MEMS THERMAL ACTUATOR BASED VARACTOR

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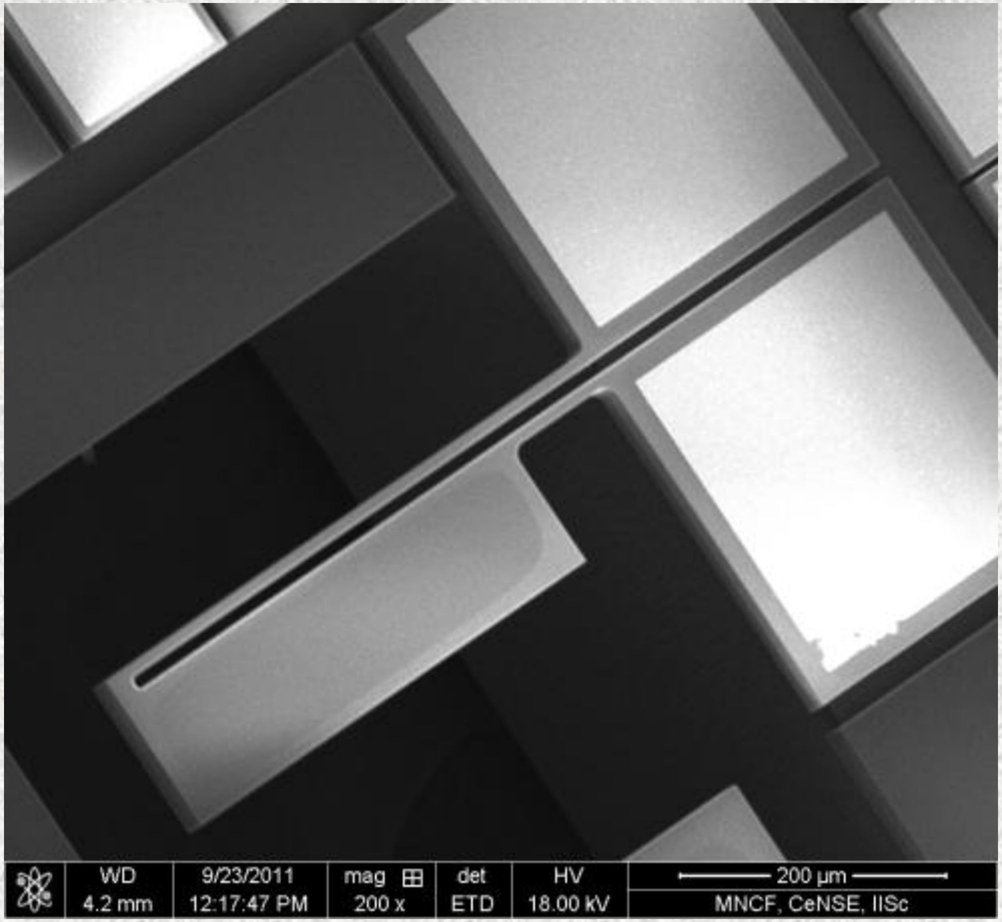
The Plan

- ✓ Introduction
  - ➢ Advantages of using thermal actuator
- ✓ Design of suitable thermal actuator for varactor application
- ✓ Geometrical modeling
- ✓ Analytical modeling
- ✓ Temperature Profile
- ✓ Deflection
- ✓ Varactor

Introduction

- ✓ Thermal actuator



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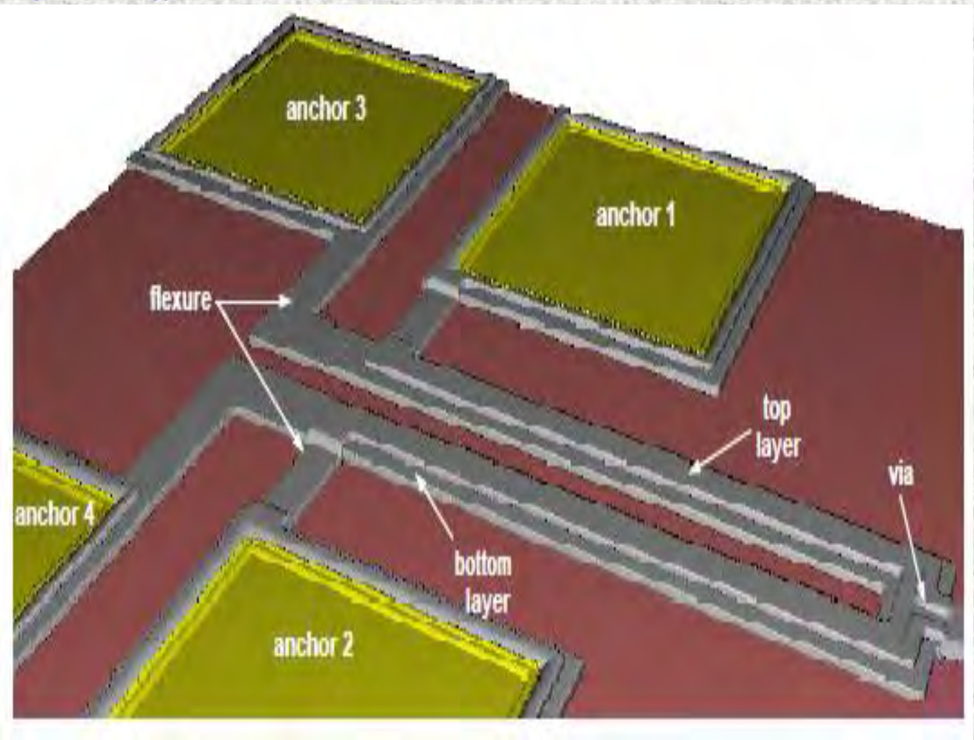
Advantages

- ✓ Avoiding the static charges collecting on the plates
- ✓ Improvement in the reliability,
- ✓ Lower driving voltages and mainly
- ✓ No pull in effect..

- ✓ Used in micro legs, micro grippers, micro positioning applications etc.
  - ➢ And in varactor

Design of a Bidirectional Vertical Thermal Actuator

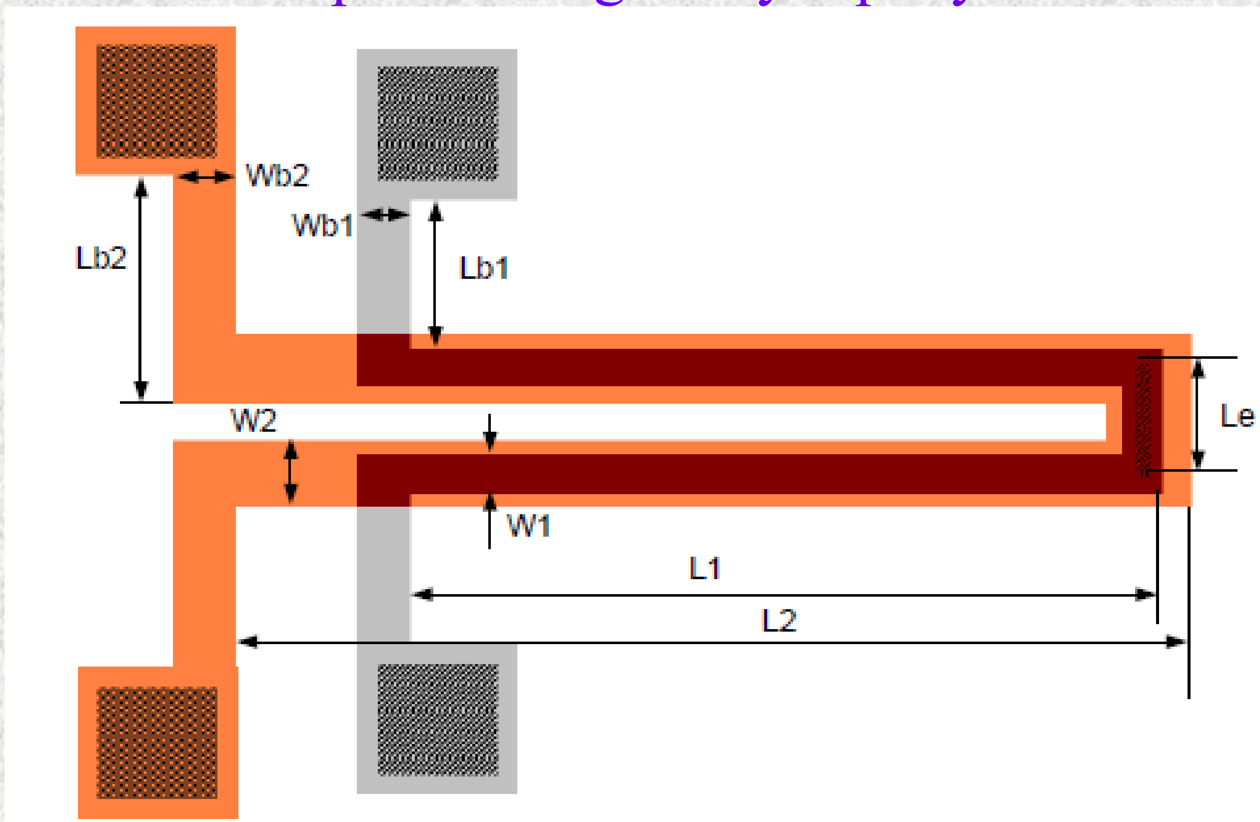
- ✓ Geometric Modelling
- ✓ Electro thermal analysis and
- ✓ Mechanical analysis



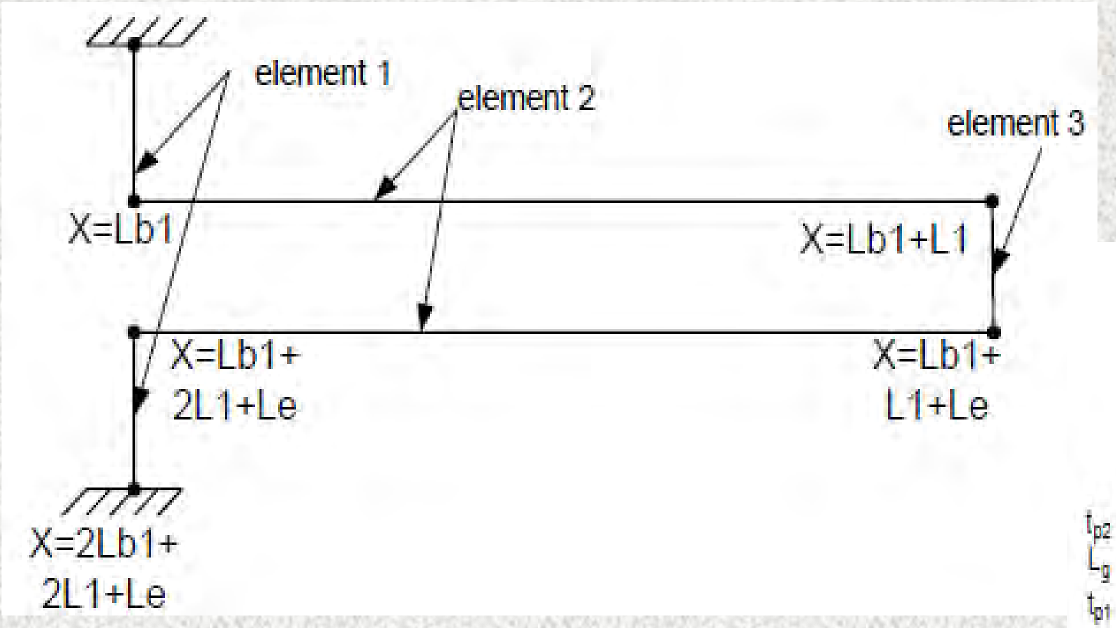
Schematic Top View Diagram of a U-shaped VTA

Analytical Modeling

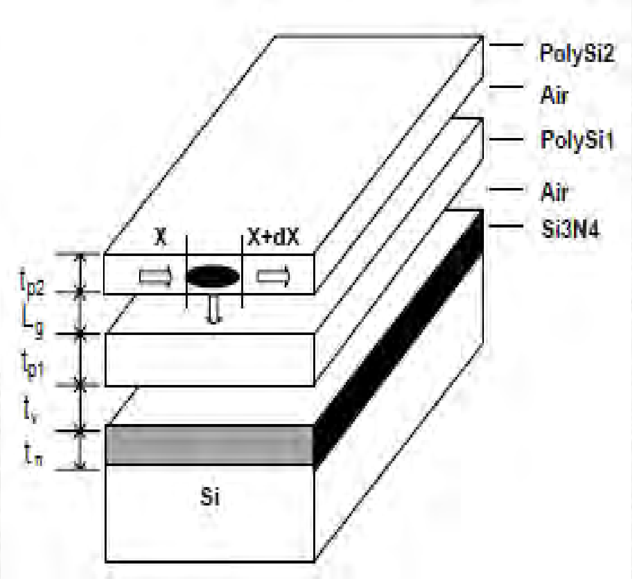
- ✓ The electro-thermal analysis of the U-shape VTA can be simplified as one dimensional heat transfer problem.
- ✓ Current is assumed to pass through only top layer of the actuator .



Analytical Modeling



- ✓ There are five microbeams connected to each other.



One element for analysis

Electrothermal Equation

- ✓ Heat balance
- ✓ Only the heat loss through conduction and convection is considered
  - ➢ Heat dissipated through radiation to the ambient is neglected.
- ✓ Under steady-state conditions, Ohmic power generated in the element is equal to heat conduction and convection out of the element,

$$-K_p w t \left[\frac{dT}{dx}\right]_x + J^2 \rho w t dx = -K_p w t \left[\frac{dT}{dx}\right]_{x+dx} + \frac{S w (T - T_s) dx}{R_T}$$

$$T = T_s + \frac{B}{A^2} + C_1 e^{Ax} + C_2 e^{-Ax}$$

Material Properties used in modeling

Material Properties	Value	Unit
Young's modulus E	162×10^{9}	Pa
Poisson's ratio υ	0.22	
Thermal expansion coefficient K	4.7×10^{-6}	C^{-1}
Thermal conductivity of polysilicon k_p	41×10^{-6}	$W.\mu m^{-1}.C^{-1}$
Thermal conductivity of air k_v	0.026×10^{-6}	$W.\mu m^{-1}.C^{-1}$
Thermal conductivity of nitride k_n	2.25×10^{-6}	$W.\mu m^{-1}.C^{-1}$
Resistivity of polysilicon ρ_0	20	$\Omega.\mu m$
Linear temperature Coefficient ξ	1.25×10^{-3}	C^{-1}

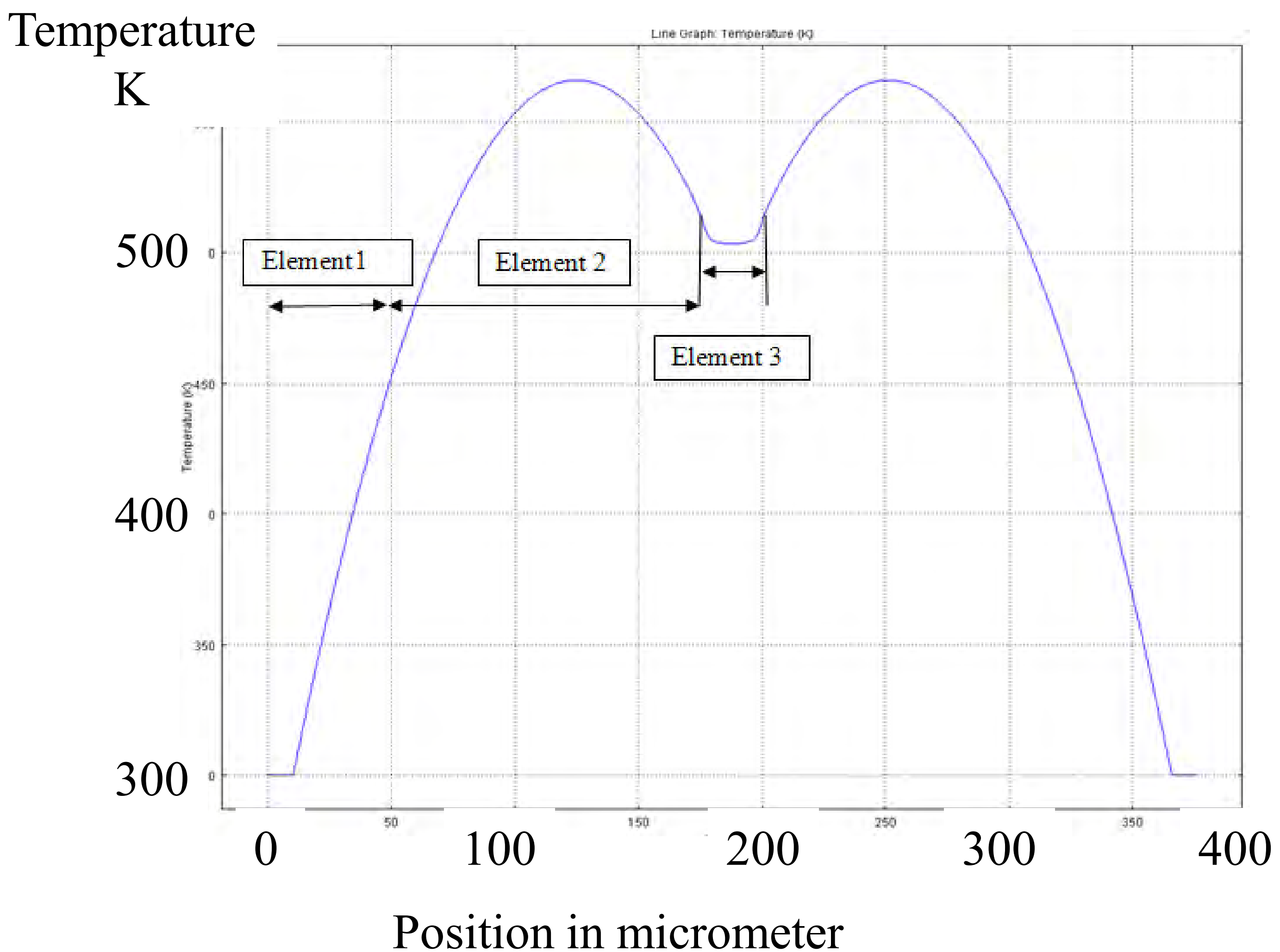
Geometrical Data

Geometrical data	Value	Unit
The length of the long beam of the top layer L1	177	µm
The length of the long beam of the bottom layer L2	217	µm
The length of the short bar of the top layer Lb1	50	µm
The length of the short bar of the bottom layer Lb2	60	µm
The width of the long beam of the top layer w1	10	µm
The width of the long beam of the bottom layer w2	18	µm
The width of the short bar of the top layer wb1	13	µm
The width of the short bar of the bottom layer wb2	15	µm
The length of the connection between two long beams Le	38	µm
The gap between the top layer and the bottom layer	0.75	µm
The thickness of the top layer Tp2	1.5	µm
The thickness of the bottom layer Tp1	2.0	µm
The thickness of air Tv	2	µm
The thickness of nitride Tn	0.6	µm

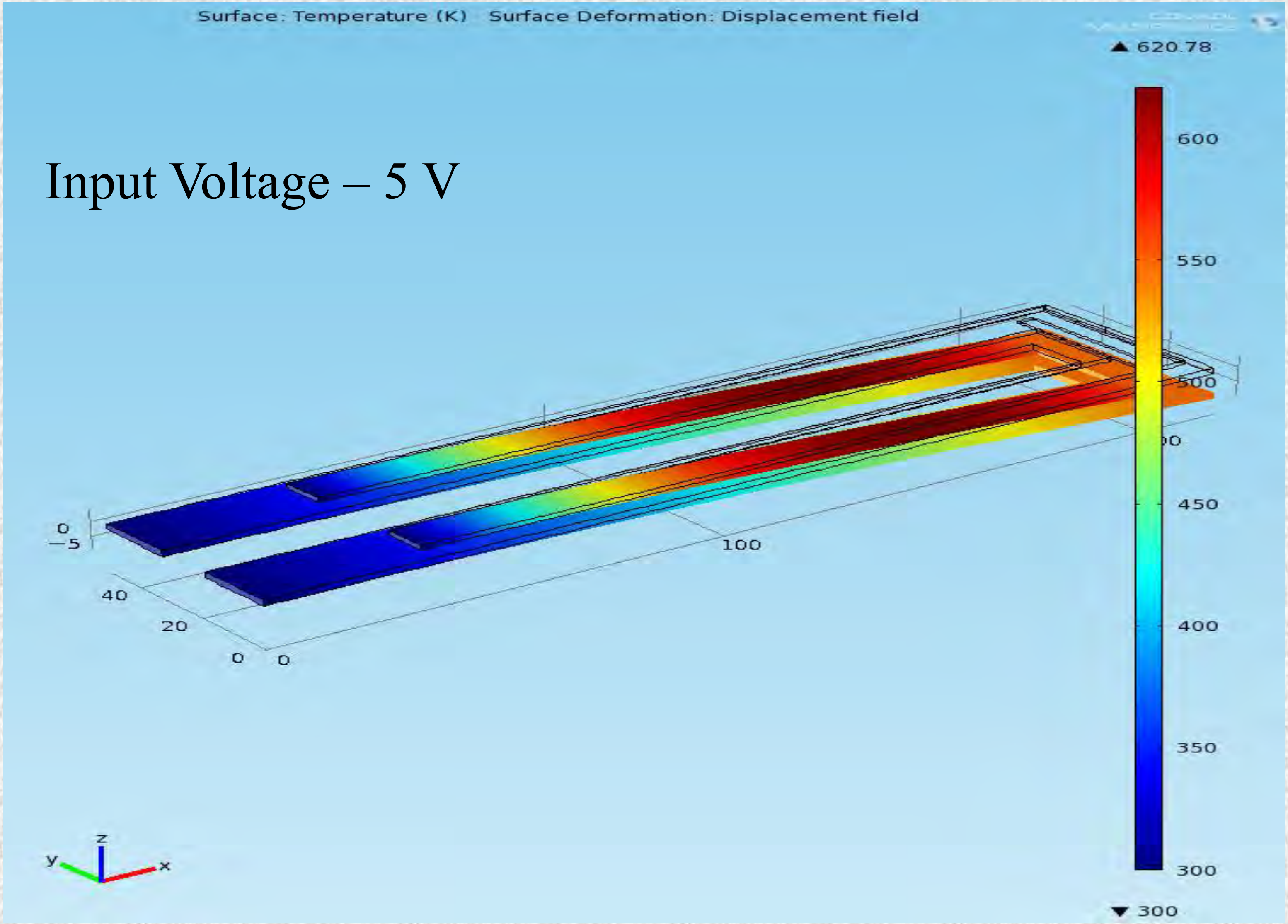
Temperature distribution

- ✓ Input voltage 4V,
- ✓ Since the U-shaped vertical thermal actuator is symmetrical about its centre line, the temperature distribution also should be symmetrical about its centre line.

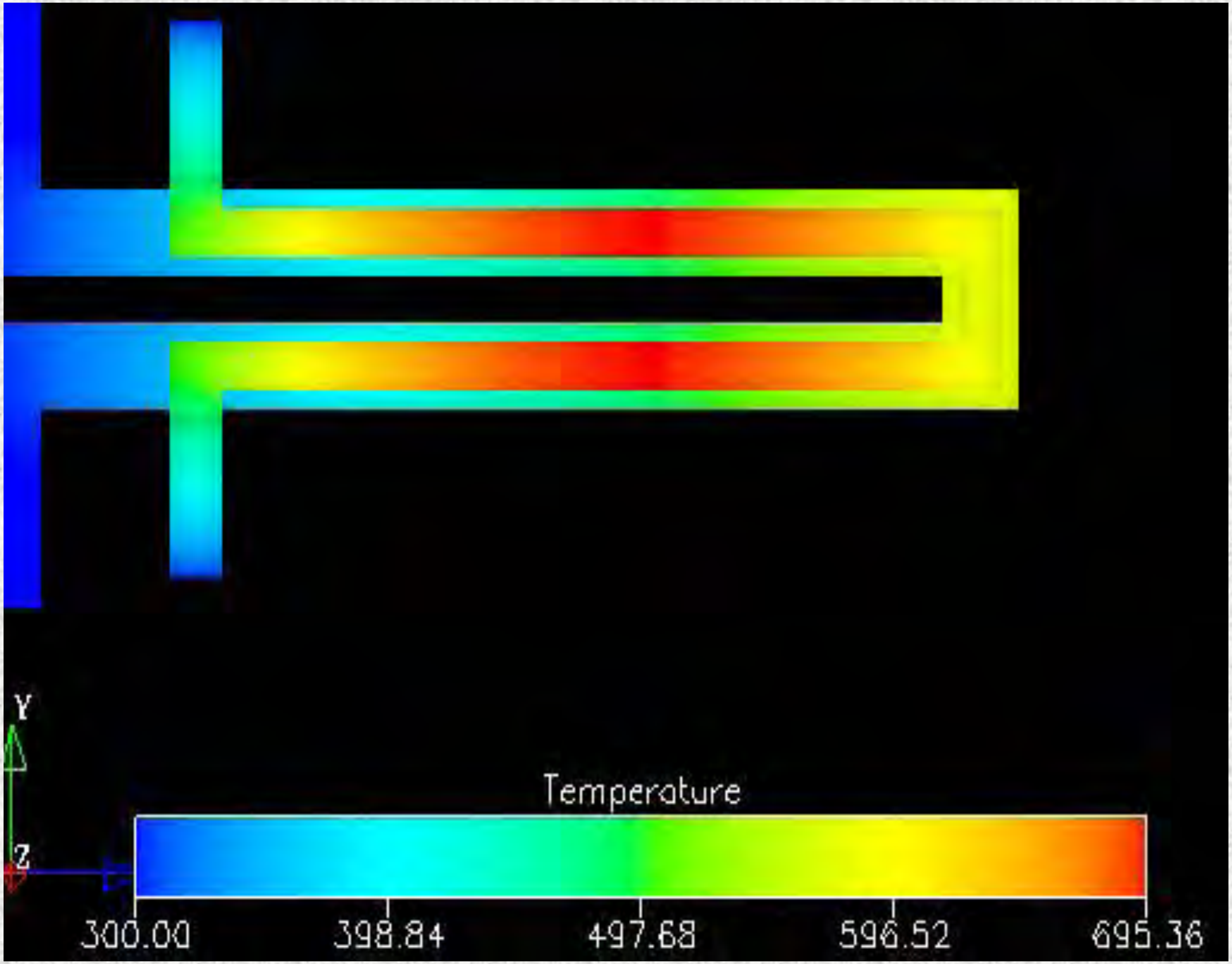
Simulation Results



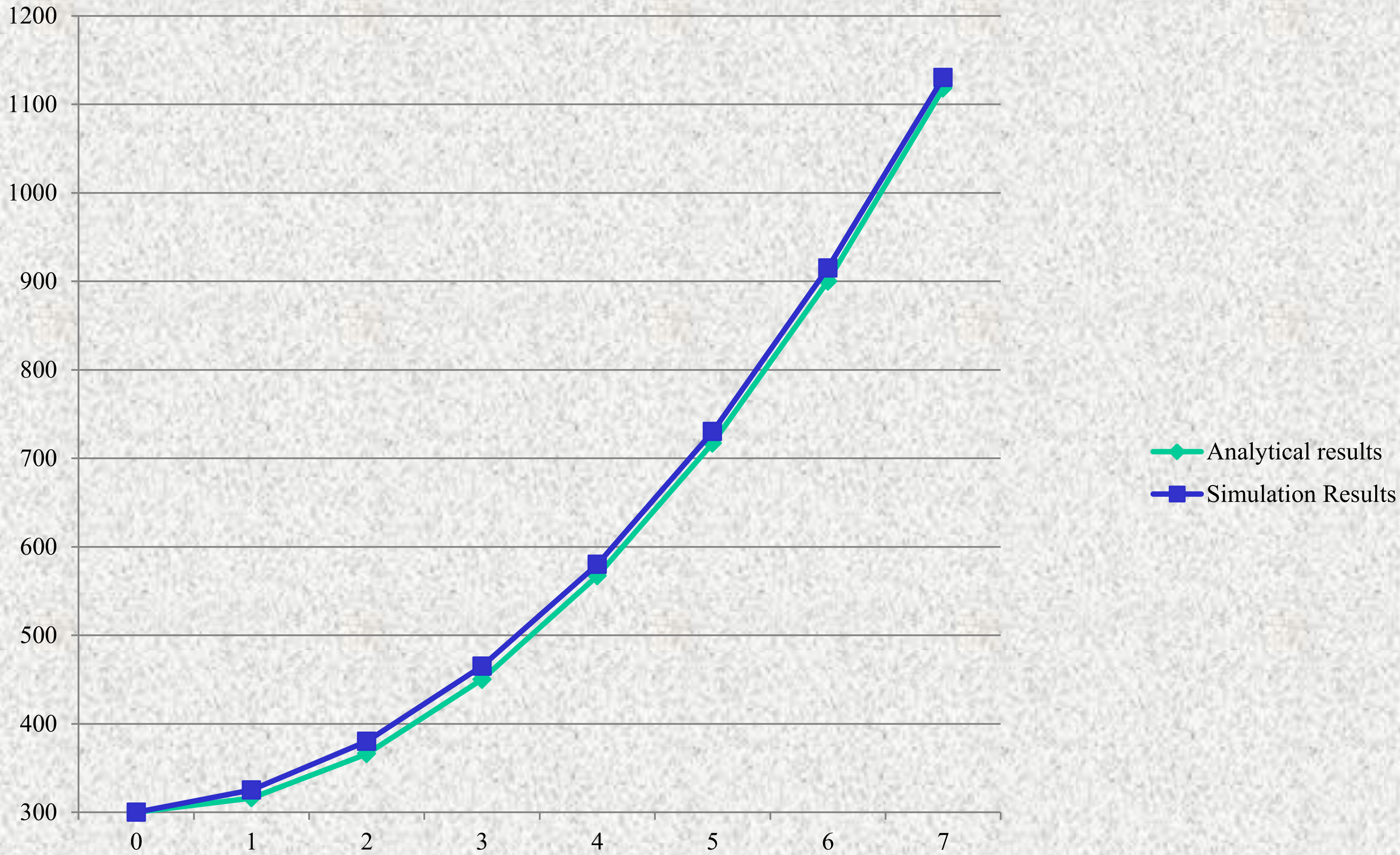
Temperature distribution



Input Voltage – 5 V

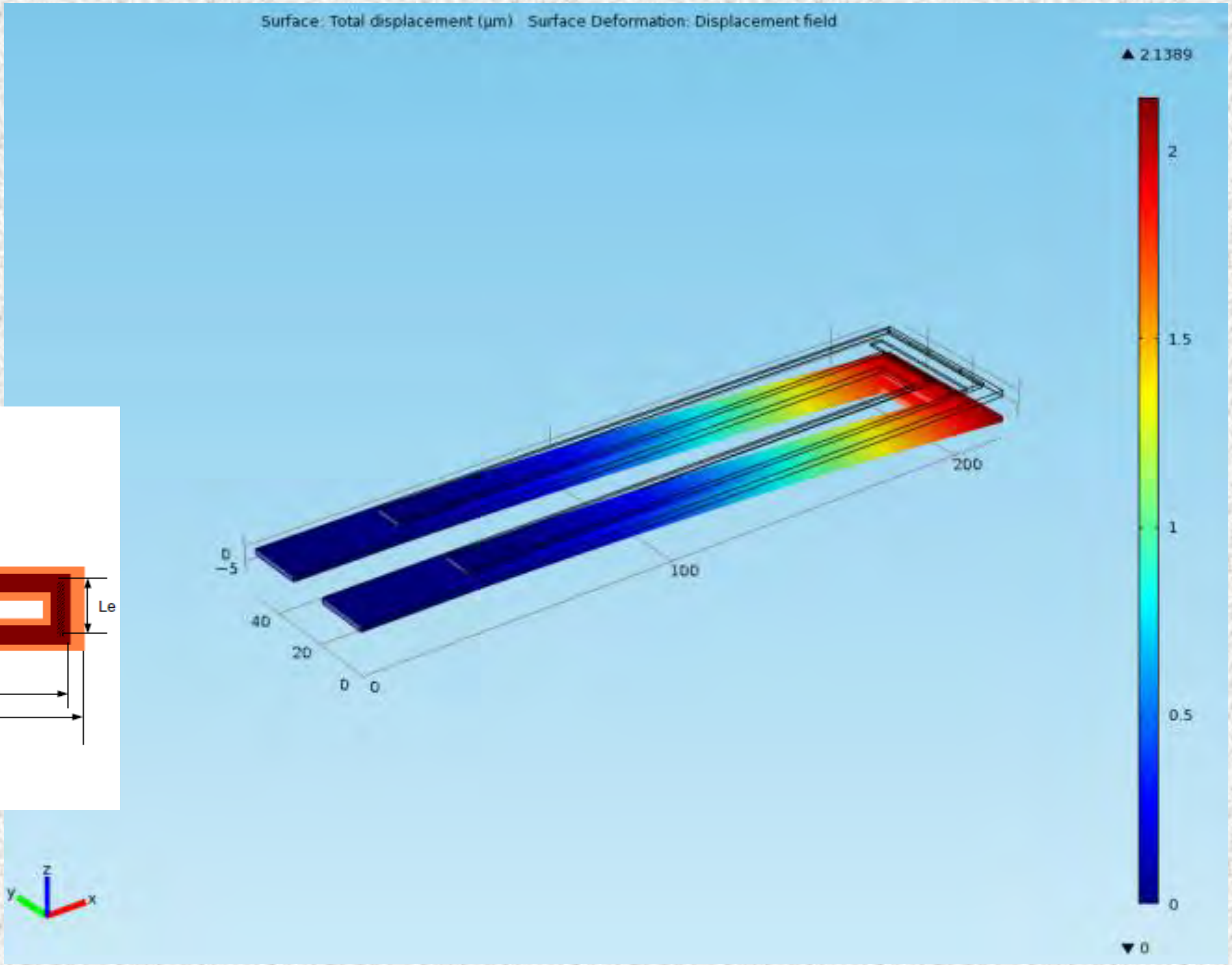


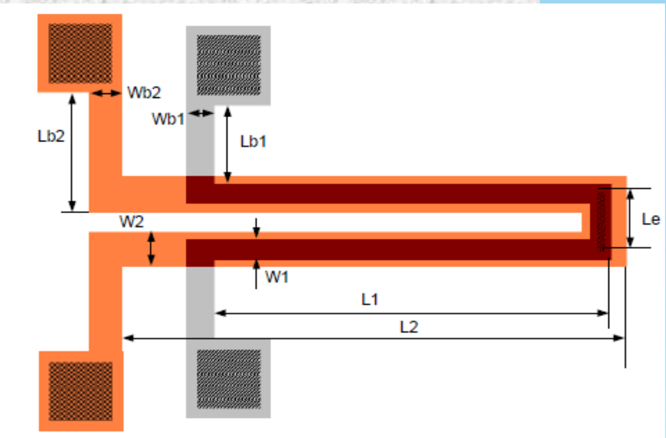
Maximum temperature at different voltage



Deflection downwards

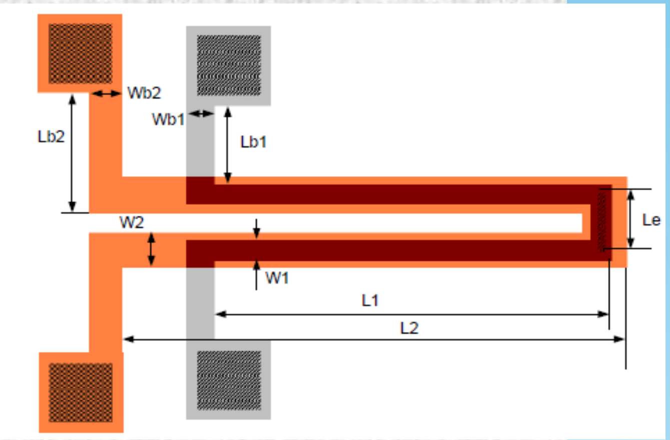
- ✓ COMSOL results with the voltage is applied to anchor 1 and 2

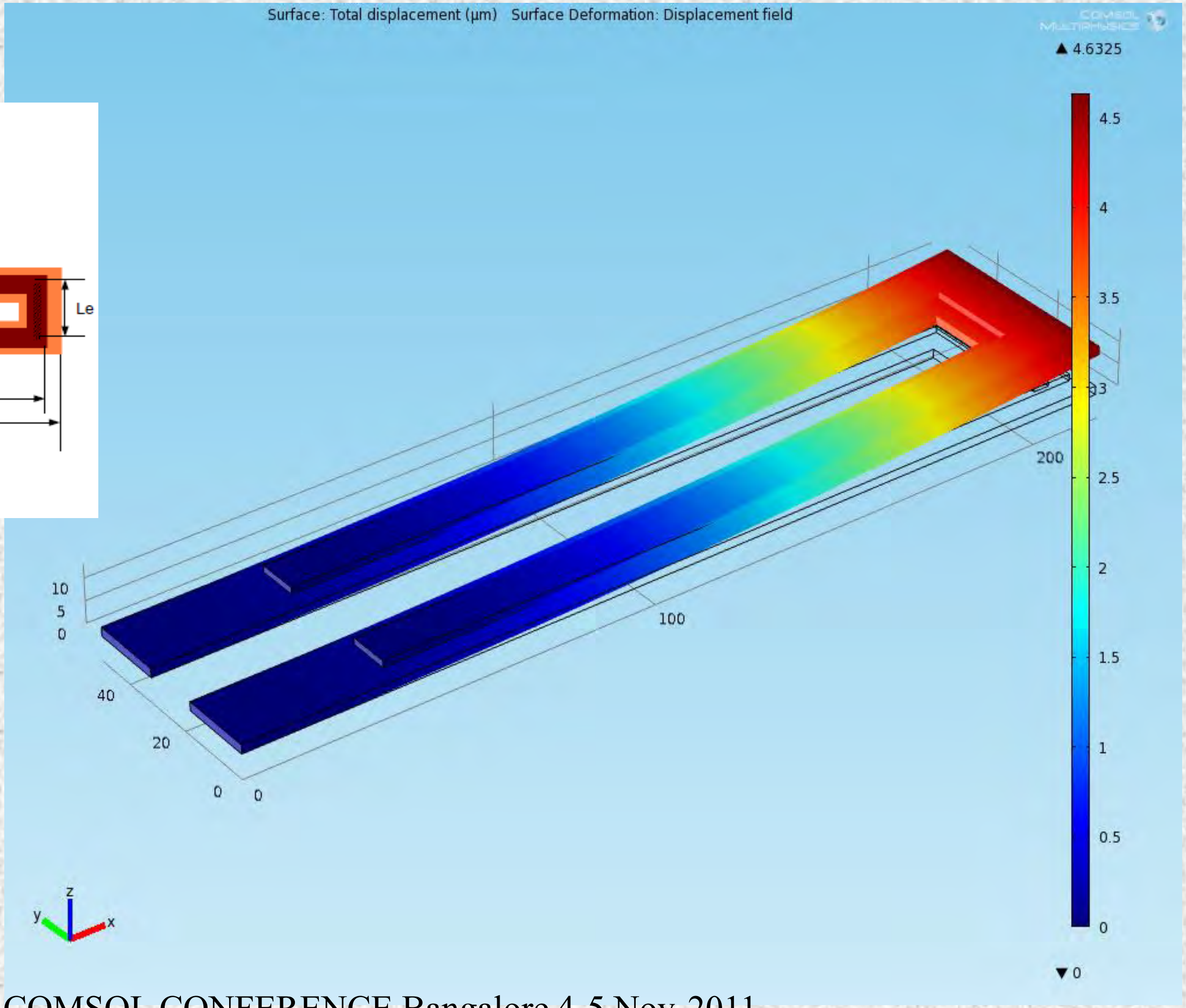




Deflection upwards

- ✓ Comsol results with the voltage is applied to anchor 3 and 4

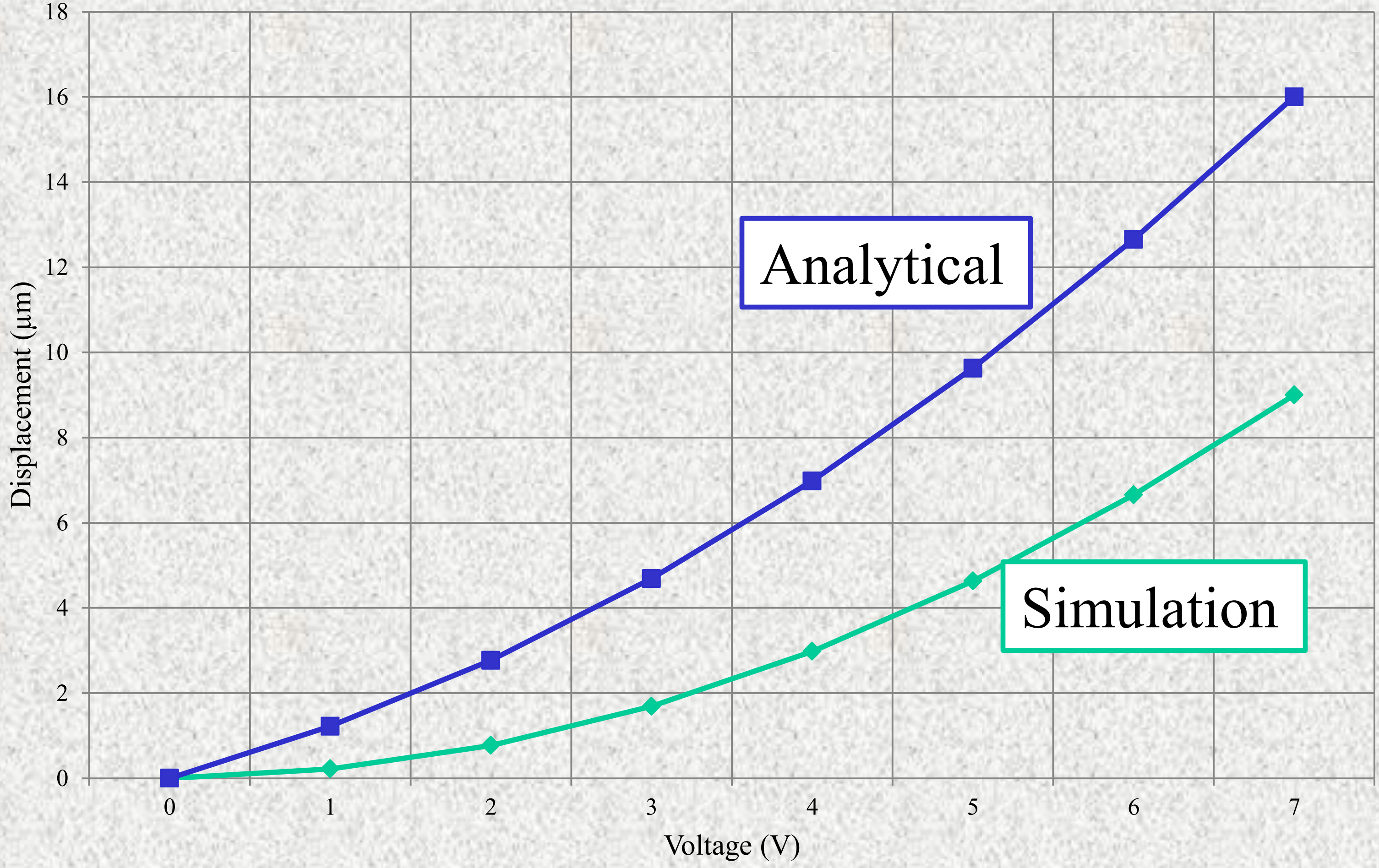




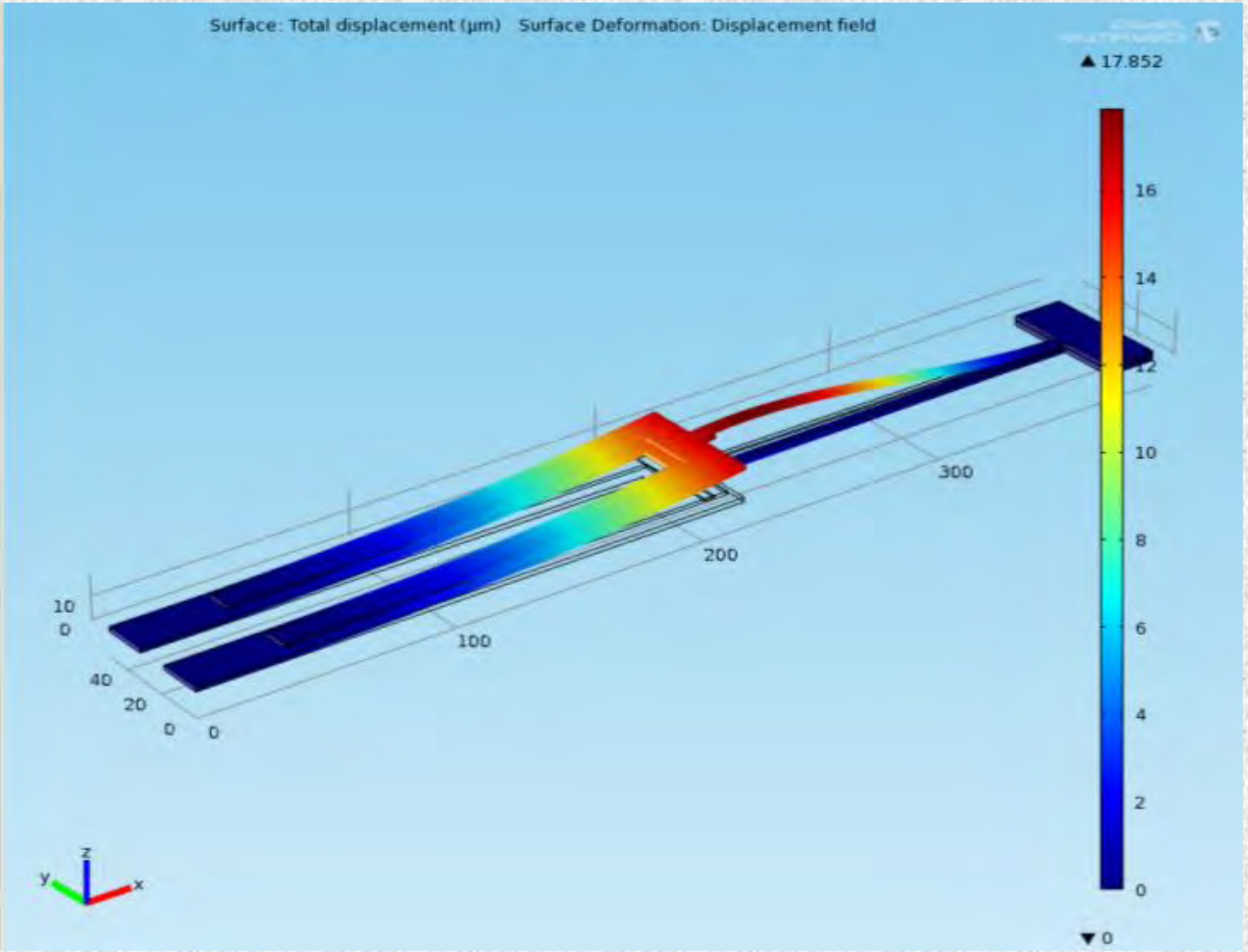
Deflection

$$u = \frac{1}{EI_1}\int_0^{L_1} M\bar{M}dx = \frac{1}{EI_1}(-\frac{1}{3}X_1L_1^3 + \frac{1}{2}X_1L_1^3L_2 - \frac{1}{2}X_2L_1^2L_g$$

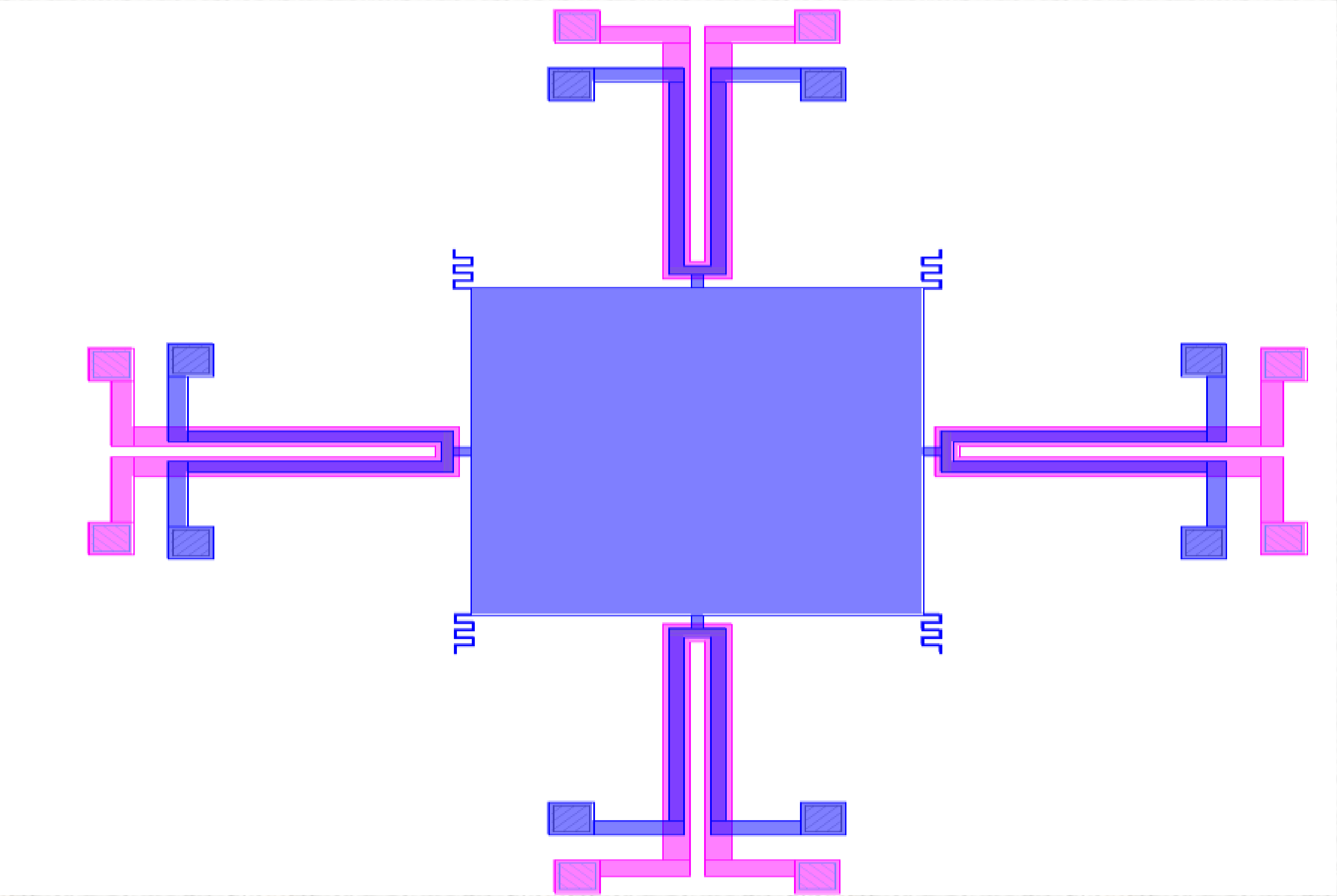
Displacement

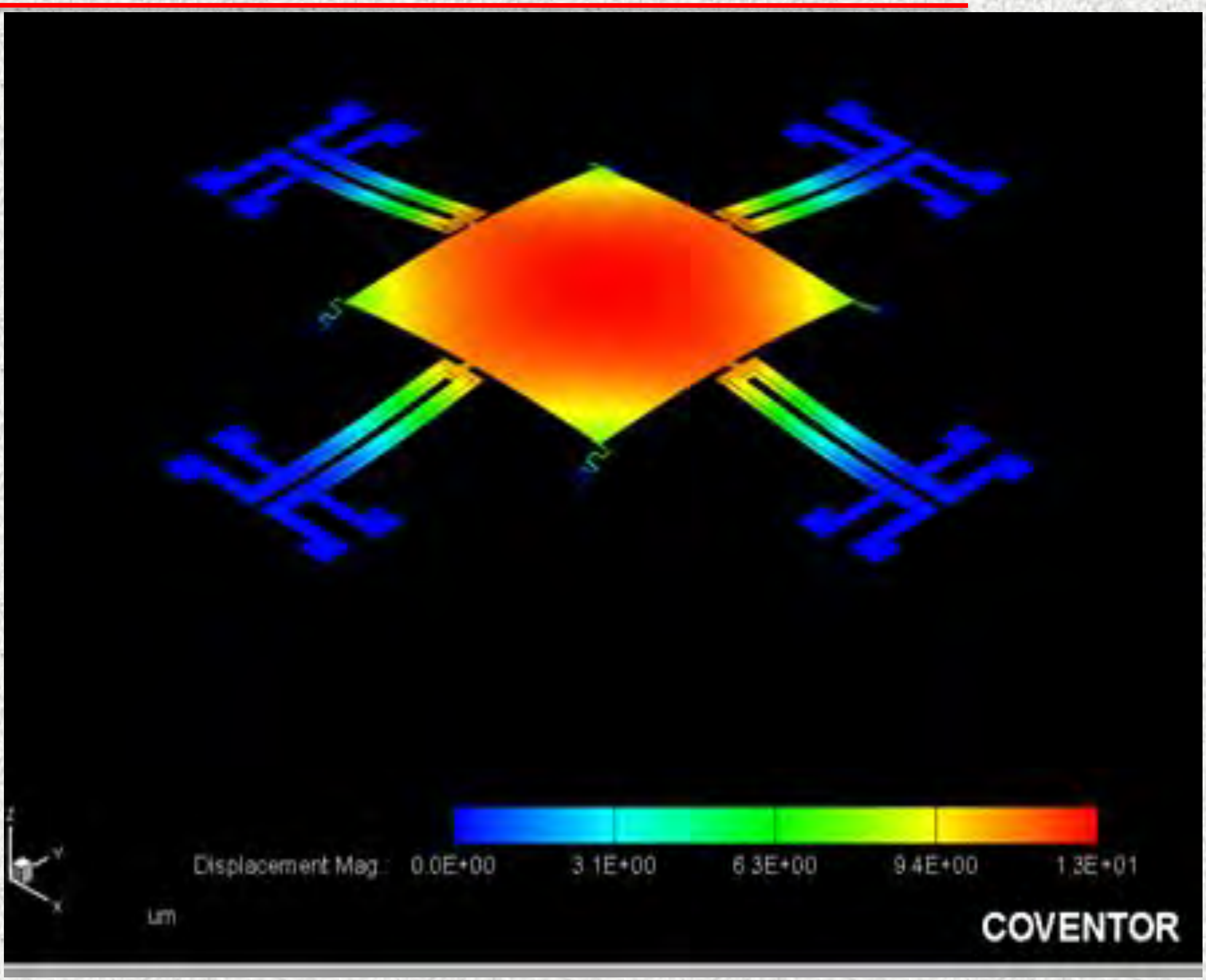


Simulation including Cantilever



Model of Varactor




Displacement Mag: 0.0E+00 3.1E+00 6.3E+00 9.4E+00 1.3E+01
um
COVENTOR

pF

Results

Voltage	Displacement(um)	Capacitance(pF)
1	0.38	2.2
2	1.213	0.7
3	2.6	0.3
4	4.54	0.175
5	7.03	0.079
6	10.08	0.079
7	13.69	0.058
8	17.8	0.0447

Acknowledgement

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