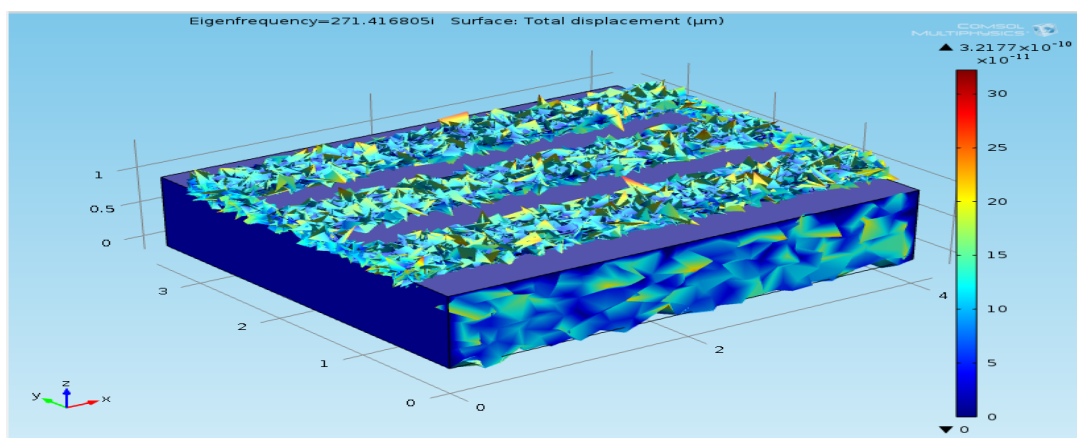


Fig 9: Stress of Multiple gates

IV. ANALYSIS OF RESULTS

The above figure 1 show the geometric structure of the Flexure FET in which the gate is suspended above the supporting arms, the figure 2 show the respective displacement of the gate with the applied pull in voltage. The double gate structure is having the more displacement when compared with the single gate structure [8]. The gate is moveable in vertical direction which is help in changing the gate capacitance when the gate moves downwards vertically which reduces the distance between the gate and the dielectric layer as a results capacitance is induces in the channel and the current from drain to source increase. We have given different pull in voltages to the gate and we have drawn respective current ratios for single gate and double gates [9]. We know that the for a normal FET the drain current is increase with increase in the gate voltage here also as the pull in voltage increase the drain current also increase in drastic manner because of high sensitivity of the device . In the case of transferable single gate and the multiple gates.

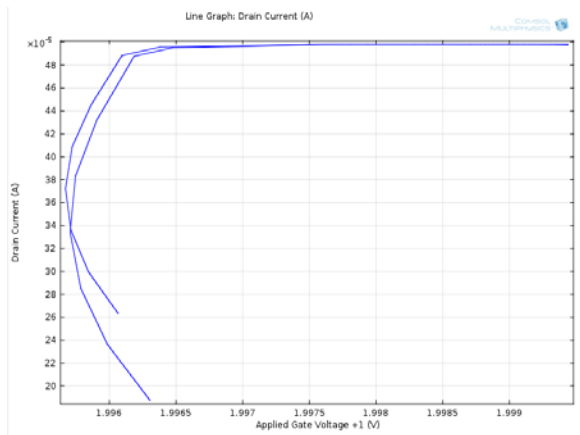


Fig 10: Single Gate Drain Current and the Applied gate voltage of Flexure FET.

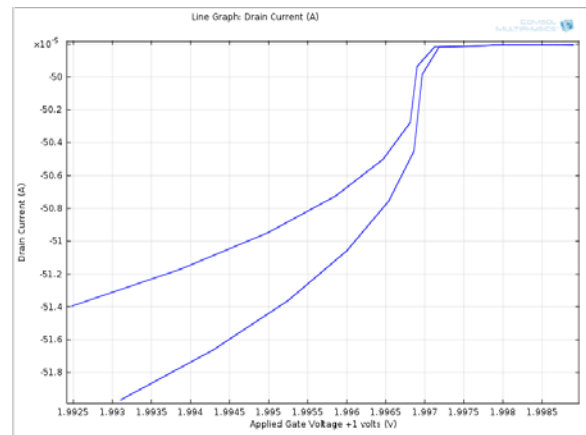


Fig 11: Multiple gate drain current and the Applied Gate Voltage of Flexure FET

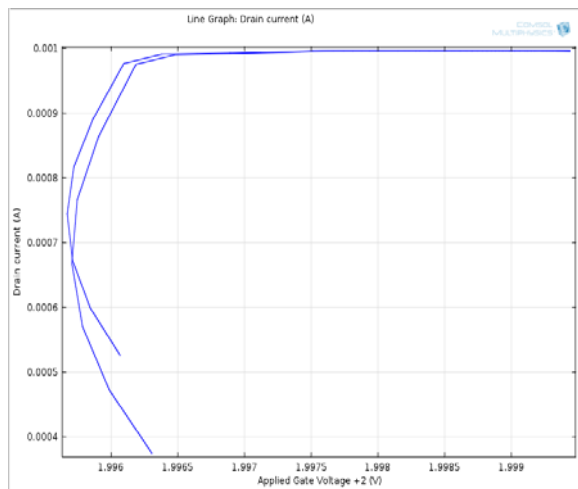


Figure 12: Single gate drain and drain current vs gate voltage of Flexure FET with gold as gate Gate metal.

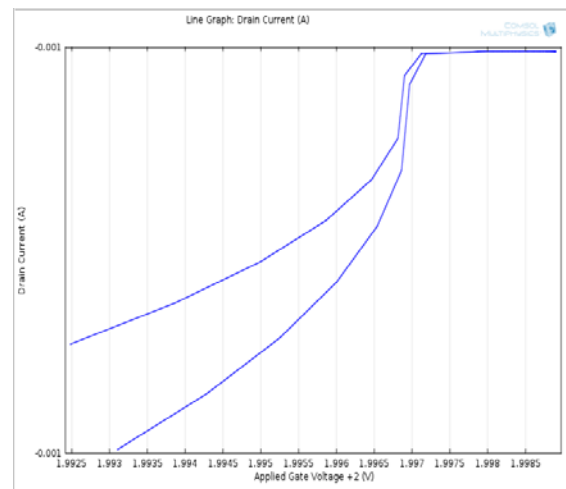


Fig 13: Multiple gate drain and drain current vs applied gate voltage of Flexure FET with gold a Gate metal

V. CONCLUSION

This paper has shown the design and simulation of Flexure FET. The FET with the single gate is having less pull-in voltage when compared to the double gate FET. The induced capacitance increases with increase in the gate area as results we having more sensitivity with increasing the gate area. But there is a problem occurs as the area is increase the power dissipation is increases but this is neglected when compared to the increased sensitivity of the device. We design the gate with different metals we have to choose the metal which will give the appropriate results with the desired application. So MEMS technology made this possibility by introducing this concept of the Flexure FET which is having many applications like current switch and bio sensor applications.

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AUTHORS PROFILE

K.Spandana is pursuing M. Tech VLSI Design in KL University. Her research interests include MEMS Design, Biosensors, Cantilever sensors, Piezoelectric Devices and Low Power VLSI.

N.Ngendra Reddy is pursuing M. Tech VLSI Design in KL University. His research interests include MEMS Design, Biosensors, Cantilever sensors, Piezoelectric Devices and Low Power VLSI.

N.Siddaiah presently working as associate professor in KLUniversity. His research interests include, MEMS Design, Biosensors,Cantilecer sensors,Pezoelctric Devices and Biological sensors.