Design and Finite Element Analysis of Electro Thermal Complaint Actuators

A.R. Kalaiarasi[1] , Dr.S.HosiminThilagar[2]
[1]Research Scholar,[2]Associate Professor
Department of Electrical and Electronics Engineering
Anna University Chennai.

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Electro thermal actuators

- Electro thermal actuators are capable of providing larger displacements compared to electrostatic actuators. [1-12]
- Thermal actuators are of two types.
  - Bimorph thermal actuator
  - Single material Electro Thermal Compliant (ETC) actuator.[1]
- Bimorph actuators are composite structure made of two or more layers of different materials.[2]
- In this work ETC device has been studied for different geometry.

Design–Displacement Improvement

- Designs
  - Rectangular beam without gold layer
  - Rectangular beam with gold layer
  - Tapered beam design 1 with gold layer
  - Tapered beam design 2 with gold layer.

- The gold layer deposition increases the displacement

- A maximum deflection of 38 μm is obtained with tapered beam design 2.

Basic ETC Actuator

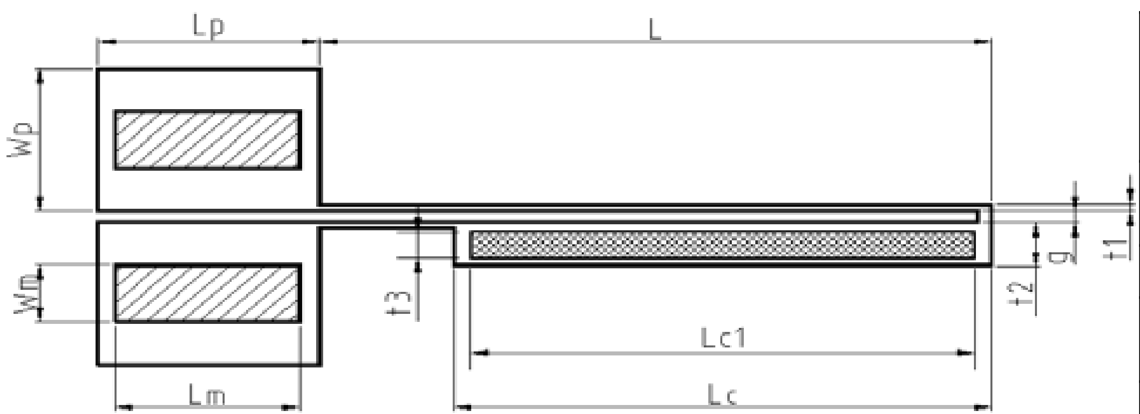


Fig 1: Electro Thermal Actuator

Symbol	Description	Dimension (um)
L	Total beam length; length of an element	200
L_c	Length of cold beam	160
g	Gap between cold and hot beam	2
t_1	Hot beam width	2
t_2	Cold beam width	15
L_p	Length of pads	66
L_m	Length of anchors	56
W_p	Width of pads	50
W_m	Width of anchors	20
L_{c1}	Length of gold layer	150
t_3	Width of gold layer	9

Material properties & COMSOL Model

Table 2: Material Properties

Sl.No	Material	Properties
1	Poly silicon	Young's modulus :169 [GPa] Poisson's ratio : 0.3 Coefficient of Thermal expansion :2.568e-6 [1/K] Electrical Conductivity :0.25e5 [S/m]
2	Gold	Young's modulus : 80 [GPa] Poisson's ratio : 0.3 Coefficient of Thermal expansion : 14.2e-6 [1/K] Electrical Conductivity : 45.6e6 [S/m]
3	Aluminum	Young's modulus :70GPa Poisson's ratio : 0.3 Coefficient of Thermal expansion : 23.1e-6 [1/K] Electrical Conductivity : 35.5e6 [S/m]

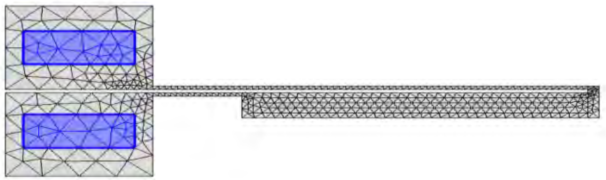
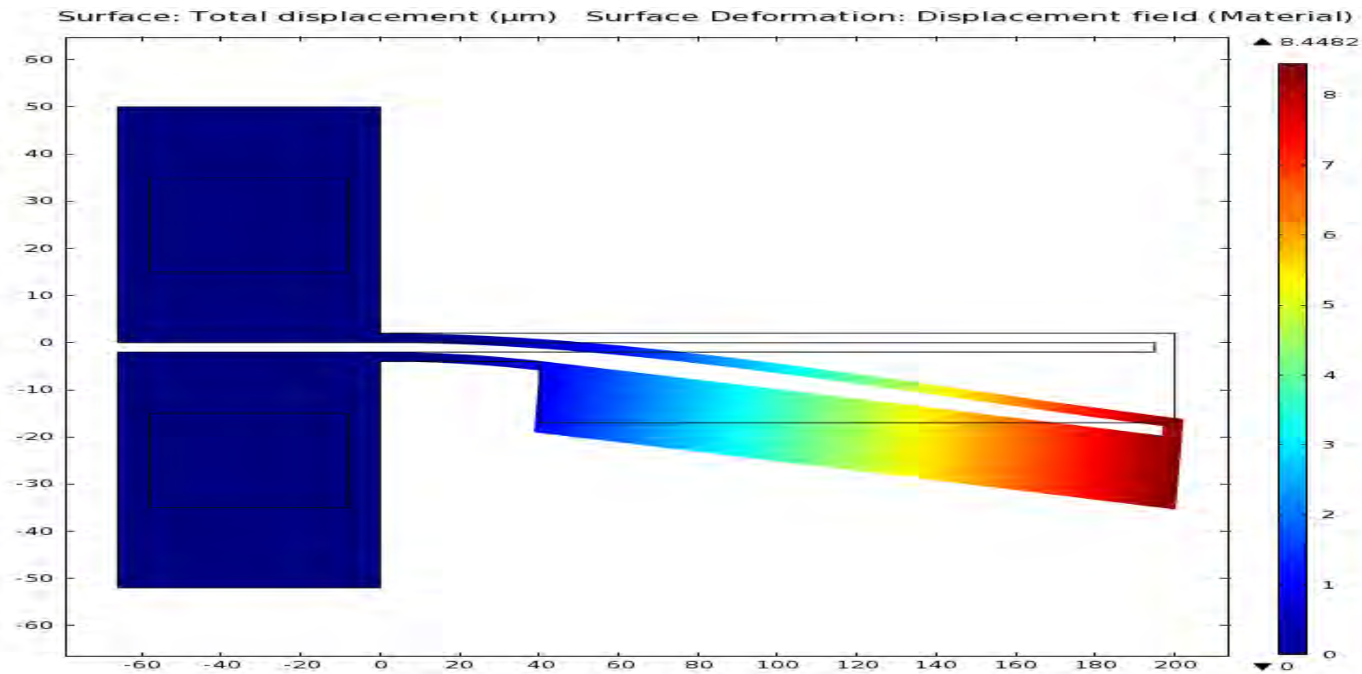


Fig 2: COMSOL Model of an Electro Thermal Actuator

Use of COMSOL Multiphysics

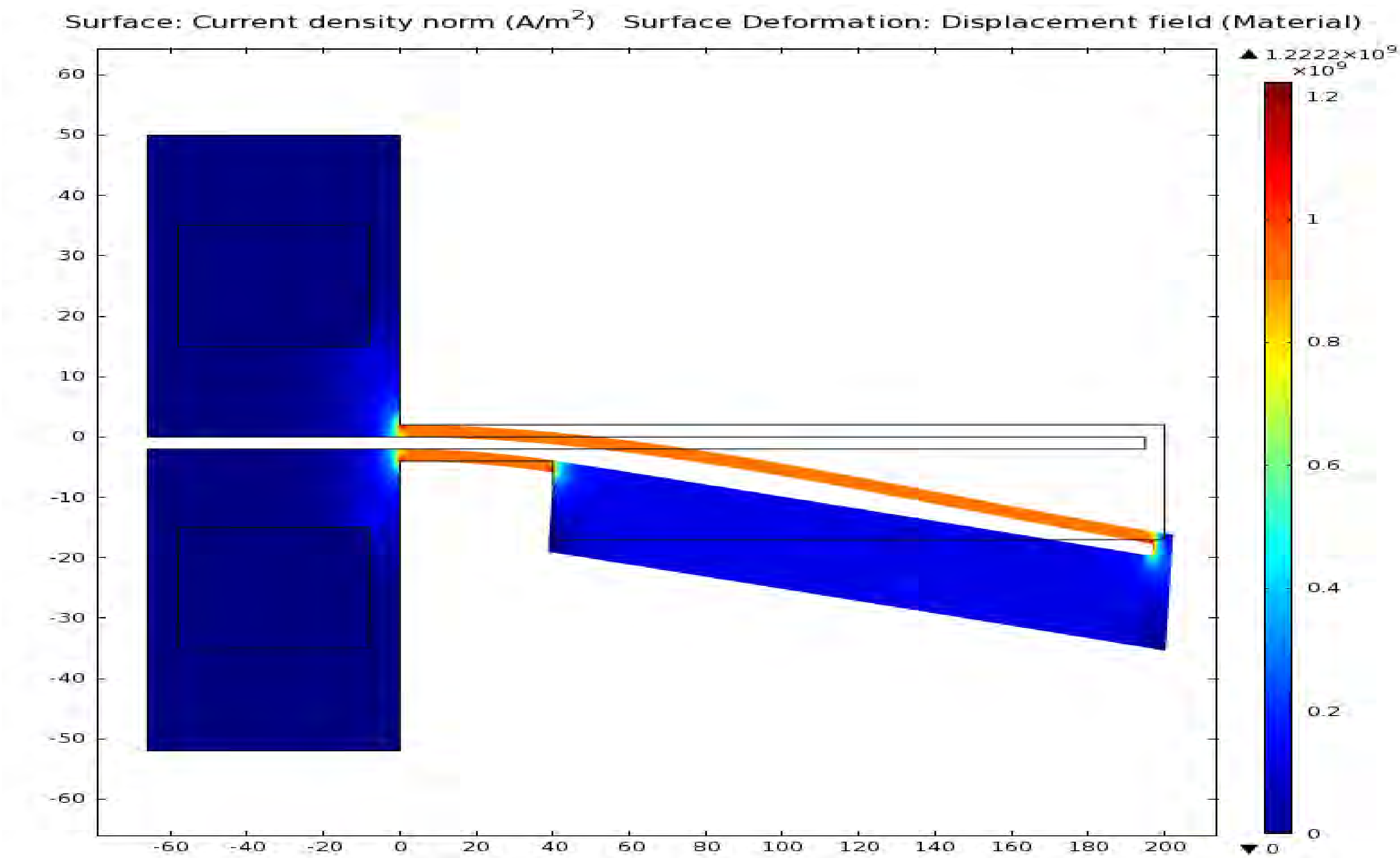
- Three coupled physics namely electric current conduction
- Heat conduction and
- Stresses due to thermal expansion.
- Bottom surfaces of the anchors are fixed in all degrees.
- DC voltage of 10 volts is applied at the bonding pads.
- Temperature of 300K is applied as the ambient temperature.

Results
1. Tip Displacement of Rectangular beam

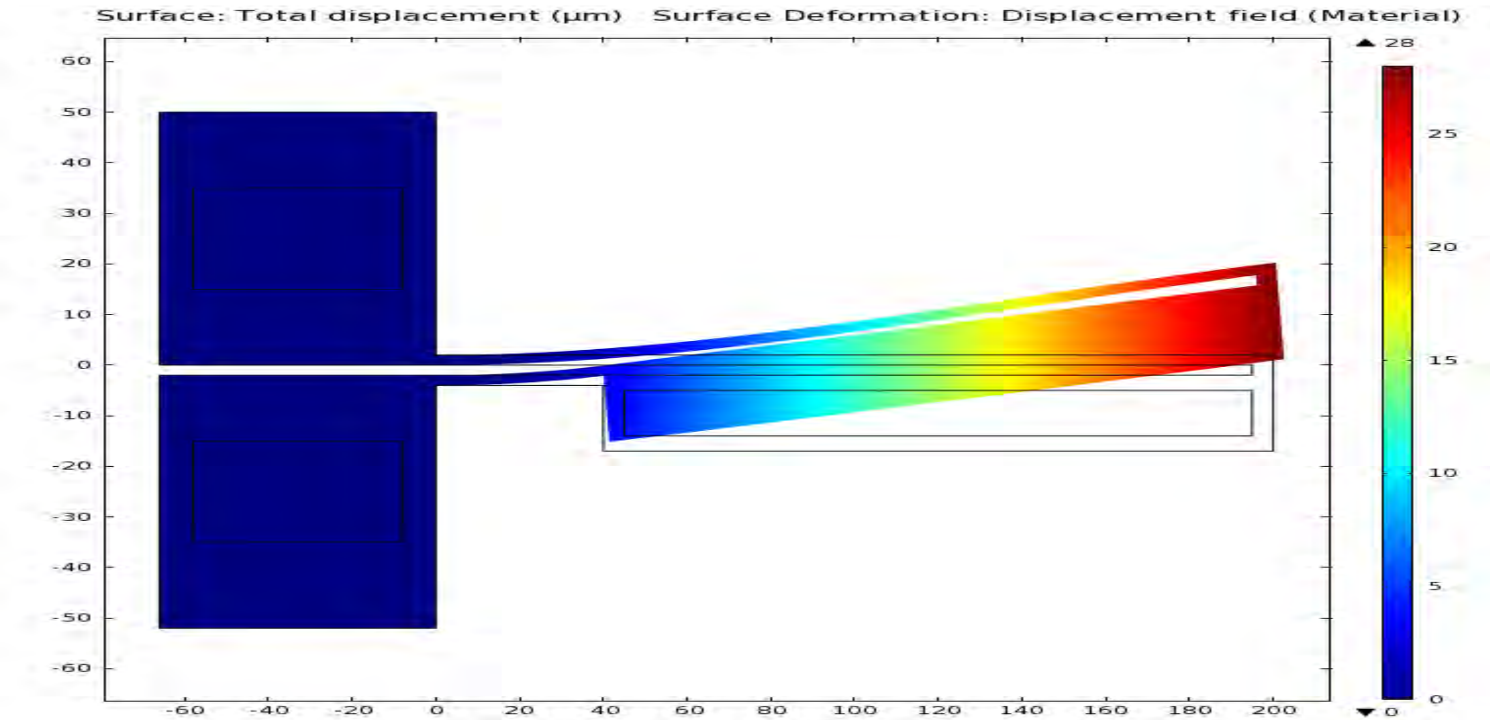


For rectangular beam without gold layer a tip displacement of about 9 µm is obtained

2. Current density of Rectangular beam

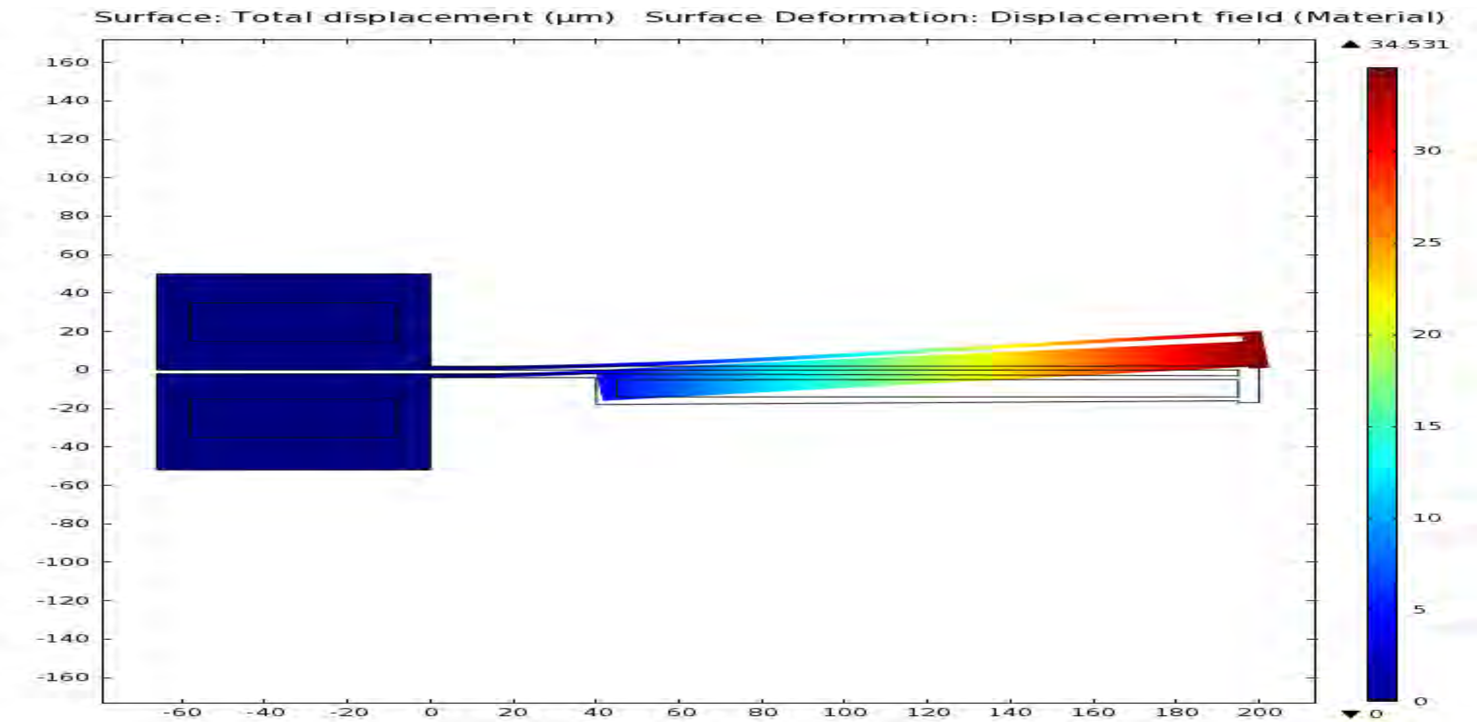


Tip Displacement of Rectangular beam with gold layer



For rectangular beam with gold layer a tip displacement of about 28 μm is obtained.
The direction of deflection is towards hot beam side.

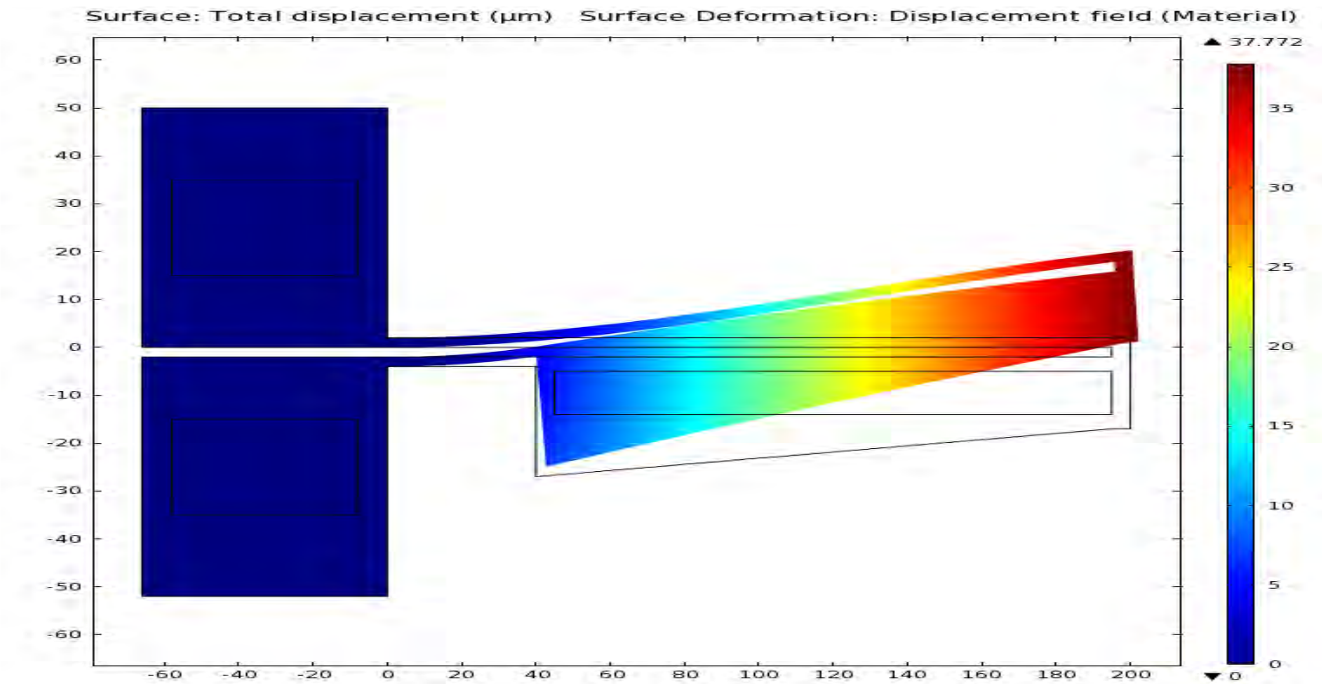
Tip Displacement of Tapered beam design 1 with gold layer



For Tapered beam design 1with gold layer, a tip displacement of about 34 µm is obtained.

The direction of deflection is towards thin beam.

Tip Displacement of Tapered beam design 2 with gold layer



For Tapered beam design 1with gold layer, a tip displacement of about 38 µm is obtained.

The direction of deflection is towards hot beam.

Conclusion

- A two dimensional finite element model of an electro thermal actuator was developed.
- The gold layer deposition increases the displacement and also the direction of deformation towards hot beam.
- Two more design as tapered beam design 1 and tapered beam design 2 is also developed.
- A maximum deflection of about 38 μm is obtained with tapered design 2.

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