ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

Designing and Simulation of Micro Resistor Beam using COMSOL

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ABSTRACT: : This paper explains about the design and analysis of micro resistor beam using COMSOL Multi Physics software V. 5. The current passing through the beam dissipates heat power due to its resistivity that displaces the entire micro beam to preferred distance through thermal expansion phenomenon. The proposed model analyses mainly the various displacements produced for the beam due to passage of currents and rise in temperature. The displacements produced in the beam for different input potentials and different material is studied.

KEYWORDS: Microresistor beam, COMSOL, Thermal expansion.

I.INTRODUCTION

Micro-electromechanical systems (MEMS) are a process technology used to create tiny integrated devices or systems that combine mechanical and electrical components. They are fabricated using integrated circuit (IC) batch processing techniques and can range in size from few micrometers to millimetres. These devices (or systems) have the ability to sense, control and actuate on the micro scale, and generate effects on the macro scale.
In the most general form, MEMS consist of mechanical microstructures, microsensors,
microactuators and microelectronics, all integrated onto the same silicon chip[1] MEMS devices are very small; their components are usually microscopic. Levers, gears,
pistons, as well as motors and even steam engines have all been fabricated by MEMS However, MEMS is not just about the miniaturization of mechanical components or
Making things out of silicon. MEMS is a manufacturing technology; a paradigm for designing and creating complex mechanical devices and systems as well as their integrated electronics using batch fabrication techniques.
Micro-Electro-Mechanical Systems (MEMS) are latest technology in area of mechanical, electrical, electronics and chemical engineering. Micro-Electro-Mechanical Systems, or MEMS, consists of mechanical, electrical systems whose order of size in microns. It is a technology used to miniaturize systems [2]. Electrical components such as inductors and tenable capacitors can be improved significantly compared to their integrated counterparts if they are made using MEMS and Nanotechnology [3]. With the materialization of micro electro mechanical systems (MEMS), major attention has been focused on the expansion of new fabrication processes, new semi conducting devices [1] to be used in various optoelectronic devices and new micro scale resistors. The micromachining technology that emerged in the late 1980's has replaced the established bulky actuators [3] with micro scale equivalent devices with more efficiency. Electromechanical coupling has been widely used to actuate and control micromechanical structures and to produce nano structured materials from micron and submicron particles.
Micro resistor beams are mostly used for accurate measurement of residual stress, like stress produced in integrated circuit chips that are included into electronic package.
The micro resistor beams are also used as actuators for controlling purpose, thermally-actuated sensors], gyroscopes, and micro engines, resonators, for micro welding purposes and in wide range of industrial applications. When current is passed all the way through a material, heat energy is degenerated due to material`s electrical resistance property this, degenerated energy heats up the material and induces thermal stress[4].
Stresses in thin films and multilayers have three primary origins: *intrinsic*, *thermal* and *mechanical*. Intrinsic and thermal stresses are often referred to as residual *stresses.*

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stresses arise due to changes in temperature when the film and substrate (or the layers in a multilayer) have different coefficients of thermal expansion (CTE). For some systems, these stresses can be huge (i.e. several GPa), and they are frequently provide the driving force for mechanical failure. When the temperature is different from the deposition temperature, the residual stresses comprise both intrinsic and thermal contributions [5].

The induced stress loads the material and deforms the structure through which current is passed. The thermal expansion depends upon the amount of current passed through it and dissipated temperature. The application of micro resistor beam is to move the entire beam to desired distance by conducting suitable magnitude of current through conductive layers and generate a temperature increase that leads to displacement through thermal expansion. The goal of this model is to estimate the amount of current and increase in temperature required to cause displacement in proposed micro beam using COMSOL software. The software package selected to model and simulates the micro resistor beam made of Copper metal at different potentials in COMSOL MultiPhysics Version5. This software is also capable of providing facilitates for the coupling of thermal, electrical, and structural analyses which is highly essential for present design.

II. DESIGN CONSIDERATION

A copper microbeam has a length of 13 μm with a height and width of 1 μm. Feet at both ends bond it rigidly to a substrate. An electric potential of different voltage ranging from 0.1v to 0.3 V applied between the feet induces an electric current. Due to the material's resistivity, the current heats up the structure. Because the beam operates in the open, the generated heat dissipates into the air. The thermally induced stress loads the material and deforms the beam.

As a first approximation, you can assume that the electrical conductivity is constant. However, a conductor's resistivity increases with temperature. In the case of copper, the relationship between resistivity and temperature is approximately linear over a wide range of temperatures:

$\rho = \rho 0\ (1+\acute{\alpha}\ (T - T0\ )\ )$

$\acute{\alpha}$ is the temperature coefficient. You obtain the conductor's temperature dependency from the relationship that defines electric resistivity; conductivity is simply its reciprocal ($\sigma = 1/\rho$).

For the heat transfer equations, set the base boundaries facing the substrate to a constant temperature of 323 K. You model the convective air cooling in other boundaries using a heat flux boundary condition with a heat transfer coefficient, *h*, of 5 $W/(m^2{\cdot}K)$ and an external temperature, *Tref* of 298 K. Standard constraints handle the bases' rigid connection to the substrate

This example illustrates the ability to couple thermal, electrical, and structural analysis in one model. This particular application moves a beam by passing a current through it; the current generates heat, and the temperature increase leads to displacement through thermal expansion. The model estimates how much current and increase in temperature are necessary to displace the beam.

Although the model involves a rather simple Physical interfaces this model is carried out in joule heating and thermal expansion multiphysics which automatically facilitates for coupling of thermal, electrical, and structural analysis. The linear thermal expansion coefficient relates the change in a material's linear dimensions to a change in temperature. It is the fractional change in length per degree of temperature change. In order to carry out simulation it is necessary to set suitable boundary conditions for the heat transfer and the conduction of electric current. This model is assumed to be carried out in open air so the convection air cooling is set by using heat flux boundary condition given by equation (1)

$qo\ = h(Text - T)$ ----------------------------- [1]

Where h is heat transfer co-efficient. Insulating boundary condition for heat transfer interfaces and conduction current is set by thermal insulation given by equation (2)

$-n.(-k.\nabla T)$ --- [2]

and electrical insulation equation (3)

$-n.j\ = 0$ --------------------------- [3]

The joule heating and thermal expansion multi physics interface includes three physics equations mentioned above along with necessary couplings. The equations describe the current and heat conduction and structural mechanics problems.

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III. RESULTS AND ANALYSIS

Analysis was carried out on various materials like Aluminium, silver, nickel and copper, by varying input Potentials applied to each material. Mainly observation was done on amount of buckle produced by passing current through the beam. Following table shows amount of buckle and temperature produced in metals at three different input potentials as shown in Table1,2 and 3. Silver produces reasonable amount of deformation compared to aluminium because of its lower value of thermal coefficient of expansion. It has the highest electrical conductivity than that of any element and the highest thermal conductivity of any metal even higher than copper, but its greater cost has restricted it from being used instead of copper for electrical appliances.

Table:1 Results observed for 0.1v

Sl.No	Name of the metal	Deformation[nm]	Temperature[k]
01	Aluminium	29.9	466
02	Silver	21.2	441
03	Copper	20.1	455
04	Nickel	5.5	323

Table: 2 Results observed for 0.2v

Sl.No	Name of the metal	Deformation[nm]	Temperature[k]
01	Aluminium	72.3	740
02	Silver	48.4	656
03	Copper	48.3	710
04	Nickel	7.95	365

Table: 3 Results observed for 0.3v

Sl.No	Name of the metal	Deformation[nm]	Temperature[k]
01	Aluminium	119	1042
02	Silver	77	884
03	Copper	79.4	993
04	Nickel	10.7	395

IV. SIMULATION

The simulation process is concedered out in two steps, initially copper micro resistor beam is constructed and its deformation is carried out for three different input potentials. In second step deformations are carried out for aluminium, silver and nickel metallic beams replacing copper material for similar input potentials. Feet of the copper beam at both ends are rigidly bond to a substrate and electric potential is applied at both ends. The applied electric potential induces an electric current in the micro resistor beam; current passing through the structure causes some retardation to flow of electrons by which energy is dissipated in the form of heat. This generated heat induces thermal stress on beam and displaces the beam. The following three figures 1,2,3, and 4 show the amount of deformation produced and temperature distribution in the beam when a potential of 0.2V is applied between the feetof microresister beam made of different materials i.e Aluminium, Silver, Copper and Nickel .

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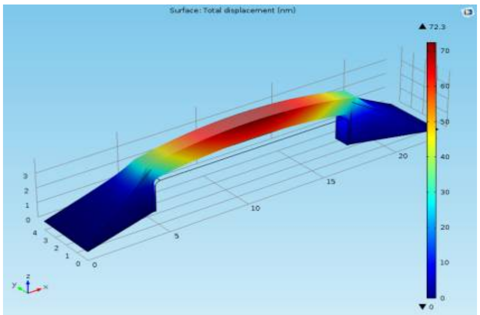
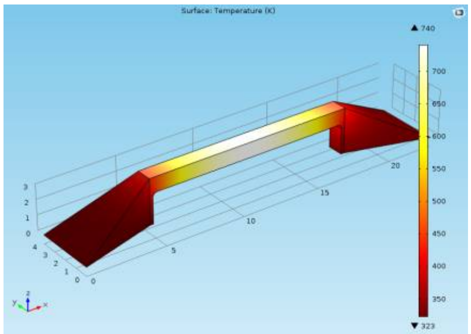
Figure: 1

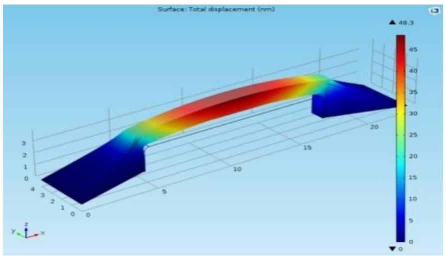


Metal: Aluminium Total Displacement

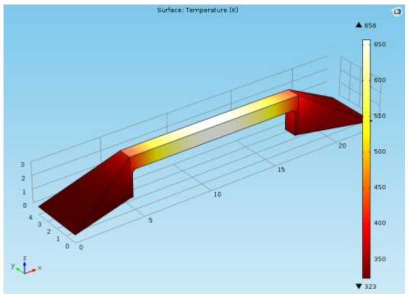


Total Temperature Distribution

Figure:2

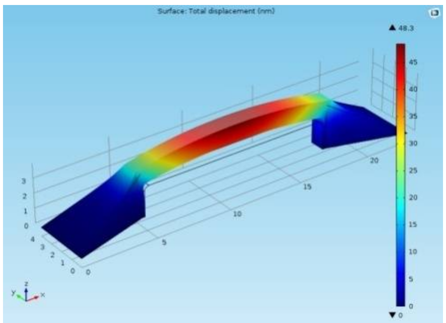


Metal: Silver Total Displacement

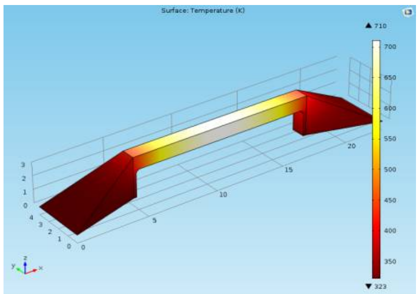


Total Temperature Distribution

Figure:3



Metal: Copper Total Displacement



Total Temperature Distribution

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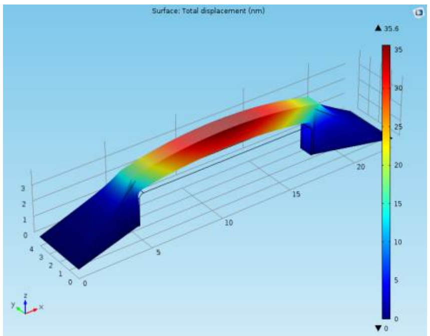
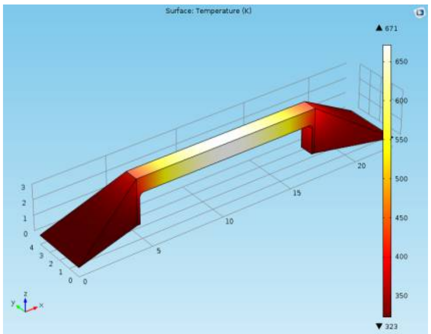
Figure: 4





Total Total Displacement **Total Temperature Distribution**

V. RESULT AND DISCUSSION

Micro resistor beam is designed using COMSOL MultiPhysics software V 5. It reports the movement Produced in the beam by conducting a current through it to generate temperature that lead to a displacement through thermal expansion. Coupling of thermal, electrical, and structural analyses makes it possible to estimate the current and temperature increase needed to displace the beam. The quantity of deformations produced for four different metallic micro beams of same design have been carried out with different input potentials. The analyses of results have indicated that the aluminium metallic micro resistor beam gives significant amount of deformation for given proposed geometry rather than other metallic beams.

VI.CONCLUSION

Micro resistor beam is designed using COMSOL MultiPhysics software V 5. It reports the movement Produced in the beam by conducting a current through it to generate temperature that lead to a displacement through thermal expansion. Coupling of thermal, electrical, and structural analyses makes it possible to estimate the current and temperature increase needed to displace the beam. The quantity of deformations produced for four different metallic micro beams of same design have been carried out with different input potentials. The analyses of results have indicated that the aluminium metallic micro resistor beam gives significant amount of deformation for given proposed geometry rather than other metallic beams.

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