

# International Journal of Innovative Research in Science, Engineering and Technology

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## Analyzing the Effect of Fringing Field in Etching Holes

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**ABSTRACT:** Etching the large area of sacrificial layer under the microstructure to be released is a common method used in microelectromechanical systems technology. In order to completely release the microstructures, many etching holes are often required on the microstructure to enable the etchant to completely etch the sacrificial layer. However, the etching holes often alter the electromechanical properties of the micro devices, especially capacitive devices, because the fringe fields induced by the etching holes can significantly alter the electrical properties. This article is aimed at evaluating the fringe field capacitance caused by etching holes on microstructures. The authors aim to find a general capacitance compensation the fringe capacitance of etching holes by the use of COMSOL simulation. According to the simulation results, the design of a capacitive structure with small etching holes is recommended to prevent an extreme capacitance decrease. The dimensions of the sphere truncates the modelling space. This paper studies the dimensions of this air domain and its impact upon the capacitance and effect of etching holes of different width. To analyze the impact of fringing field during a capacitance and during the etching holes, we've got design a 2 capacitive models one could be a rectangular model and another could be a rectangular model with different widths of etching holes between the plates of the capacitance.

**KEYWORDS:** Fringing Field, Etching Holes, Capacitance, COMSOL.

### I. INTRODUCTION

For MEMS technology field, the accurate determination of capacitance is an important issue because which affects the performance of capacitive devices. For example, the fringing field capacitance should be considered to exactly determine the electromechanical behavior of a curled cantilever beam. Moreover, for the semiconductor industry, the capacitance estimation of the MIM capacitor, interconnection, and MOS capacitor also affect the performance of the whole circuit. The three-dimensional fringing fields must be taken into consideration if the wires or microstructures are short. Therefore, how to fast and accurately determine the three-dimensional capacitance becomes a major task in order to improve device quality.

There are several types of capacitors usually used nowadays, such as parallel-plate capacitors, MIM capacitors, comb capacitor etc. Among the aforesaid kinds of capacitors, parallel-plate capacitor can be regarded as a typical and basic model of capacitor. However, most parallel plate capacitance models lead to very large errors due to the rapid size-shrink of devices encountered in the present day. Thus, analyzing the characteristics of a parallel-plate capacitor with fringing field effect is essential.

### II. PROBLEM STATEMENT

Formula to calculate the capacitance of a capacitor only gives us the value due to direct fields only. But there also exist a field on the edges of the capacitive devices called as fringing field. In this paper we proposed a more accurate model to compute the effect fringing field on capacitance. We found that the devices with minimum gap produce more capacitance and the effect of fringing field travel more distance. Fringing is the bending of the electric flux lines near the edge of the parallel plate capacitors. Fringing is also known as " edge effect ". Normally the flux lines inside

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the capacitor are uniform and parallel. But at the edges, the flux lines are not straight and bend slightly upward due to the geometry. This is known as fringing effect.

In the fabrication process of micro devices, it is generally required to etch the sacrificial layer under the microstructure to form a movable sensing or actuating microstructure: such a method is called the release process. To completely and rapidly etch the sacrificial layer, generally a lot of etching holes are made on the microstructure to be released, which enables the etchant to uniformly and rapidly permeate into the sacrificial layer. The arrangement of etching holes, including the density, size, shape, etc, depends on the properties of the etchant, namely the etching rate and selectivity between the materials of the microstructure and the sacrificial layer. However, etching holes may alter the characteristics of the device, such as mechanical properties, magnetic field, and electrical field, which will significantly decrease the fabrication yield of the micro devices.

### III. MOTIVATION

Movable suspended microstructures are the common feature of sensors or devices in the fields of Complementary-Metal-Oxide-Semiconductors and Micro-Electro-Mechanical Systems which are usually abbreviated as CMOS-MEMS. To suspend the microstructures, it is commonly to etch the sacrificial layer under the microstructure layer. For large-area microstructures, it is necessary to design a large number of etching holes on the microstructure to enhance the etchant uniformly and rapidly permeate into the sacrificial layer. This paper aims at evaluating the fringe capacitance caused by etching holes on microstructures and developing empirical formulas. The formula of capacitance compensation term is derived by curve-fitting on the simulation results by the commercial software COMSOL.

### IV. EXPERIMENTAL RESULTS

The capacitor consisting of 2 metal discs during a spherical volume of air. The dimensions of the sphere truncates the modelling space. This model studies the dimensions of this air domain and its impact upon the capacitance and effect of etching hole. To analyze the impact of fringing field during a capacitance and during the etching holes, we've got design a 2 capacitive models one could be a rectangular model and another could be a rectangular model with different widths of etching holes between the plates of the capacitance.

To analyze the effect of fringing field in a capacitance, we have design a two capacitive models one is a rectangular model and another is a rectangular model with different widths of etching holes.

#### A). Rectangular Plate Model with no hole

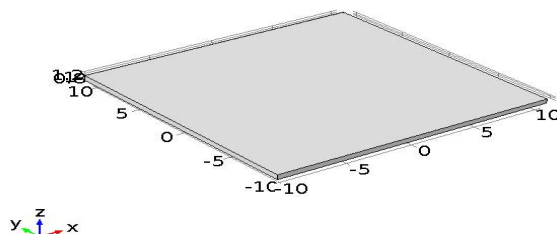


Figure 1: first rectangular plate.

First we draw a block with length and width of  $21 \mu\text{m}$  and height of  $0.5 \mu\text{m}$  as shown in above figure.

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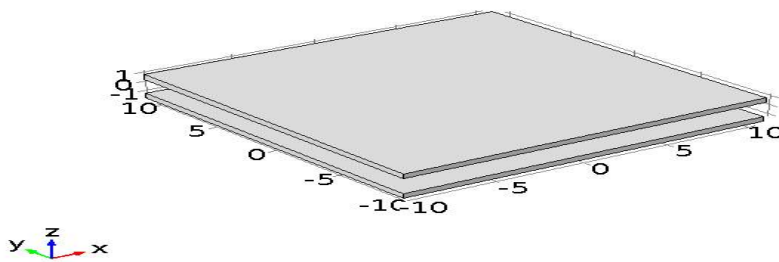


Figure 2: Second rectangular plate.

Then we draw another block of same dimension as first rectangle with a gap of 2  $\mu\text{m}$  between the both blocks.

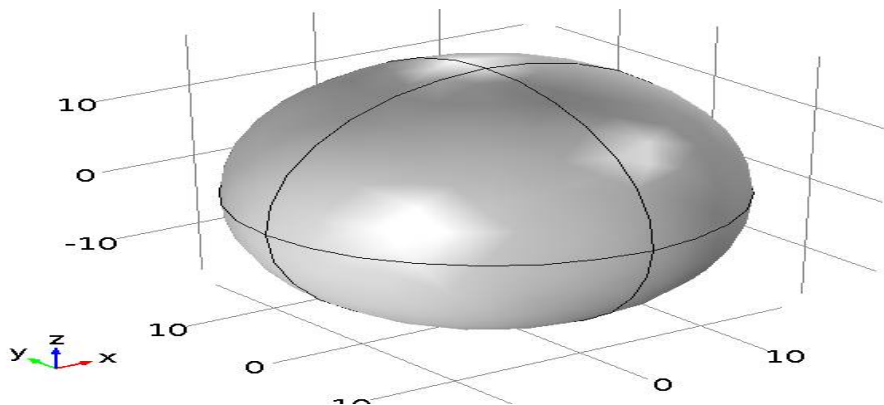


Figure 3: Air domain.

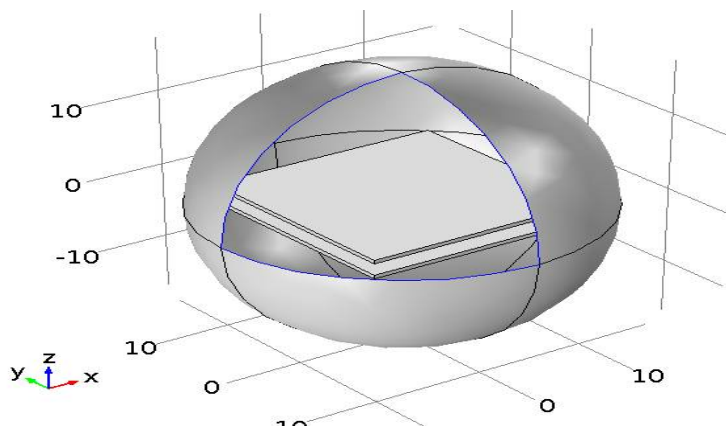


Figure 4: Final Model Geometry.

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Then we draw an air domain sphere with  $17\ \mu\text{m}$  radius, to analyze the fringing field effect of capacitor.

Figure 4 shows the final model design, the outer sphere shows the air domain and the inner two block plates act as capacitor.

## B). Rectangular Plate Model with hole width $1\ \mu\text{m}$

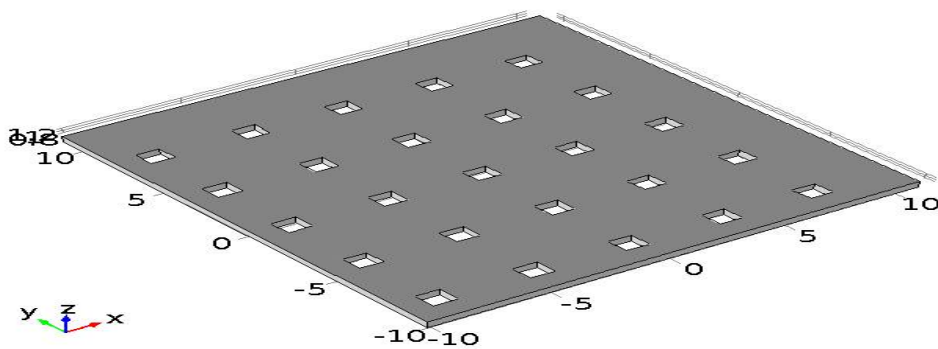


Figure 5: Rectangular Plate with  $1\ \mu\text{m}$  hole.

First we draw a block with length and width of  $21\ \mu\text{m}$  and height of  $0.5\ \mu\text{m}$  as shown in above figure with  $5 \times 5$  array of etching holes of width  $1\ \mu\text{m}$ .

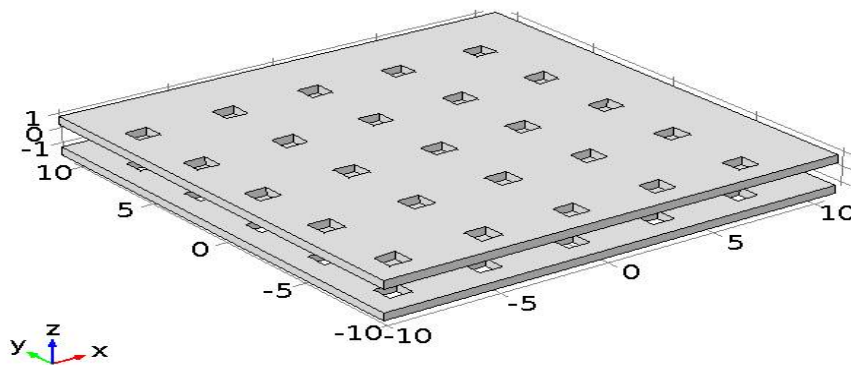


Figure 6: parallel rectangular plate with  $1\ \mu\text{m}$  hole.

Then we draw another block of same dimension as first rectangle with a gap of  $2\ \mu\text{m}$  between the both blocks.

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## C). Rectangular Plate Model with hole width 2 $\mu\text{m}$

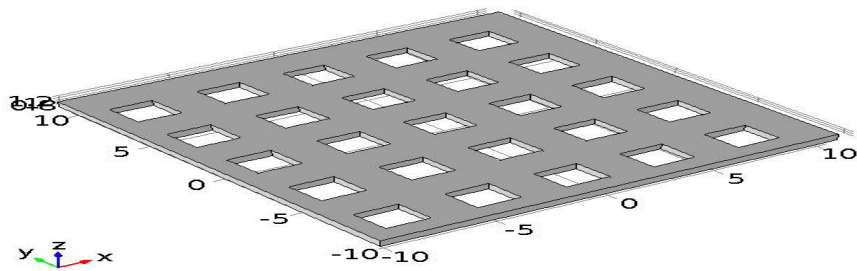


Figure 7: Rectangular Plate with 2 $\mu\text{m}$  hole.

First we draw a block with length and width of 21  $\mu\text{m}$  and height of 0.5  $\mu\text{m}$  as shown in above figure with 5\*5 array of etching holes of width 2 $\mu\text{m}$ .

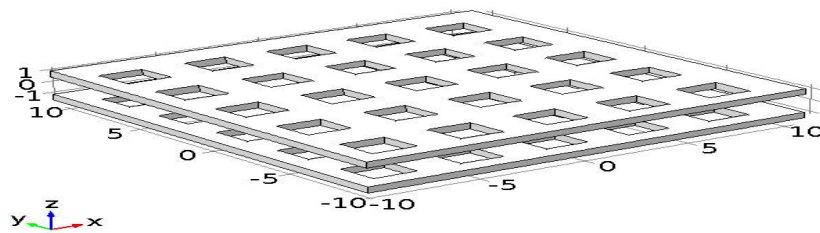


Figure 8: parallel rectangular plate with 2 $\mu\text{m}$  hole.

Then we draw another block of same dimension as first rectangle with a gap of 2  $\mu\text{m}$  between the both blocks.

## D). Rectangular Plate Model with hole width 3 $\mu\text{m}$

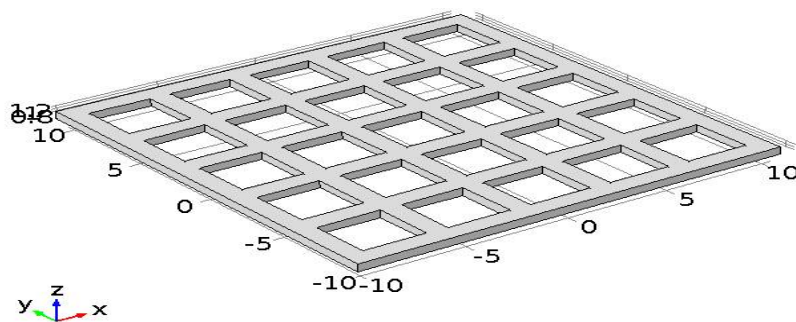


Figure 9: Rectangular Plate with 3 $\mu\text{m}$  hole.

First we draw a block with length and width of 21  $\mu\text{m}$  and height of 0.5  $\mu\text{m}$  as shown in above figure with 5\*5 array of etching holes of width 3 $\mu\text{m}$ .

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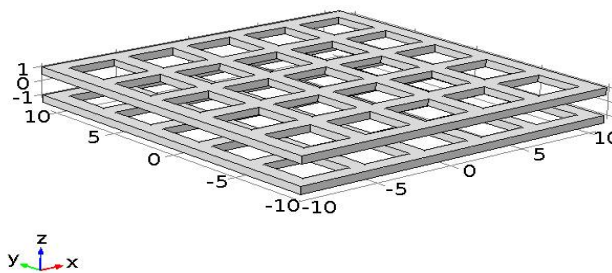


Figure 10: parallel rectangular plate with 1um hole.

Then we draw another block of same dimension as first rectangle with a gap of 2  $\mu\text{m}$  between the both blocks.

## APPLYING MATERIAL

Both the models are made up of perfect conductors. The capacitor consisting of two metal discs in a spherical volume of air. The size of the sphere truncates the modeling space. This model studies the size of this air domain and its effect upon the capacitance.

## APPLYING PHYSICS

One of the plates is specified as ground, with a voltage of 0 V. The other plate has a specified voltage of 1 V. It is only the difference in the voltage between these plates that affects the capacitance and electric field strength, the voltage itself is arbitrary.

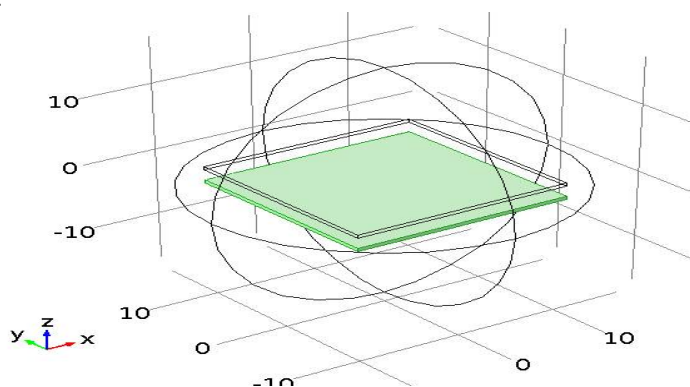


Figure 11: Terminal plate.

The air sphere boundary can be thought of as one of two different physical situations: It can be treated as a perfectly insulating surface, across which charge cannot redistribute itself, or as a perfectly conducting surface, over which the potential will not vary.

The modeling realization of the perfectly insulating surface is the Zero Charge boundary condition. This boundary condition also implies that the electric field lines are tangential to the boundary.

The modeling realization of the perfectly conducting surface is the Floating Potential boundary condition. This boundary condition fixes the voltage of all of the boundaries of the sphere to a constant, but unknown, value that is



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computed during the solution. The boundary condition also implies that the electric field lines are perpendicular to the boundary.

## MESHING

Dividing the whole model in smaller parts to further solve it further. Meshing is a technique to differentiate the model into smaller parts.

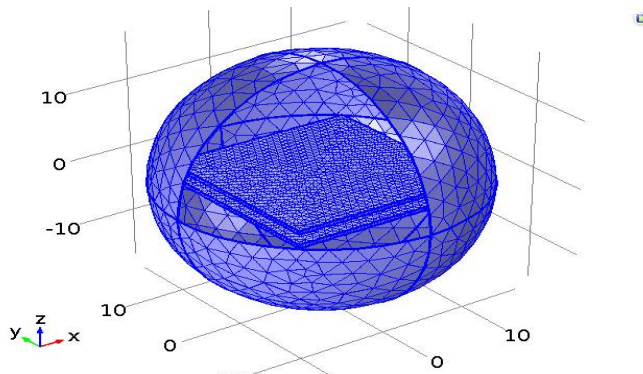


Figure 12: Meshing.

## STUDY

When studying convergence of results with respect to the surrounding domain size, it is important to fix the element size. In this model, the element size is fixed as the domain size is varied as shown in figure 13.

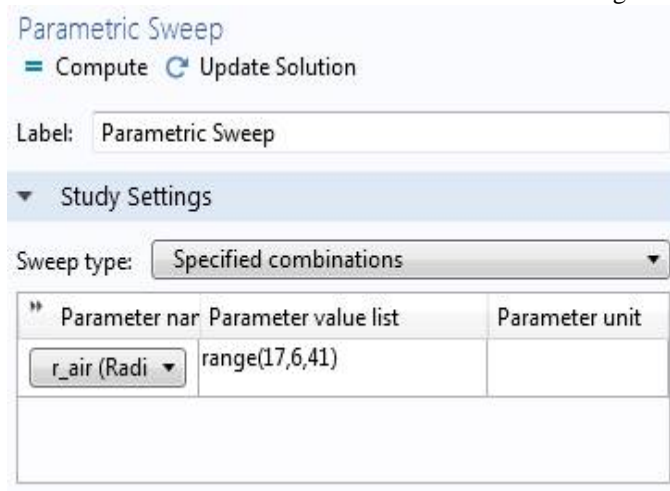


Figure 13: Study Setting.

### A). Models with no gap:

Electric Field in rectangular model with no hole is shown in figure 14. The electric field for the cases where the air sphere boundary is treated as perfectly insulating is given 1.59GV/m and 1.59GV/m for perfectly conducting, respectively. The fields terminate differently on the boundaries of the air sphere.

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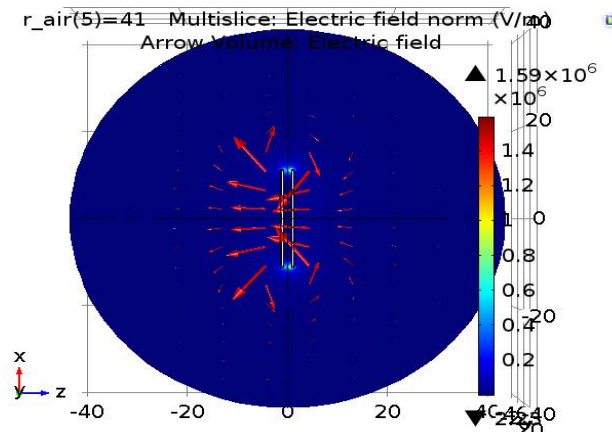


Figure 14: The electric field norm (multislices) and electric field (arrows) for the case of the Floating

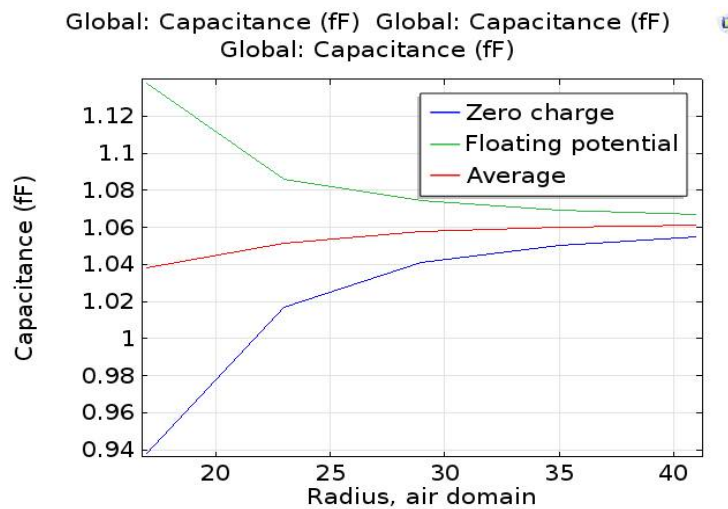


Figure 15: Capacitance of rectangular model with no hole.

The capacitance for the floating potential is larger than the 1.12 fF and the zero charge capacitance is less than 0.94 fF and the average value of the two is given by 1.04 fF for no hole model.

## B). Models with 1 $\mu\text{m}$ hole:

Electric Field in rectangular model with 1  $\mu\text{m}$  hole is shown in figure 17. The electric field for the cases where the air sphere boundary is treated as perfectly insulating is given 1.505MV/m and 1.506MV/m for perfectly conducting, respectively. The fields terminate differently on the boundaries of the air sphere.



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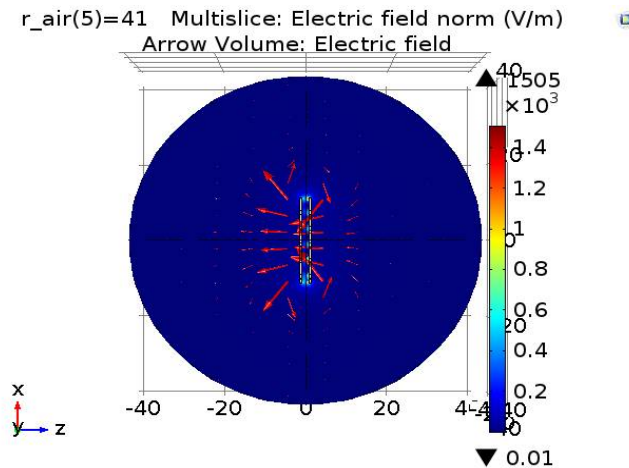


Figure 16: The electric field norm (multislices) and electric field (arrows) for the case of the Floating Potential boundary condition of rectangular model with 1  $\mu\text{m}$  hole.

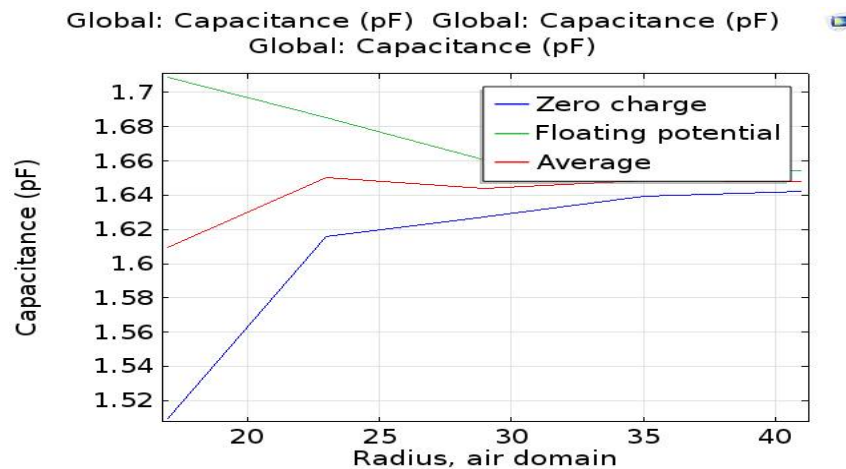


Figure 17: Capacitance of Circular model with gap 1  $\mu\text{m}$ .

The capacitance for the floating potential is larger than the 1.7 fF and the zero charge capacitance is less than 1.52 fF and the average value of the two is given by 1.64 fF for the rectangular model with 1  $\mu\text{m}$  hole.

### C). Models with 2 $\mu\text{m}$ hole:

Electric Field in rectangular model with 2  $\mu\text{m}$  hole is shown in figure 18. The electric field for the cases where the air sphere boundary is treated as perfectly insulating is given 1.663MV/m and 1.663MV/m for perfectly conducting, respectively. The fields terminate differently on the boundaries of the air sphere.

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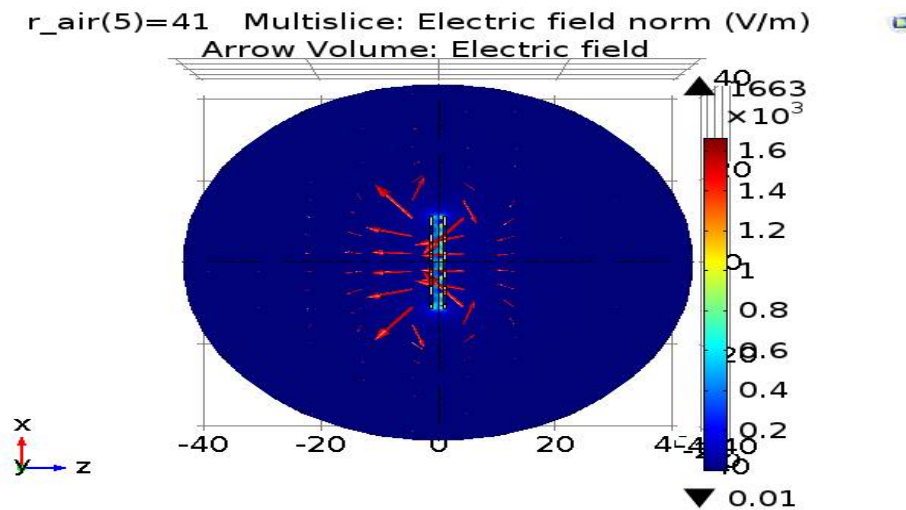


Figure 18: The electric field norm (multislices) and electric field (arrows) for the case of the Floating Potential boundary condition of rectangular model with 2  $\mu\text{m}$  hole.

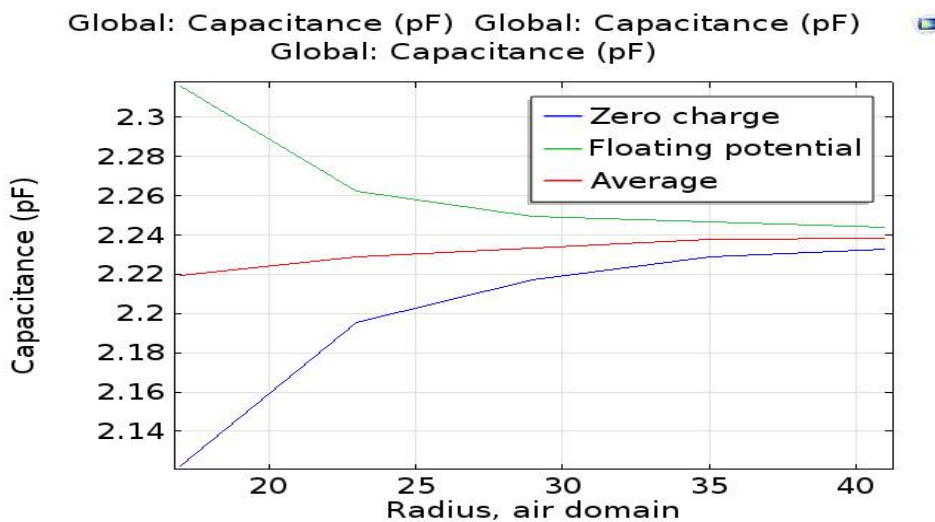


Figure 19: Capacitance of Circular model with gap 2  $\mu\text{m}$ .

The capacitance for the floating potential is larger than the 2.3 fF and the zero charge capacitance is less than 2.14 fF and the average value of the two is given by 2.22 fF for the rectangular model with 2  $\mu\text{m}$  hole.

### D). Models with 3 $\mu\text{m}$ hole:

Electric Field in rectangular model with 3  $\mu\text{m}$  hole is shown in figure 20. The electric field for the cases where the air sphere boundary is treated as perfectly insulating is given 1.307MV/m and 1.307MV/m for perfectly conducting, respectively. The fields terminate differently on the boundaries of the air sphere.

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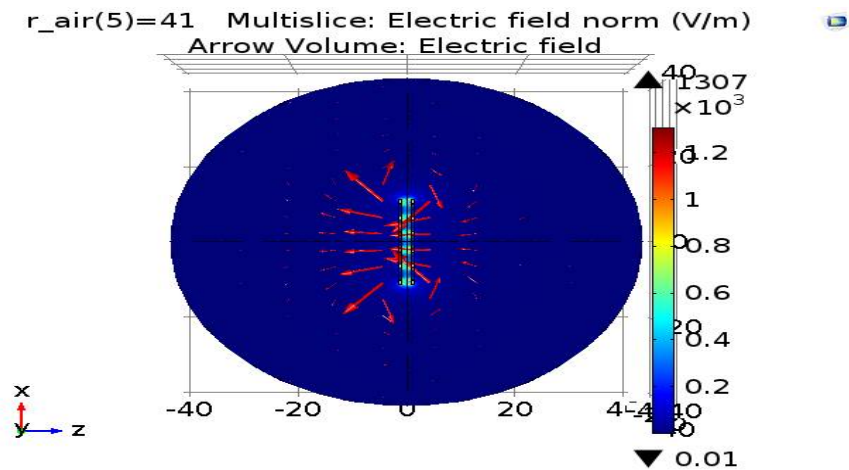


Figure 20: The electric field norm (multislices) and electric field (arrows) for the case of the Floating Potential boundary condition of rectangular model with 3  $\mu\text{m}$  hole.

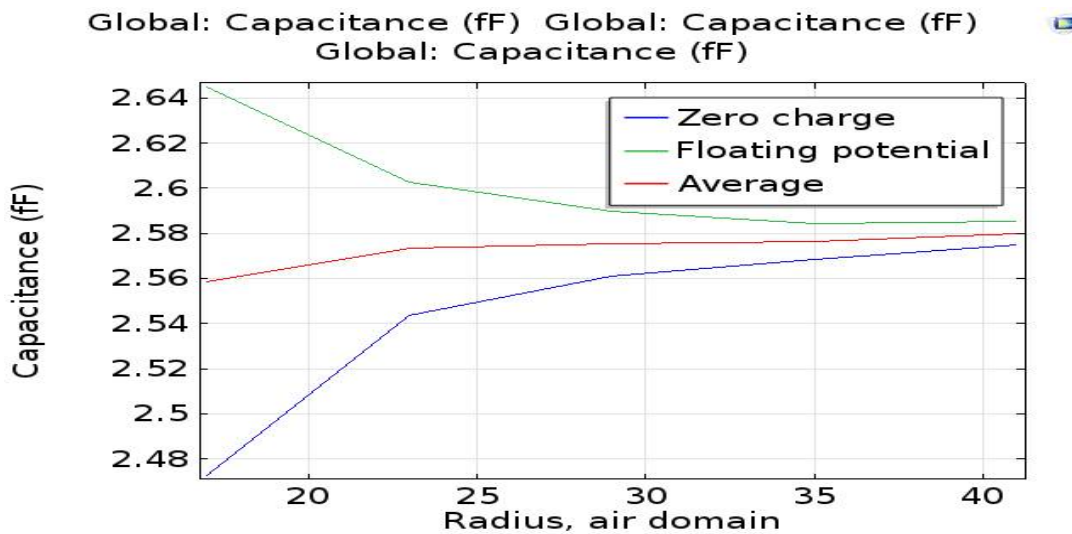


Figure 21: Capacitance of Circular model with gap 3  $\mu\text{m}$ .

The capacitance for the floating potential is larger than the 2.64 fF and the zero charge capacitance is less than 2.48 fF and the average value of the two is given by 2.56 fF for the rectangular model with 3  $\mu\text{m}$  hole.

## V. CONCLUSION

The electric field distribution produced by any disposition of insulating and conducting materials is a key aspect in electrical design, but exact values can only be obtained in simple geometries. In this work, using commercially available F.E.M. software we show the influence of the edge-effect on the electric field distribution of a two parallel-plane conducting plates with different etching holes system surrounded by an insulating medium taking into account the thickness of the conducting plates. We compare our results with previous published works. Finally, we obtain the relationship between capacitance and insulation characteristics, with different etching holes width. Greater the etching hole width greater is the fringing field.

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