Metal MEMS Membrane Based Electric Field Sensor

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Abstract

Introduction: Measuring the electric field under the HVDC transmission lines is important for several atmospheric analyses. Mills are known as conventional devices for measuring the electric field under the HVDC transmission line, however do to their high power consumption there is an interest for using low power consumption devices such as micromachined electric field mills (MEFMs) instead. Several groups have made different type of MEFMs before [1-2]. The first try by our group was an electrostatic force deflected membrane based sensor. Roncin et al. build a laser deflection measurement system (Figure 1) for measuring the deflection of the membrane [3]. The problem with the laser system was the integration and power consumption, therefore the next version of the sensor designed to use capacitive interrogation of the deflected membrane position (Figure 2) [4]. The metalized membrane will be deflected to the voltage source due to the electrostatic force and the deflection will result in the change of the capacitance between membrane and electrode beneath. The change in the capacitance is measured with a capacitance to digital convertor chip and send to the computer for post processing. The first generation of the sensor is successfully fabricated and tested by using of the SOI wafer due to the need for low stress material. However, the SOI wafers are expensive and for reducing the cost of fabrication electroplating of the low stress thick metals instead of SOI wafer could be an alternative. The other benefits of electroplated thick films (copper or nickel) are their robustness. Therefore our group is designing the next generation of our sensors with electroplated thick copper. The first step for that is simulation to check the spring constant and range of the membrane deflection for designing the sensor. Here we are presenting the sensor model and the set up which are simulated by COMSOL Multiphysics® and finally comparing the simulation results with the expected theoretical model.

Use of COMSOL Multiphysics: The sensor is consisted of a membrane which is connected to the four springs (Figure 3). The membrane is 1mm x 1mm and the springs are 30 µm wide with length of 470 µm. Two set of simulation has been done with 5 and 10 µm for thickness of the membrane and springs. By using symmetry only a quarter of the sensor has been simulated in order to save time and memory. Electromechanics module is used for defining mechanical and electrical conditions of the model. A box of air is surrounding the sensor in the model and an electrical potential is applied to the top side of that while the springs, membrane and bottom side of the box are electrically grounded. The end of each spring is defined as a fixed constraint.
Results: Due to the limitation in fabrication process and need for enough strength for the membrane, thicknesses between 2 to 10 µm are investigated. The results for the deflection of the membrane for different electric fields for thickness of 5 and 10 µm are shown in Table 1 and in

Table 2 the expected deflection values based on the theoretical formula are shown.

Reference

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[3] Andrew Roncin, Cyrus Shafai, D.R. Swatek, "Electric field sensor using electrostatic force deflection of a micro-spring supported membrane", Sensors and Actuators A: Physical, vol. 123-124, pp. 179-184, Sept. 2005.
[4] Tao chen, Ehsan Tahmasebian, Cyrus Shafai, " MEM electric Field sensor using force deflection mechanism", Manitoba material conference, Spring 2013.

Figures used in the abstract

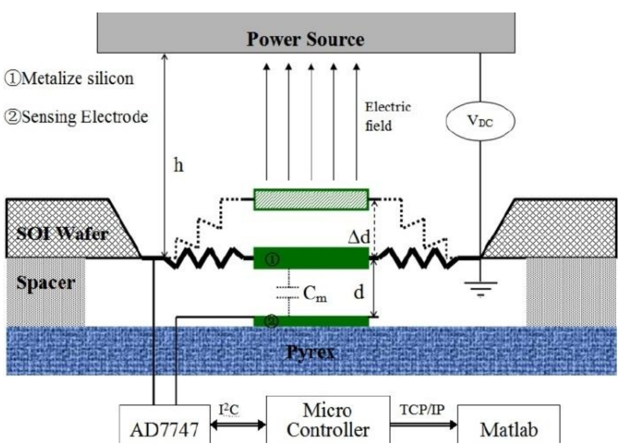

Figure 1

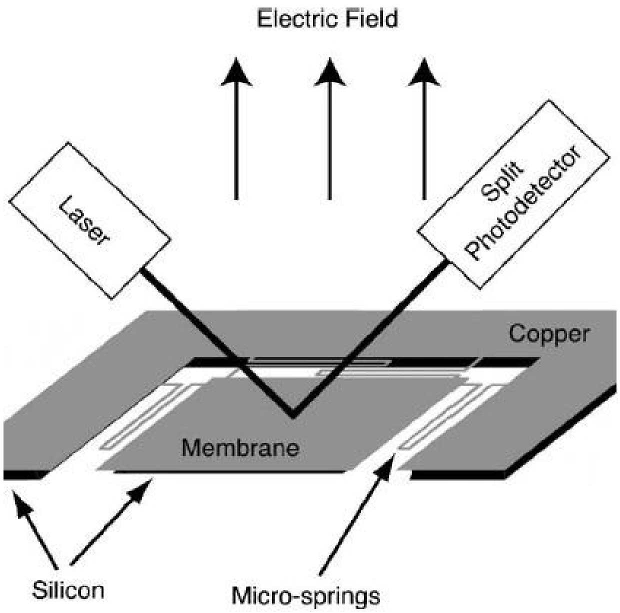

Figure 2

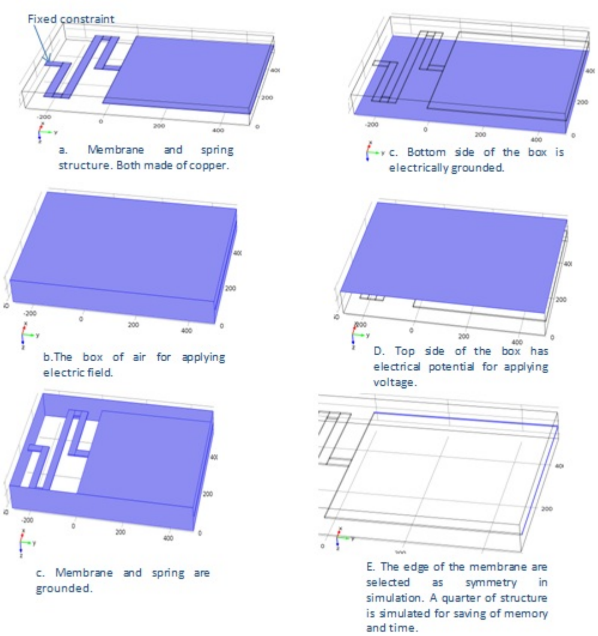

Figure 3

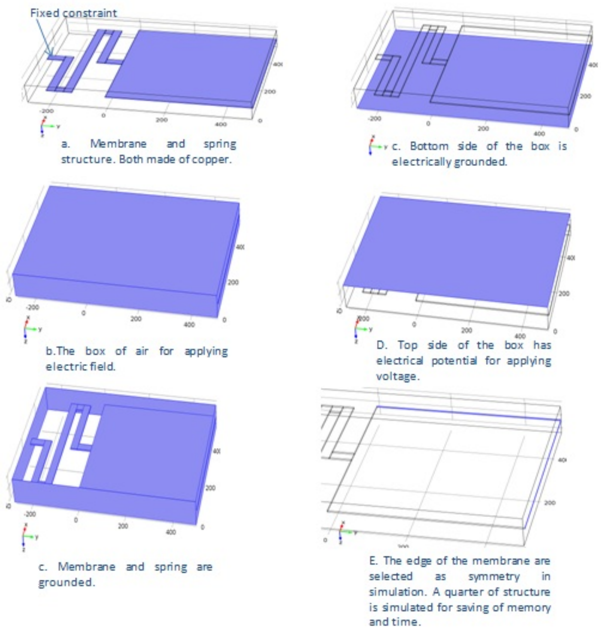
Fixed constraint
a. Membrane and spring structure. Both made of copper.
c. Bottom side of the box is electrically grounded.
b.The box of air for applying electric field.
D. Top side of the box has electrical potential for applying voltage.
c. Membrane and spring are grounded.
E. The edge of the membrane are selected as symmetry in simulation. A quarter of structure is simulated for saving of memory and time.

Figure 4