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Modelling and Simulation of three Arm Electrothermal Actuator using Comsol

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ABSTRACT: In this paper we present the modelling and simulation of MEMS two hot arm thermal actuator made of polysilicon. The actuator is actuated through thermal expansion. The temperature required to deform the two hot arms, and thus displace the actuator, is obtained through joule heating (resistive heating). The greater expansion of the hot arms compared to cold arm, causes a bending of the actuator. The geometric optimization for the thermal actuator was performed by wide range of geometries using COMSOL Multiphysics, a commercial Finite Element Analysis (FEA) Package. In this paper simulated results obtained for different applied voltages ranging from 5 to 15 volts and changing the length the actuator from 150[um] to 300[um] and the corresponding stress, temperature distribution and tip displacement are studied.

Keywords: MEMS, Thermal actuator, COMSOL etc.

I. INTRODUCTION

Micro-Electro Mechanical-Systems (MEMS) are integrated devices which are made up of micro components such as actuators, sensors and electronic transistors. “Micro” indicates the scale of the device; “electrical” indicates the involvement of electronics components “mechanical” indicates the usage of movable and flexible mechanical structures that could be used for sensing and actuating; “systems” indicates the integration of different mechanical and electrical elements to a system level device. In general, MEMS is a cross-disciplinary technology that could develop micro scale integrated devices for various applications. The micro mechanical device embedded with electronics/electrical system fabricated through a mix of integrated circuit manufacturing and micro-machining process where material is shaped by etching away micro layers is called Micro Electro Mechanical System (MEMS).

In recent years microcroactuators in MEMS are emerging and revolutionary technologies that brought both opportunities and challenges in manufacturing and electronics industries. MEMS based micro actuators can be operated using electrotermal, electrostatic, piezoelectric and magnetic actuation mechanisms. Electrothermal microactuators are promising solution for large, linear displacement with relatively low voltage levels compared to other actuation schemes. The MEMS based thermal actuators are actuators which convert thermal energy into motion. One of the most important design constraints in ectrothermal actuators is the range of motion. The application areas of the actuators are microgrippers, Thermometers, Heat engines etc. Since the introduction of electrothermal actuator by Guckkel *et.al* [1] many studies have been done to improve their deflection range. However the majority of these actuators are limited to operate in one dimension and are unidirectional. A.R Kalarasi *et.al* [2] developed a two dimensional finite element model of an electrothermal actuator with four different designs with same material properties and same dimensions are studied. Maximum deflection of 38 [um] is obtained with tapered design.

Sakshi pathneja etal[3] studied the tip displacement of the of the thermal actuators for different geometrical variations. This paper encounters the designing and simulation of three arm electrothermal actuator made of polysilicon. The material properties of polysilicon are temperature dependent, which means that the involved physics phenomena are fully coupled. The electric current through the hot arms increases the temperature in the actuator, which in turn causes thermal expansion and changes the electrical conductivity of the material.

The actuator’s operation thus involves three coupled physics phenomena: electric current conduction, heat conduction with heat generation, and structural stresses and strains due to thermal expansion.

Geometric optimization for the thermal actuator was performed by wide range of geometries using COMSOL Multiphysics, a commercial Finite Element Analysis (FEA) Package. In this paper simulated results for different length of the actuators ranging from 150um to 300um for an applied voltages 5 to15 volts. The corresponding simulation results for stress, temperature distribution and displacement are obtained.

II. MODEL DEFINITION

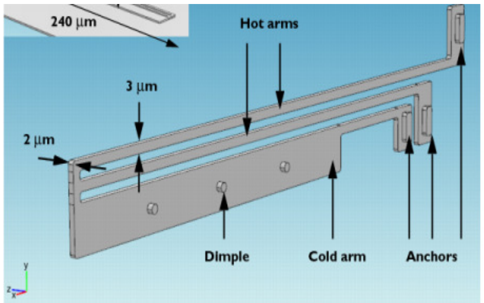

Fig. 1. Actuator's parts and dimensions as well as its position on top of a substrate surface.

III. BOUNDARY CONDITIONS AND CONSTRAINTS

An electric potential is applied between the bases of the hot arms' anchors. The cold arm anchor and all other surfaces are electrically Insulated. The temperature of the base of the three anchors and the three dimples is fixed to that of the substrate's constant temperature. Because the structure is sandwiched, all other boundaries interact thermally with the surroundings by conduction through thin layers of air. The heat transfer coefficient is given by the conductivity of air divided by the distance to the surrounding surfaces for the system. This exercise uses different heat transfer coefficients for the actuator's upper and other surfaces.

All three arms are mechanically fixed at the base of the three anchors. The dimples can move freely in the plane of the substrate.

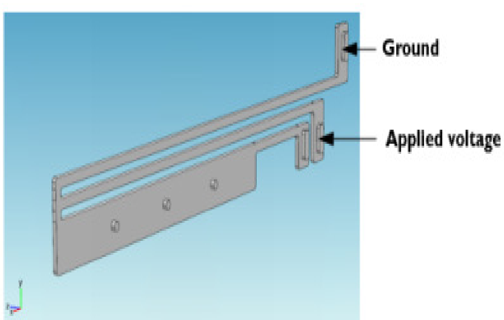

Fig. 2. Electrical boundary conditions.

IV. DESIGN DEFINITION

In this analysis, the design uses the mechanism of hot and cold arm to achieve the movement of the structure. The structure includes 2 hot arms and 1 cold arm. The parameters of the actuator are listed in Table 1.

Table 1: Parameters of the actuator.

Description	Dimension in [µm]	Symbol
Height of the hot arm	3	D
Height of the cold arm	15	Dw
Gap between arms	3	Gap
Width of the base	10	Wb
Difference in length between arms	25	Wv
Actuator length	240	L
Length of the longest hot arm	230	L1
Length of the shortest hot arm	205	L2
Length of the cold arm thick part	150	L3
Length of the cold arm thin part	40	L4

V. SIMULATION RESULTS

In order to analyze the behaviour of the three arm thermal actuator using COMSOL mulitiphysics. We have applied a voltage of 5v for different length of the actuator varying from 150[um] to300[um] temperature distribution, deformation and stress with the displacement of the arms The simulation has been carried out for the same lengths by applying 10v and 15v also. The results for different applied voltages are as shown in Table 2.

Table 2.

APPLIED VOLTAGE = 5[V]			
LENGTH [µm]	MAX. TEMPERATURE [k]	MAX.STRESS N/m^2	TIP DEFLECTION[µm]
150	787	1.03*10^8	0.65
200	590	0.67*10^8	0.41
250	494	0.957*10^8	0.59
300	437	0.45*10^8	0.28
APPLIED VOLTAGE = 10[V]			
LENGTH [µm]	MAX. TEMPERATURE [k]	MAX.STRESS N/m^2	TIP DEFLECTION[µm]
150	2077	3.45*10^8	2.2
200	1307	2.2*10^8	1.4
250	972	3.16*10^8	2.0
300	785	1.51*10^8	0.95
APPLIED VOLTAGE = 15[V]			
LENGTH [µm]	MAX. TEMPERATURE [k]	MAX.STRESS N/m^2	TIP DEFLECTION[µm]
150	3411	6.19*10^8	3.6
200	2182	4.03*10^8	2.5
250	1573	5.87*10^8	3.8
300	1226	2.85*10^8	1.8

It is observed that as the applied voltage increases the temperature distribution, stress, and tip deflection of the actuator also increases. The temperature distribution for the length less than 200 [µm] and applied voltage for 10v and 15v are found that more than the melting point temperature of polysilicon material. The graph of length versus temperature, stress and displacement are as shown in below figures from 3 to 5.

It is observed that, as the applied voltage increases the temperature distribution along the actuator, stress, and tip deflection increases. The temperature distribution for the length less than 200 [µm] and applied voltage for 10v and 15v are found that more than the melting point temperature of polysilicon material.

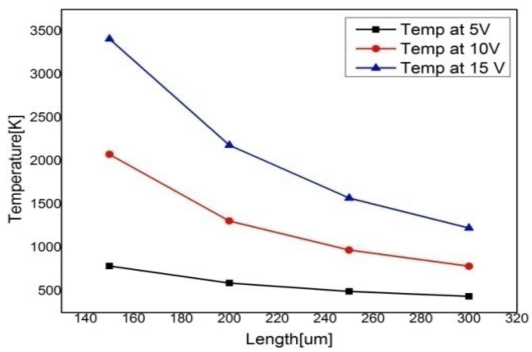

Fig. 3. Length versus Temperature.

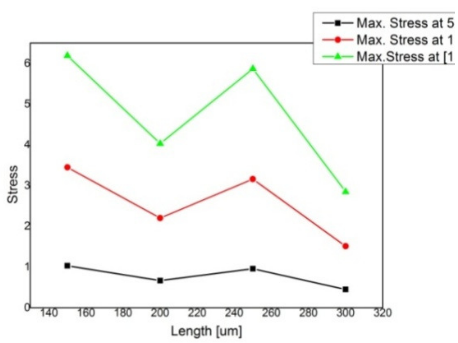

Fig. 4. Length versus Stress.

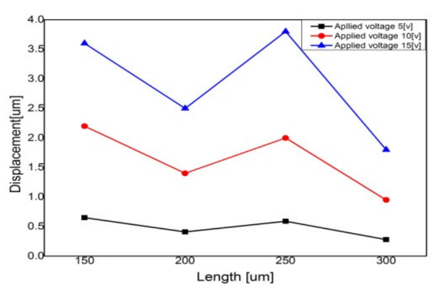

Fig. 5. Length versus Displacement.

The snap shot of the surface temperature, stress with displacement of the actuator with an applied voltage of 5v,10v and 15v of length 250[um] are shown in Fig 6 to 11.

It shows that the current flow is maximum in the narrow arm hotter than the wide arm, So the structure tends to move along the wide arm. Maximum temperature is at the centre of the hot arm.

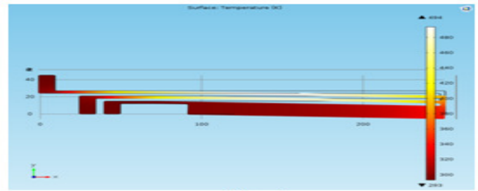

Fig. 6

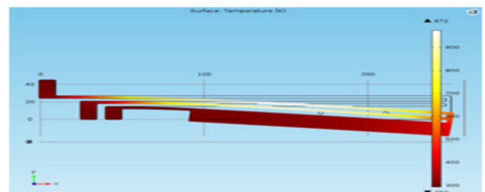

Fig. 7

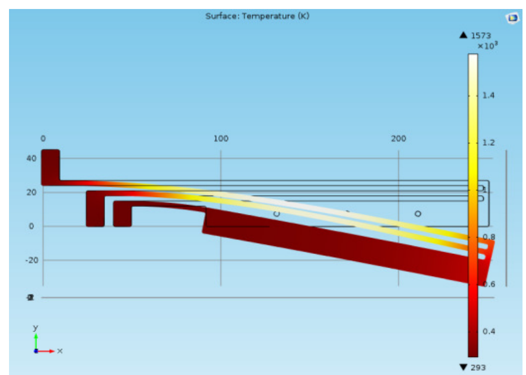

Fig. 8

Fig 6 to 8 simulation result of the thermal actuator showing Surface temperature for length 250[um] at 5v, 10v and 15v respectively

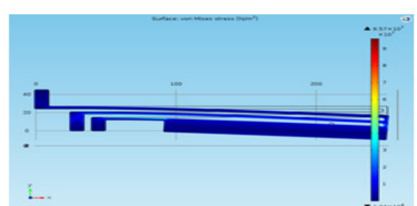

Fig.9

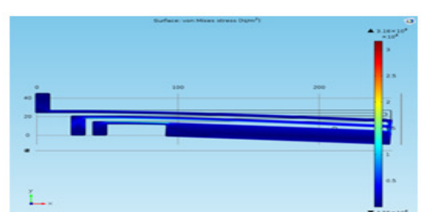

Fig. 10

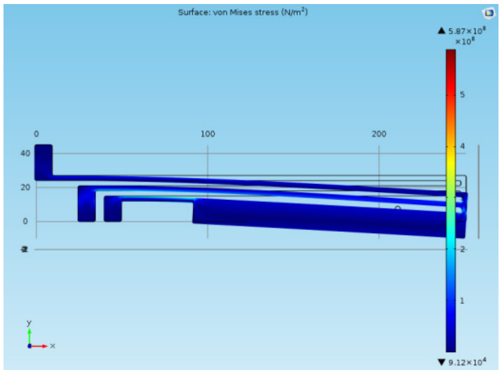

Fig. 11

Fig 9 to11 simulation result of the thermal actuator showing Stress for length 250[um] at 5v, 10v and 15v respectively

VI. CONCLUSIONS

Three arm thermal actuator with two hot and one cold arm is modelled and simulated using the comsol/Multiphysics software. The actuation results are compared for different lengths for the applied different voltages .It is found that as the applied voltage increases the temperature distribution, stress and displacement also increases. A longer actuator is capable of a larger deflection but as the length increases the overall electrical resistance increases which requires an increased applied voltage to obtain a sufficient high current density. At the large lengths like 300[um] the thin arm bends

touching the substrate and losses heat causing it to shrinkup. The length of the actuator is appropriate in between 200 [um] to 250 [um] to obtain upto the mark of the displacement. It is observed that at high temperature above 800 - 1000°C the electrical resistivity of polysilicon shows a decrease with temperature due to high current and heat causing melting.

REFERENCES

[1] J. H. Comtois, M. A. Michalicek, C.C. Barron, "characterization of ectrothermal actuators in a four-level, planarized surface micromachine dpolycrystalline process", *proc. IEEE International Conference on Solid-State Sensors and Actuators*, Chicago, il, pp. 769-772, jun 1997.

[2] A. R. Kalaiarasi1, Dr. S. HosiminThilagar21Research Scholar, Associate Professor Anna University, Chennai.**"** Design and Finite Element Analysis of Electrothermal Compliant Micro actuators" Excerpt from proceedings of COMSOL conference 2011, Bangalore.

[3] Sakshi Pathneja, P. Raja (ECE Department, BRCM 1College of Engineering &Technology, BAHAL, BHIWANI, India) "Analysis and Optimization of an Electro-Thermally and Laterally Driven Poly-Silicon Micro-Actuator" *Journal of Engineering Research and Applications* ISSN:2248-9622,Vol.**4** Issue 7(Version 5),July 2014

[4] V.S. Selvakumar, M. Siddhartha Goutham, M. Saravanan, S. Suganthi and L. Sujatha, 2011 " Design and analysis of micro-tweezers with alumina as gripper using COMSOL Multiphysics", COMSOL Conference in Bangalore.

[5] Seyed Majid Karbasi, Mahnaz Shamshirsaz, Mahyar Naraghi, Mohammad Maroufi, 2010 "Optimal design analysis of electrothermally driven microactuators", *Microsyst Technol,* **16**: 1065–1071.

[6] **J.** Comtois and V. Bright, "Surface micromachined polysilicon thermal actuator arrays and applications", *Proc. Solid-State Sensors and Actuators Workshop,* pp. 74-77, (1996).