

Design and Simulation of MEMS based Thermal Actuators for RF Application

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Abstract: A 3-D structure of two Thermal Actuators were designed and simulated using COMSOL Multiphysics 5.3a. A MEMS Thermal actuator is a micro mechanical device that typically generates motion by the thermal expansion amplification. A small amount of thermal expansion of one part of the device translates to a large amount of deflection of the overall device. Here the fabricating material is silicon (single crystal & isotropic), the increase in temperature can be achieved internally by electrical resistive heating or by a heat source. These Thermal micro actuators can be integrated into micromotors. In terms of minimizing the power consumption, a better way to amplify the mechanical motion is by varying the geometrical dimension of the structure rather than changing the input voltage

Keywords: MEMS, Thermal Actuator, Thermal Expansion

1. INTRODUCTION

The actuators have an important role in Micro Electro Mechanical Systems (MEMS). They aim to change the parameters of the controlled environment, as a result of the information, obtained from the sensors in the system. The thermal micro actuators are only one type of the wide variety actuators used in MEMS. As a result of heating, they make some displacement, which allows them to be used in different fields like optics, medicine, communications, positioning, computer systems, fluid pumping etc.

Thermal actuation has been extensively employed in MEMS. It includes a broad spectrum of principles, such as tetralemmatic, shape memory alloy (SMA) effect, bimetal effect, mechanical thermal expansion, etc. According to the principle used for actuation, the thermal actuators can be classified as thermal bimetallic, thermal pneumatic, electrothermal and thermal mechanical expansion micro actuator. Bulk and surface micromachining are two basic and major micromachining techniques, which are used in MEMS. The previous researches on the development of thermal micro actuator focused in improving the performance and capability of the thermal micro actuator by introducing a new design and optimization techniques, but here we check the conditions if the thermal actuator model parameters like material and boundary conditions are changed.

II. METHODOLOGY

To design the thermal actuators there are several steps that we followed.

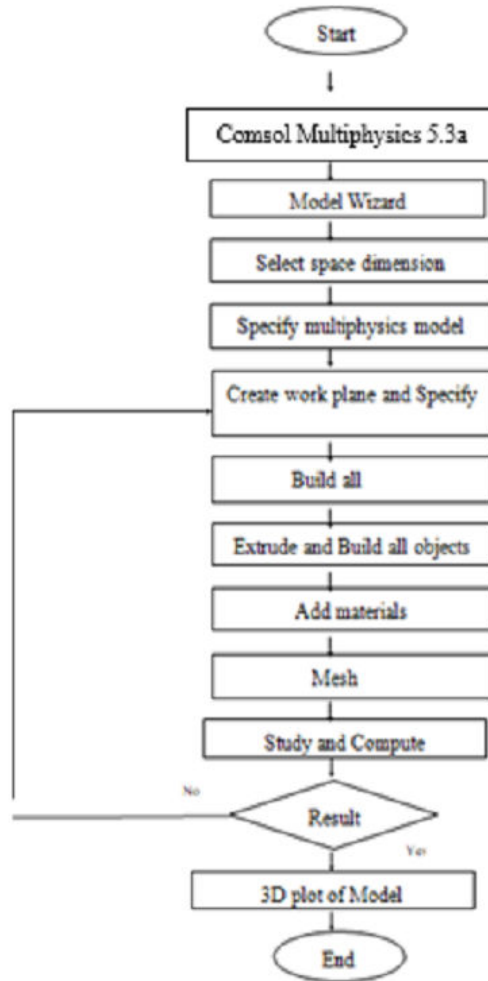


Figure: Design Methodology

1. In the COMSOL software selecting the model wizard and 3D model. In the select physics add the structural mechanics as Joule heating and Thermal expansion. In the select study tree select preset studies for selected physics interface.

2. Defining the following Parameters in the global

Name	Expression	Value	Description
d	3 [um]	3E-6m	Height of the hot arm
dw	15[um]	1.5E-5m	Height of the cold arm
gap	3 [urn]	3E-6m	Gap between arms
wb	10[um]	1E-5m	Width of the base

wv	25[um]	2.5E-5m	Difference in length between hot arms
L	240[um]	2.4E-4m	Actuator length
L1	L-wb	2.3E-4m	length of the longest hot arm
L2	L-wb-wv	2.05E-4m	length of the shortest hot arm
L3	$L-2*wb-wv-L/6$	1.5E-4m	length of the cold arm, thick part
L4	$L/6$	4E-5m	length of the cold arm, thin part
htc_s	$0.04[W/(m*K)]/2[um]$	$2E4W/(m^2.K)$	Heat transfer coefficient
htc_u s	$0.04[W/(m*K)]/100[um]$	$400 W/(m^2.K)$	Heat transfer coefficient, upper surface
DV	5[V]	5V	Applied voltage

Table: Parameters

3. Building the Geometry

4. Adding the material polycrystalline silicon and the properties of the material is given below

Property	Unit	Value
Electrical conductivity	5e4	S/m
Electrical conductivity	2.6	I/K
Heat capacity at constant pressure	678	J/(KgK)
Relative permittivity	4.5	-
Density	2320	Kg/m ³
Thermal conductivity	34	W/(mK)
Young's Modulus	112	GPa
Poisson's ratio	0.22	-
Tensile strength	113	MPa

Table: Design Properties

5. Defining the boundary conditions

6. Applying the mesh

7. Computing the results

8. Analyzing the results and again changing the material and comparing the results

III. SIMULATION RESULTS

Effects of varying the material: Initially by adding these polycrystalline silicon material and defining the boundary conditions, we measure the stress, temperature, and the isothermal contours and the observation is tabulated below.

The below figures show the stress distribution for the actuator

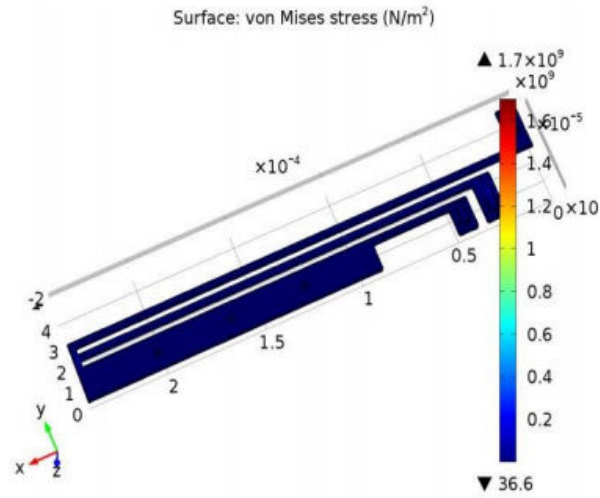


Figure: Stress Distribution of Two-hot Arm Thermal Actuator

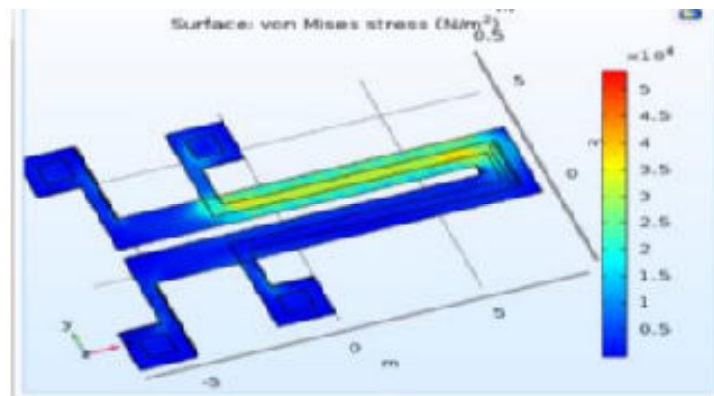


Figure: Stress Distribution of Vertical Thermal Actuator

The below figures show the distribution of temperature over the actuator

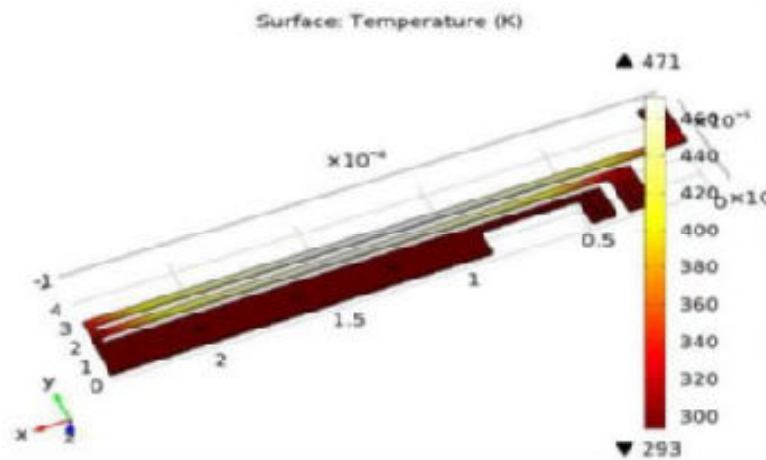


Figure: Temperature distribution of Two-hot Arm Thermal Actuator

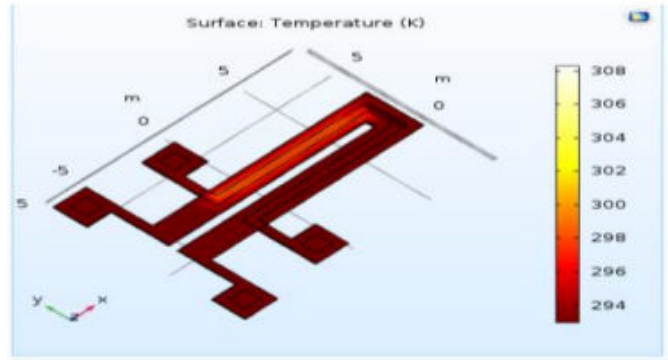


Figure: Temperature distribution of Vertical Thermal Actuator

The below figures show the distribution of the isothermal contour of the actuator

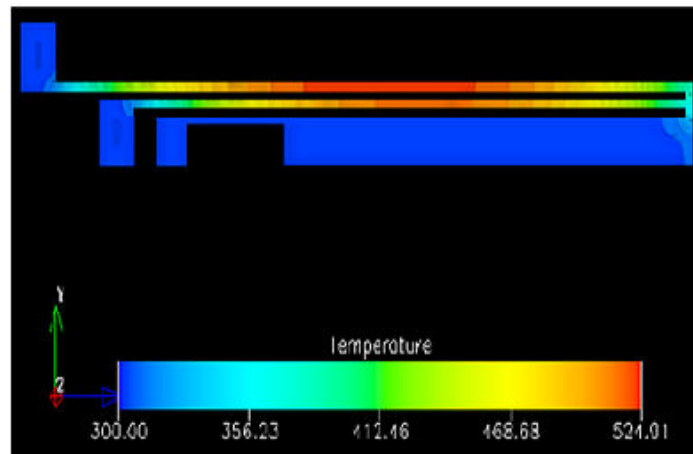


Figure: Isothermal Temperature Distribution of Two-hot Arm Thermal Actuator

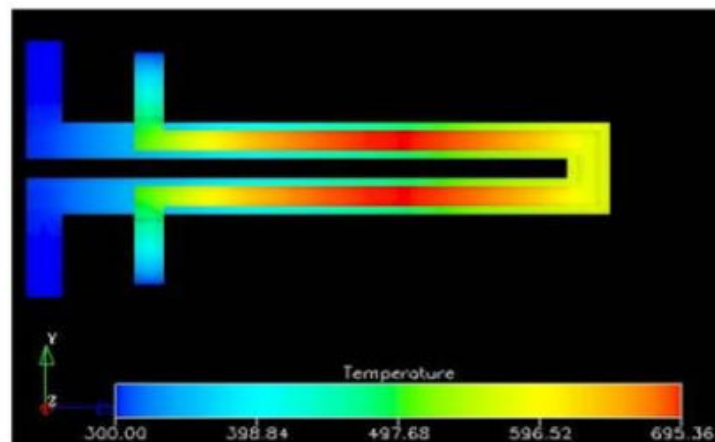


Figure: Isothermal Temperature Distribution of Vertical Thermal Actuator

The below figures show the Maximum temperature as a function of input voltage: Comparison between analytical and simulation results.

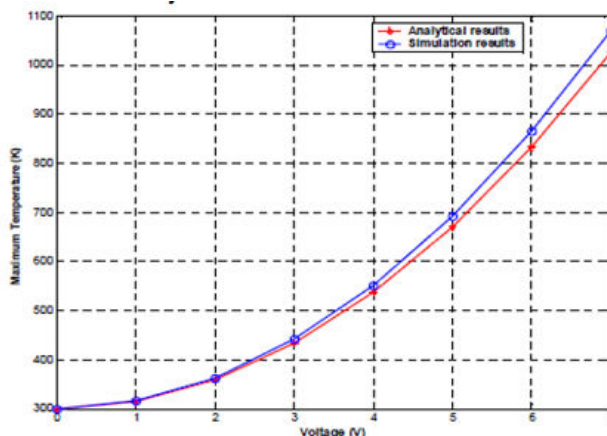


Figure: Comparison of the maximum temperature as a function of input voltage in Two-hot Arm Thermal Actuator

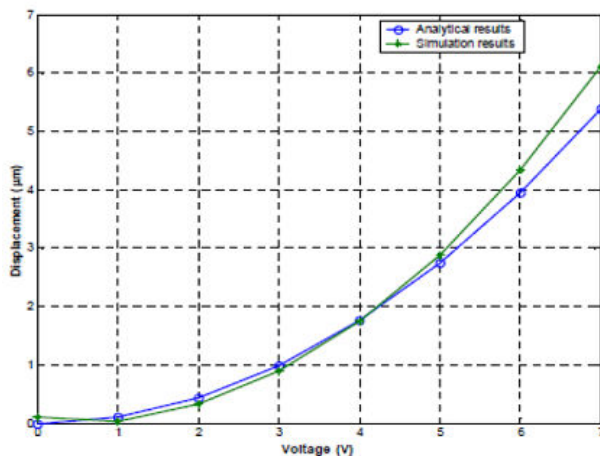


Figure: Deflection of the tip of the vertical thermal actuator as a function of input voltage

Parameters	Values
Stress	36.6-1.7* 10 ⁹ N/m ²
Temperature	471-293 K.
Isothermal Temperature	462-302 K.
Electric Potential	7-0 V

Table: Results Tabulation

IV. CONCLUSION

The modeling and simulation of two thermal actuators using the software COMSOL is presented in the current study. A simplified analytical model to explain the analysis is also presented. The effect of the material and solid mechanics to the maximum temperature, stress and isothermal contour is discussed. The results obtained by simulation are in close agreement with the analytical results.

V. FUTURE WORK

This design work can be further developed and simulated using COMSOL Multiphysics software tool. Where we can design the multiport switch with a latching mechanism with a tunable capacitor by using this Thermal Actuators which can be used as RF MEMS switch. Which can be used in radio frequency switching mechanism.

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