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Comparative study of RF-MEMS capacitive switch using gold than aluminum using coventorware

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Abstract: In this paper, a detailed analysis of, comparison of the beam material gold with aluminum for RF MEMS two anchor capacitive switch, has been done. The reliability of capacitive switches continues to be limited by dielectric charging. Dielectric charging occurs when electric charge tunnels into a dielectric material and becomes trapped. As a result, the applied potential is screened and device operation degrades. Eventually, the trapped charge becomes large enough that either the switch will remain in the down-state position when the actuation voltage is removed or the beam will not actuate when a voltage is applied. Choosing a proper dielectric material can minimize the dielectric charging problem and is critical for successful RF device operation. We will study the effect on using different dielectric material i.e. gold and aluminum for the switch with the help of coventorware.

Keywords: Capacitive Switch ,Coventorware, Gold Beam.

1. Introduction

The term MEMS refers to a collection of micro sensors and actuators which can sense its environment and have the ability to react to changes in that environment with the use of a microcircuit control. They include, in addition to the conventional microelectronics packaging, integrating antenna structures for command signals into micro electromechanical structures for desired sensing and actuating functions. The system also may need micro power supply, micro relay and micro signal processing units. Micro components make the system faster, more reliable, cheaper and capable of incorporating more complex functions. Micro-Electro-Mechanical-Systems (MEMS) is the technology of very small mechanical devices driven by electrical, thermal, or fluidic means. MEMS are composed of components between 1 to 100 micrometers in size (i.e. 0.001 to 0.1 mm) and MEMS devices generally range in size from 20 micrometers (20 millionths of a meter) to a millimeter. [1]

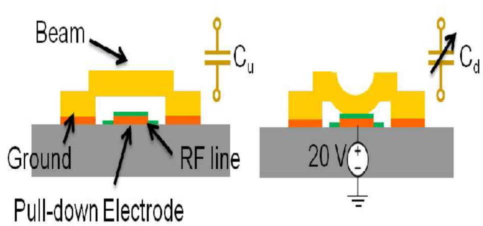

Fig. Normal and actuation mode of RF MEMS capacitive switch.[2]

The term RF MEMS refers to the design and fabrication of MEMS for RF integrated circuits. Its hold not be interpreted as the traditional MEMS devices operating at
RF frequencies. MEMS devices in RF MEMS are used for actuation or adjustment of a separate RF device or component, such as variable capacitors, switches, and filters.
The RF MEMS development to date can be classified into the following categories based on whether one takes an RF or MEMS view point [1,3].A shunt-capacitive MEMS switch consists of a thin metal membrane bridge suspended over the center conductor of a coplanar waveguide (CPW) [4] or microstrip line and fixed at both ends to the ground conductors of the CPW line .The electrostatic and electromagnetic simulation results of RF MEMS capacitive shunt switches for K-band (18-26.5 GHz) applications have been carried out, RF MEMS switches. Coplanar waveguide (CPW) is a Planar transmission line. In this Signal line and two ground lines are on the same plane. It is a substrate height independent transmission line.

2. RF-MEMS CAPACITIVE SWITCHES

A typical capacitive RF MEMS switch consists of a fixed thin metallic membrane which is encrafted over a bottom electrode insulated by a dielectric film. When the switch is not active, there is low capacitance between the membrane and the bottom electrode, and the device is in the OFF state[5]. When voltage is applied between the movable structure and the fixed bottom electrode, electrostatic charges are induced on both the movable structure and the bottom electrode. The electrostatic charges cause a distributed electrostatic force, which deforms the movable structure. In turn, such deformation leads to storage of elastic energy, which tries to restore the structure to its original shape. The structure deformation also results in the reorganization of all surface charges on the device.RF MEMS capacitive switches and switched-capacitors demonstrate low-loss, high linearity and very low power consumption compared to BST and GaAsvaractor diodes [2, 3]. However, they suffer from self actuation at high RF power levels. Self-actuation is deteriorated by the elevated temperature of the switch at high RF powers, which reduces it power handling capabilities ,. Considerable efforts have been invested in developing RF MEMS switches with low temperature sensitivity and higher power handling; designs based of special membrane materials such as molybdenum [9], curved membranes , buckle-beam design ,multitude of anchors with varying spring constant and orientation , devices with cutouts next to the anchor for improved spring design , and separation of the RF and actuation electrodes, all have been demonstrated with varying degrees of success.Capacitive switches are two-state capacitors. The typical switch is a metal bridge suspended above a CPW signal line with both ends of the bridge anchored to ground. The switch has the minimal loading effect on the signal line in this state (the passing state) and signals propagate with minimal reflection. [4,7]

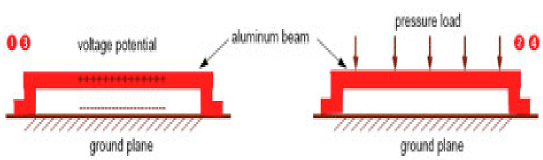

Fig. Beam Design [7]

The switch is snapped down when a voltage exceeding the electrostatic pull-in voltage is applied between the bridge and the signal line. In this state (the down-state) incident signals are reflected due to the formation of a low impedance path through the dielectric and the switch bridge to ground . From an electrical contact point of view the MEMS switches can be two types: a) Capacitive contact, and b) DC contact.

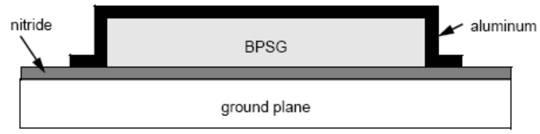

Fig. Deposition

A dielectric is deposited on top of the bottom electrode of the capacitive contact switch. When the suspended beam is in the upstate the capacitance is in the range of pF. When a DC actuation voltage is applied between the actuation electrode and the suspended beam, the suspended beam will move downward and collapse on the bottom electrode. This will increase the capacitance in the range of pF, 20-100 times higher than the upstate capacitance[6].

The upstate capacitance depends mainly on the initial gap. The downstate capacitance depends on the dielectric thickness, dielectric constant etc. SiO_2, Si_3N_4, TiO_2 can be used as dielectric for RF MEMS switches. The capacitive contact switch is suitable for high frequency application. At low frequency (DC), the impedance always will be very high for a capacitive switch, whatever the capacitance.when thebeam thickness increases, switch stiffness increases, resultingin smaller switch opening times. [5,8]

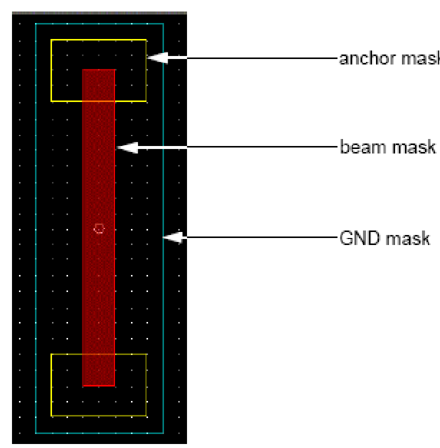

Fig. 2D Layout

The optimizer also tries to maximize the beam widthat the actuation pad, to maximize the area affected by the voltage; thus, the pull-down force is also maximized, for the same voltage value. When the beam width at the anchoring point increases, the beam stiffness increases; thus, the pull-in voltage increases, and the opening time decreases. It should be noted that the optimum results presented in this paper are based on the use of gold as the switch material. Gold is chosen because of its ease of accessibility in most labs.

The optimum parameters are expected to vary if a different structural/contactmaterial is used.

3.General Introduction COVENTORWARE

Coventorware provides electromechanical component libraries and field solvers. Therefore design and simulations of many MEMS and microfluidics application can be realized with coventorware . For instance accelerometers, switches, biochips, and mirror designs can be realized. The software has three modules. These are Architect, Designer and Analyzer. Architect is a schematic-based system level modeling tool, in which different designs with different materials can be realized. Designer is a physical design tool that contains 2-D layout editor and the model generator. Analyzer is a physical and numerical analysis tool. Analyzer has many solver types such as MEM Electro (EM solver), MEM Mech (mechanical solver) or Micro fluidics solver.

3.1 Beam Design

To aim of this is to design a solution for an electrostatically actuated fixed beam with conformal supports. The tutorial is educative for editing process sequence, creating the 3-D model, and simulation with electrostatic and mechanical solvers.

3.2 Process Editor

The process editor supplies the information to construct the 3-D model of the structure. The layers are created with deposition and etching steps. Adjustable process parameters are material thickness, sidewall angles, deposition type and mask polarity

3.3 Layout

The next step is creating the 2-D layout. This can be done with the Layout Editor from the Designer tab.

3.4 Building the solid model and Meshing

Next step is to build a 3-D model using the thickness and tech profile information from the process file and 2-D layout mask information. The Preprocessor tool was used. Then, the necessary name settings and face selections were done. After that, meshing of the structure was done. Meshing is done in order to present the structure to the solver for finite element analysis. A Quadrilateral mesh type was selected for the ground and Manhattan Bricks was selected for the beam.

3.5 MEM Electro Simulations

First analysis is the uncoupled electrostatic simulation, MEM Electro. The MEM Electro solver produces an electrostatic solution by solving for the charge and capacitance interaction between the beam and the ground components. It uses the Boundary Element Method (BEM). MEM Electro computes the charge on each surface panel and presents a final solution with charge distribution calculated for all the panels in the model. Conductor beam is adjusted to have 1 V potential.

3.6 Mem MECH Simulations

Mechanical analysis was performed using MemMECH which solves for the mechanical stress and displacement at each node. From the surface boundary conditions window, pressure load of 0.001 MegaPascals is applied onto the top surface of the beam in –z direction.

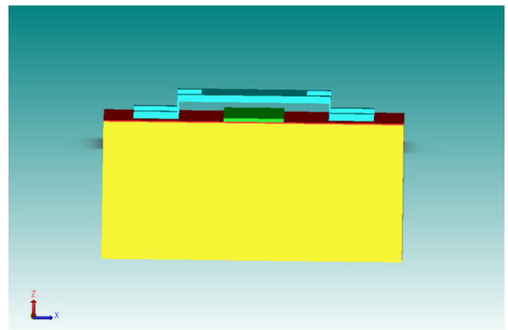

Fig. 3D Layout

The results of displacements in each direction and the applied reaction forces on the anchors are shown below 3-D display shows surface stress along the beam surface which shows that maximum deflection is at the beam center and maximum surface stress is at the fixed anchor.

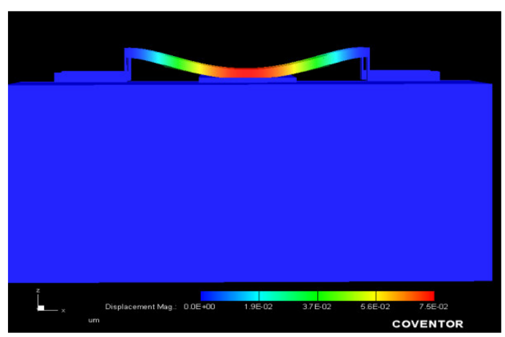

Fig. Stressed Structure

3.7 CoSolveEM Simulations

The CoSolveEM solver couples the electrostatic and mechanical solvers. The electrostatic results are input to the mechanical solver, and the results are used as feedbacks until convergence is achieved. Before strating with this analysis, the external pressure load is removed from the system. The voltage for the beam is set to 10 V.

The resulting CoSolve displacement results are in the window below.

Displacements

Displacements	Step	Delta	Maximum	MaxX	MaxY	MaxZ	MinX	MinY
step 0	0.0	3.624942E-02	3.624942E-02	5.205002E-04	3.181973E-03	7.670852E-04	-5.205002E-04	-3.181973E-03
step 1	1.000000E00	1.191085E-02	4.815926E-02	5.198117E-04	3.227920E-03	7.792155E-04	-5.198564E-04	-3.227905E-03
step 2	2.000000E00	9.957414E-05	4.825882E-02	5.198939E-04	3.228281E-03	7.793085E-04	-5.199400E-04	-3.228266E-03

Fig. Displacement Table

The displacement results are given below. The maximum displacement was observed to be on the –z direction as expected. Coventor Ware is an integrated suite of software tools for designing and simulating Micro Electro Mechanical Systems (MEMS) and micro fluidics devices. Coventor Ware supports two distinct design flows, which may be used separately or in combination. The Architecture module provides a unique system-level approach to MEMS design, whereas the Designer and Analyzer modules work together to provide a more conventional physical design flow. Both design flows require information about the fabrication process as a starting point, and this information is provided via a Process Editor and the Material Properties Database.

4. Applications of MEMS

4.1 Pressure Sensors

MEMS pressure microsensors typically have a flexible diaphragm that deforms in the presence of a pressure difference. The deformation is converted to an electrical signal appearing at the sensor output. A pressure sensor can be used to sense the absolute air pressure within the intake manifold of an automobile engine, so that the amount of fuel required for each engine cylinder can be computed.

4.2 Accelerometers

Accelerometers are acceleration sensors. An inertial mass suspended by springs is acted upon by acceleration forces that cause the mass to be deflected from its initial position. This deflection is converted to an electrical signal, which appears at the sensor output.

4.3 Inertial Sensors

Inertial sensors are a type of accelerometer and are one of the principal commercial products that utilize surface micromachining. They are used as airbag-deployment sensors in automobiles, and as tilt or shock sensors.

4.4 Micro Engines

A three-level poly silicon micromachining process has enabled the fabrication of devices with increased degrees of complexity. The process includes three movable levels of poly silicon, each separated by a sacrificial oxide layer, plus a stationary level.

4.5 Instrumentation

Automatic Test Equipment (ATE) and wideband electronic instrumentation are ideally suited for RF MEMS metal-contact switches. ATE systems require both DC and RF to pass through switching networks with low loss and good isolation.

4.6 Telecommunications Equipment

Base-stations and microwave communications links can benefit from RF MEMS technology. RF MEMS metal-contact switch scan be used to implement new antenna architectures with beam scanning and pattern nulling capabilities

4.7 Defense Systems

Defense systems typically prioritize performance and reliability over other factors. RF MEMS can find applications in wide-band transceivers and phased array systems.

5. RESULTS

This thesis presents the comparative study of MEMS RF Capacitive switches using Aluminum and Gold .In this topic the pull-in voltage is calculated by taking different cases into account ,one of them is using beam of Aluminum with and without holes and using two and the second is using the beam made of Gold with holes and without holes configuration .

Pull In Voltage			
Aluminum		Gold	
With Holes	Without Holes	With Holes	Without Holes
4.97E01 to 5.00E01	8.14E01 to 8.17E01	2.85E01 to 2.88E01	4.97E01 to 5.006E01

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