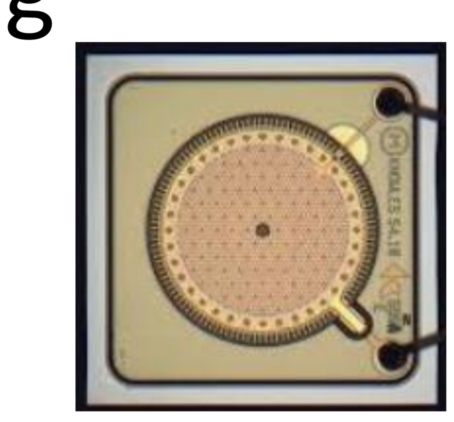
Estimating Parasitic Capacitances in MEMS Microphones using Finite Element Modeling



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INTRODUCTION: In this work, an approach to estimate the parasitic capacitances in the typical MEMS microphones using Finite Element Modeling technique is demonstrated. The parasitic capacitances are generally the acoustically inactive section that deteriorates the electro acoustics performance of the microphone. Therefore, a good estimation of parasitic capacitance is very important to improve the acoustic characteristic of the microphone. The simulated results are then compared with the analytical and the experimental results, which are in good accordance with each other.

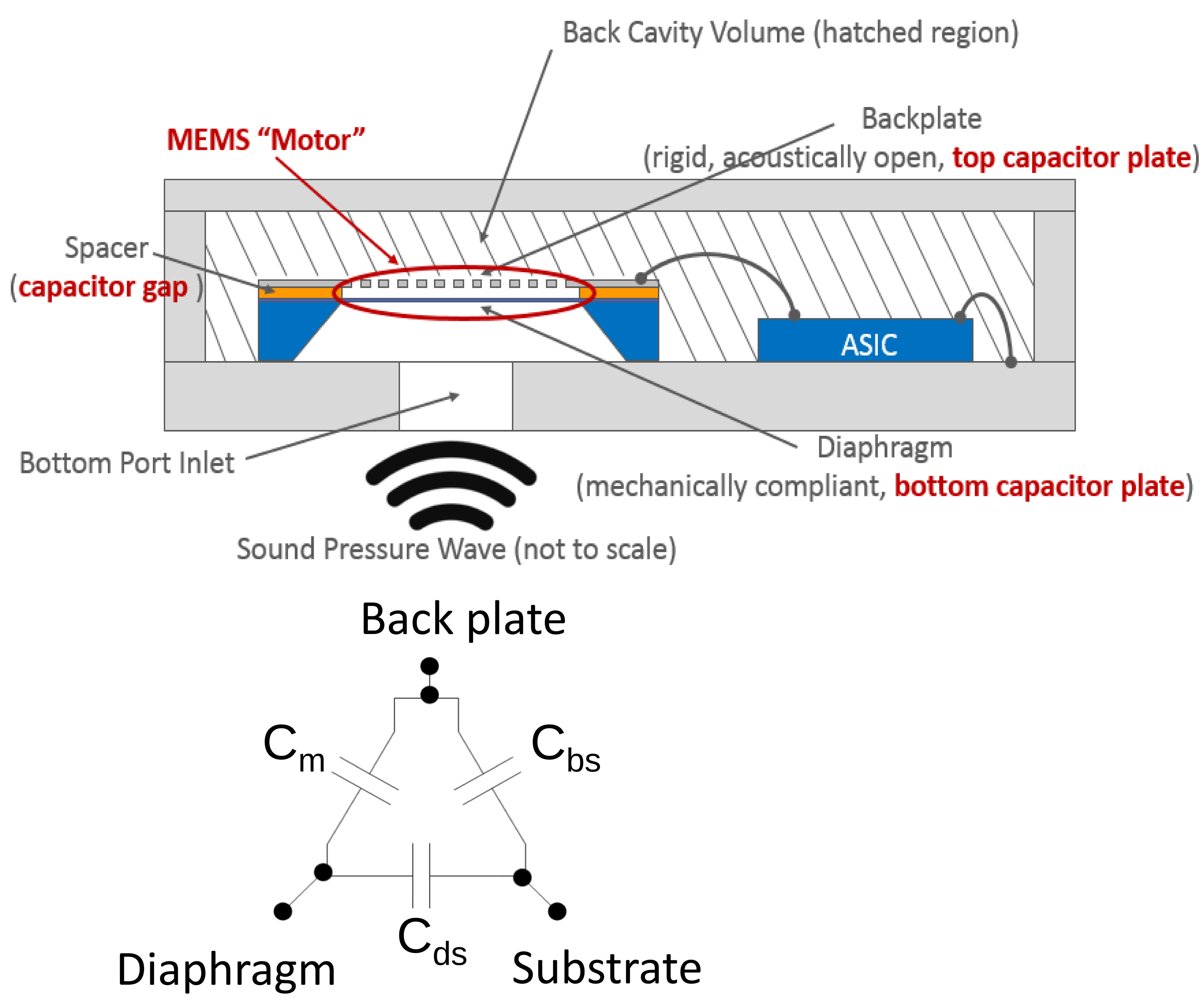

Figure 1. A typical MEMS microphone with equivalent circuit representation of parasitic capacitances

COMPUTATIONAL METHODS: 2D and 3D models have been implemented to estimate the parasitic capacitance in the AC/DC module of the COMSOL Multiphysics® simulation software. Electrostatics physics interface is used to calculate the capacitance between the diaphragm/substrate, back plate/substrate and due to bond pads and metal trace. The analytical expression is represented as mentioned.

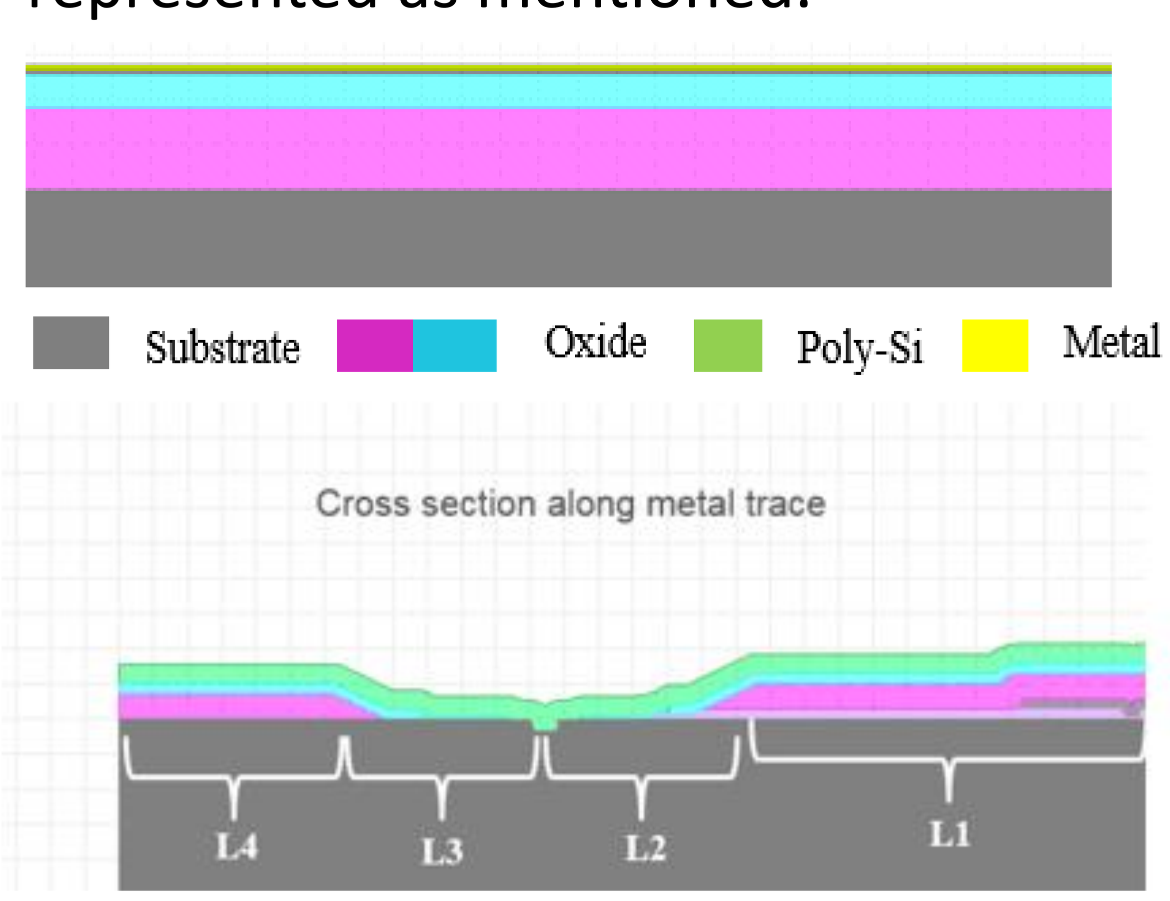

Figure 2. Cross section for diaphragm/substrate bond pad and metal trace connected to back plate

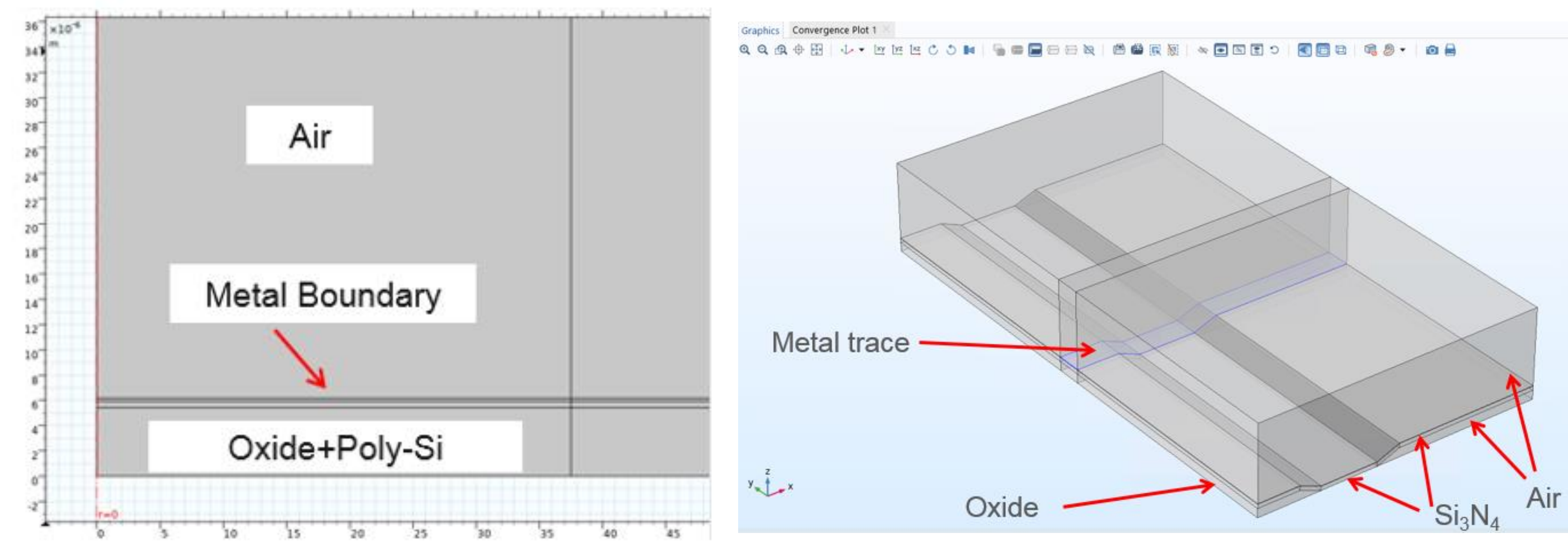

Figure 3. Simulation set up for estimating parasitic capacitances for diaphragm/substrate bond pad and back plate/substrate due to metal trace

$$Cwire = (L1 + 2 * L2)\left[\frac{w\epsilon o}{t.SiO2+\frac{t.SiN}{9.2}} + 2\pi * \frac{\epsilon o}{\log\left(\frac{t.SiO2+\frac{t.SiN}{9.2}}{Hmetal}\right)}\right] + (L4 + 2 * L3)\left[\frac{w.\epsilon SiO2}{t.SiO2+t.SiN\left(\frac{4.2}{9.2}\right)} + 2\pi * \frac{\epsilon.SiO2}{\log\left(\frac{t.SiO2+t.SiN\left(\frac{4.2}{9.2}\right)}{Hmetal}\right)}\right]$$

$$\& \; Cpad = \left[\epsilon.SiO2 * \frac{\pi r^2}{t.SiO2+t.SiN\left(\frac{4.2}{9.2}\right)}\right] + \left[\pi\,\epsilon.SiO2 * (2\pi r)\frac{1}{\log\left(\frac{t.SiO2+t.SiN*\left(\frac{4.2}{9.2}\right)}{Hmetal}\right)}\right]$$

Material	Relative Permittivity
Air	1
Silicon Oxide	4.2
Polysilicon	4.5
Silicon nitride	9.7

Parameters	Value
Si3N4 layer thickness	2.45 um
Oxide layer thickness	5.425 um
Metal thickness	0.25 um
Metal trace width	15 um
L1	160 um
L2	28 um
L3	28 um
L4	26 um

Table 1. Different material permittivity and dimensions used in design

RESULTS:

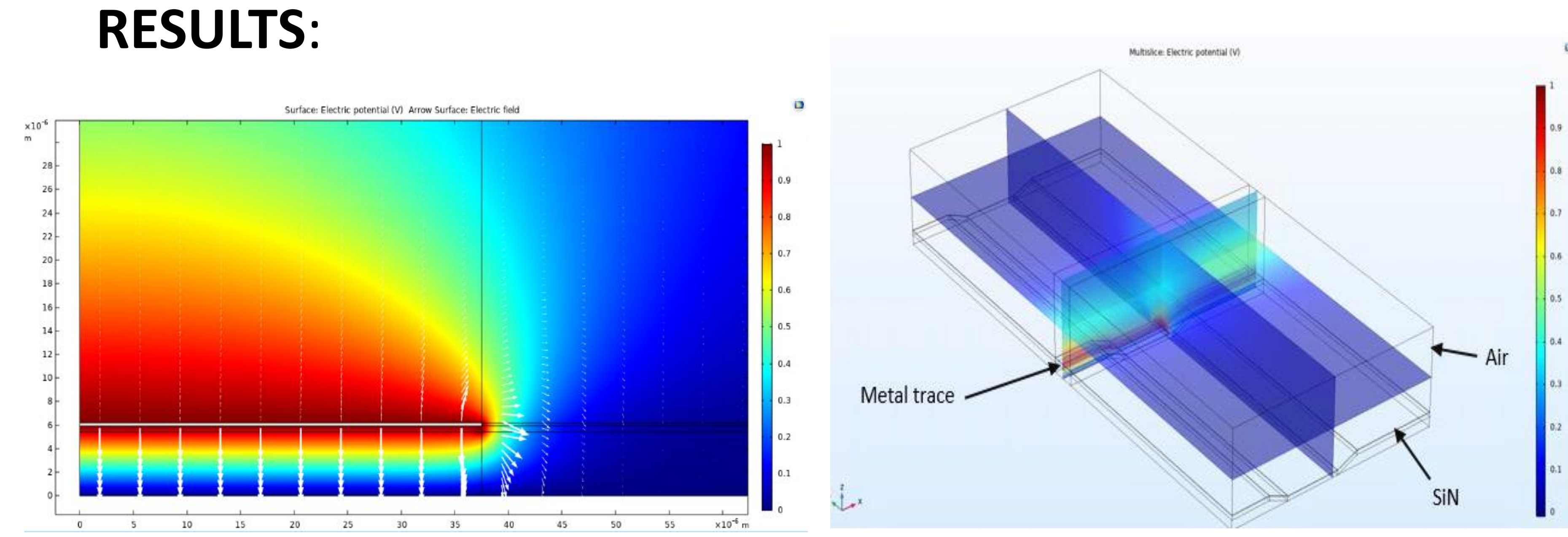

Figure 4. Electric potential and electric field distribution for diaphragm/substrate bond pad and back plate/substrate due to metal trace

	Experimental result	Analytical Calculation	FEM Simulation
Total Parasitic Capacitance	0.12pF	0.1094pF	0.11pF

CONCLUSIONS:

The obtained results with the analytical calculation and FEM using COMSOL Multiphysics® Software, simulation is within ~10% of the measured value experimentally. Thus, the simulation tool is really handy when it comes to predict the parasitic capacitance in MEMS microphones within permissible error. Future work can be done to improve accuracy of the model to match experimental data results.

REFERENCES:

[1] J. M. Rabaey, A. Chandrakasan and B. Nikolic, Digital Integrated Circuits: A Design Perspective. Prentice-Hall, 2003.
[2] E. Barke, "Line-to-ground capacitance calculation for VLSI: A comparison", IEEE Trans. Comput.-Aided Des. Integr. Circuits Syst., vol. 7, no. 2, pp. 295-298, 1988.
[3] W. C. Chew and J. A. Kong, "Effects of fringing field on the capacitance of circular microstrip disk", IEEE Trans. Microwave Theory Tech, vol. MTT-28, pp. 98-104, 1980.