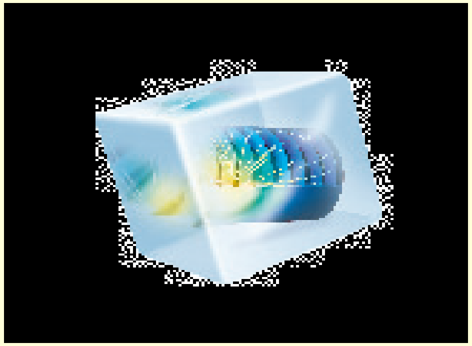
OPTIMIZING THE PERFORMANCE OF MEMS ELECTROSTATIC COMB DRIVE ACTUATOR WITH DIFFERENT FLEXURE SPRINGS



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MEMS

- Microelectromechanical systems (MEMS) are very small devices or groups of devices that can integrate both mechanical and electrical components.

- MEMS can be constructed on one chip that contains one or more micro-components and the electrical circuitry for inputs and outputs of the components.

- The term MEMS first started being used in the 1980's.

- Microcomponents make the system faster, more reliable, cheaper and more capable.

MEMS is based upon three blocks:-

- **Microsensor:** It measure a physical parameter (such as pressure, acceleration) and report it in the form of an electrical signal (e.g. Temperature, Vibration, Rotation etc.).
- **Microactuator:** It convert the electrical signal into mechanical form of energy e.g., resonating beams, switches and micropumps. In other words, actuators are used to convert the non mechanical input energy into mechanical output energy.
- **Control Unit:** They manage and control the whole system by analyzing the data, reaching the appropriate conclusion and determining the actions required.

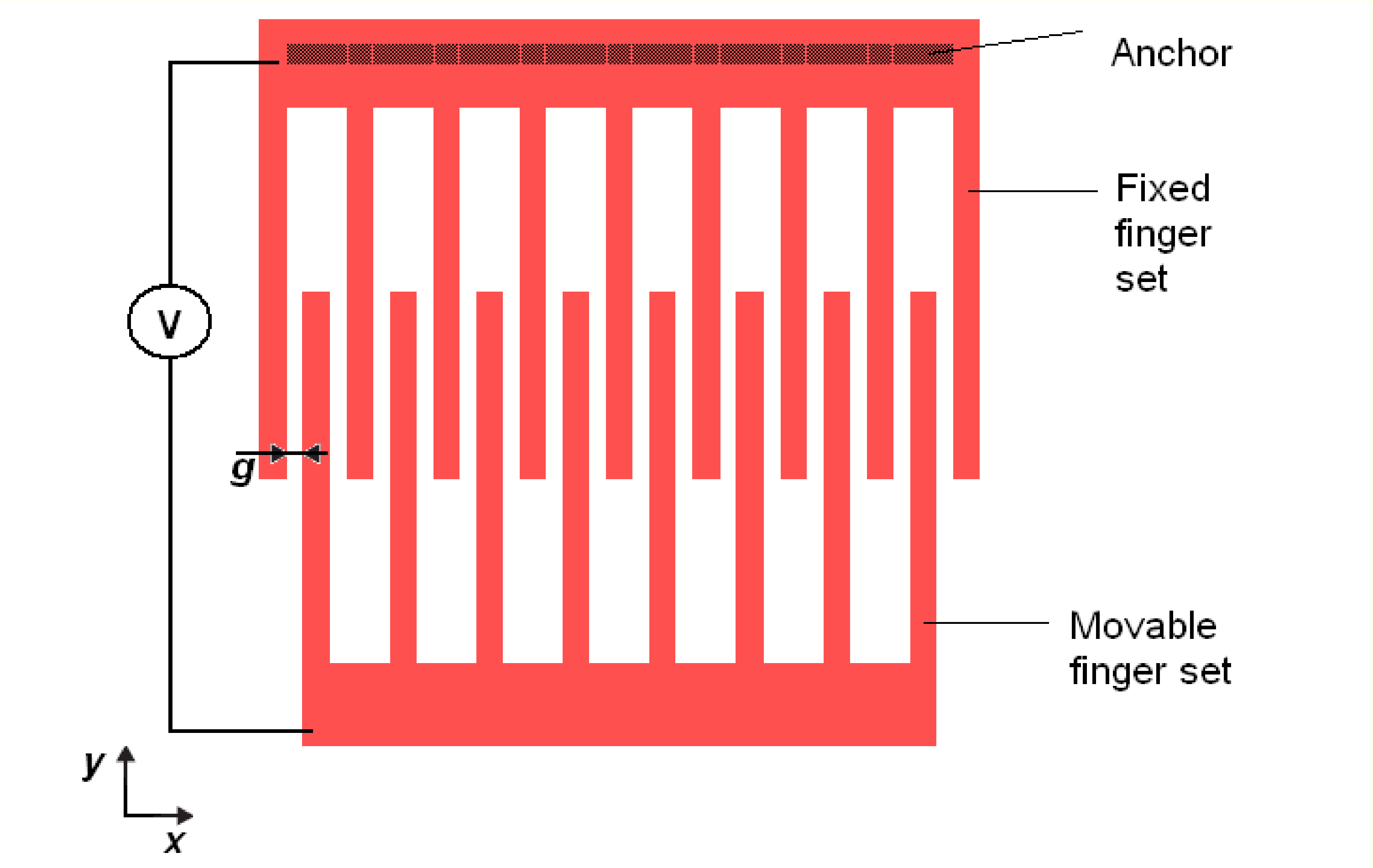
Actuator

It converts non mechanical input energy into mechanical output energy.

Electrostatic Comb Drive Actuator

- *Comb Drive actuator is the main application of Electrostatic Actuator*

What is comb drive?



What is COMB DRIVE?

- Comb-drive actuator consists of interdigitated finger structures, where one comb is fixed and other is connected to complaint suspension. This suspension can have different shapes and different designs.
- The combs are arranged so that they never touch. Typically the teeth are arranged so that they can slide past one another until each tooth occupies the slot in the opposite comb.

- Applying a potential difference across the comb structure will result in deflection of the movable comb structure, this deflection is due to generated electrostatic forces in the system.
- The position of the movable fingers is controlled by balance between electrostatic forces and the mechanical forces. Mechanical forces are generated through spring structures. They directly depend upon the stiffness of the flexures. By changing the flexures, mechanical forces changes which changes displacement.

PRINCIPLE OF COMB DRIVE

- The Electrostatic force is based on **Coulomb's law.**

It states that electrostatic force is directly proportional to the magnitude of each charge and inversely proportional to the square of the distance b/w two charges.

$$F = \frac{Q_1 Q_2}{4 \prod \varepsilon_0 r^2}$$

- Mainly depends upon size of structures and distance between two electrodes.

APPLICATIONS

- RESONATORS
- ELECTROMECHANICAL FILTERS
- OPTICAL SHUTTERS
- MICROGRIPPERS
- VOLTMETERS

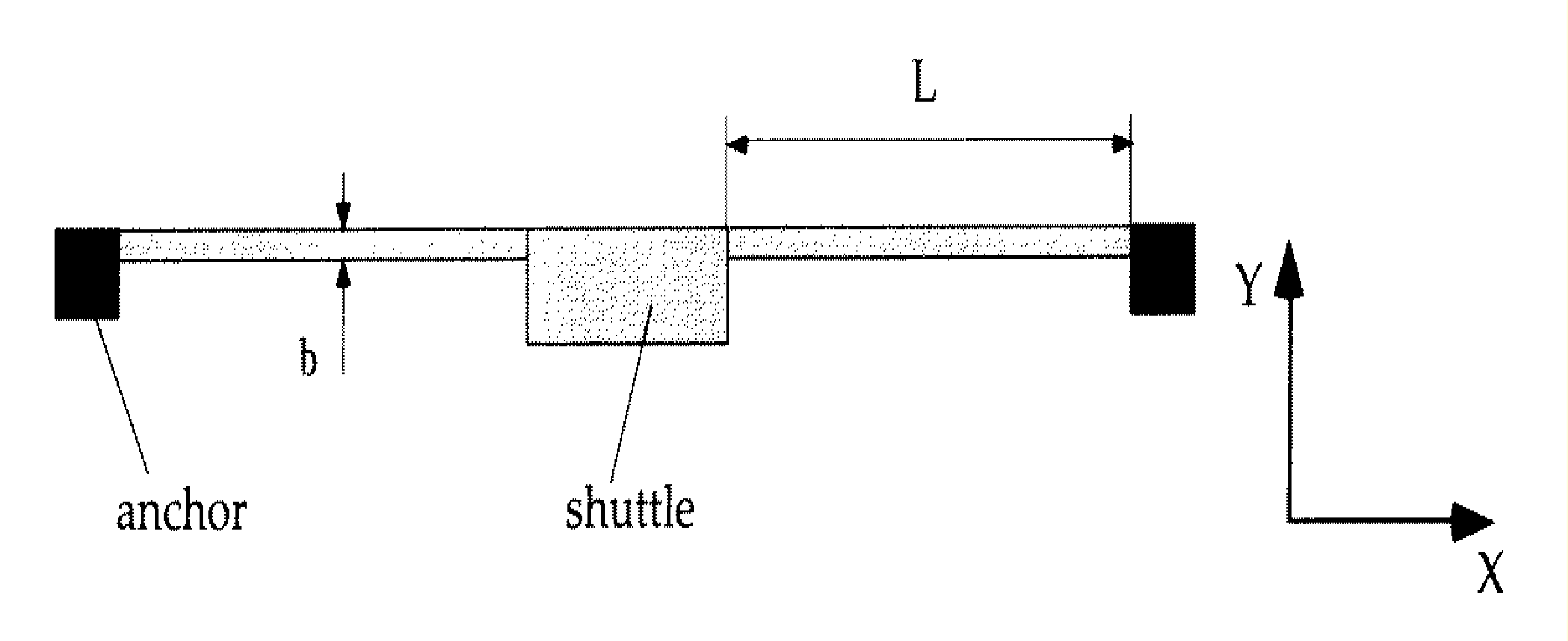
OBJECTIVE

Large deflections at low actuation voltage.

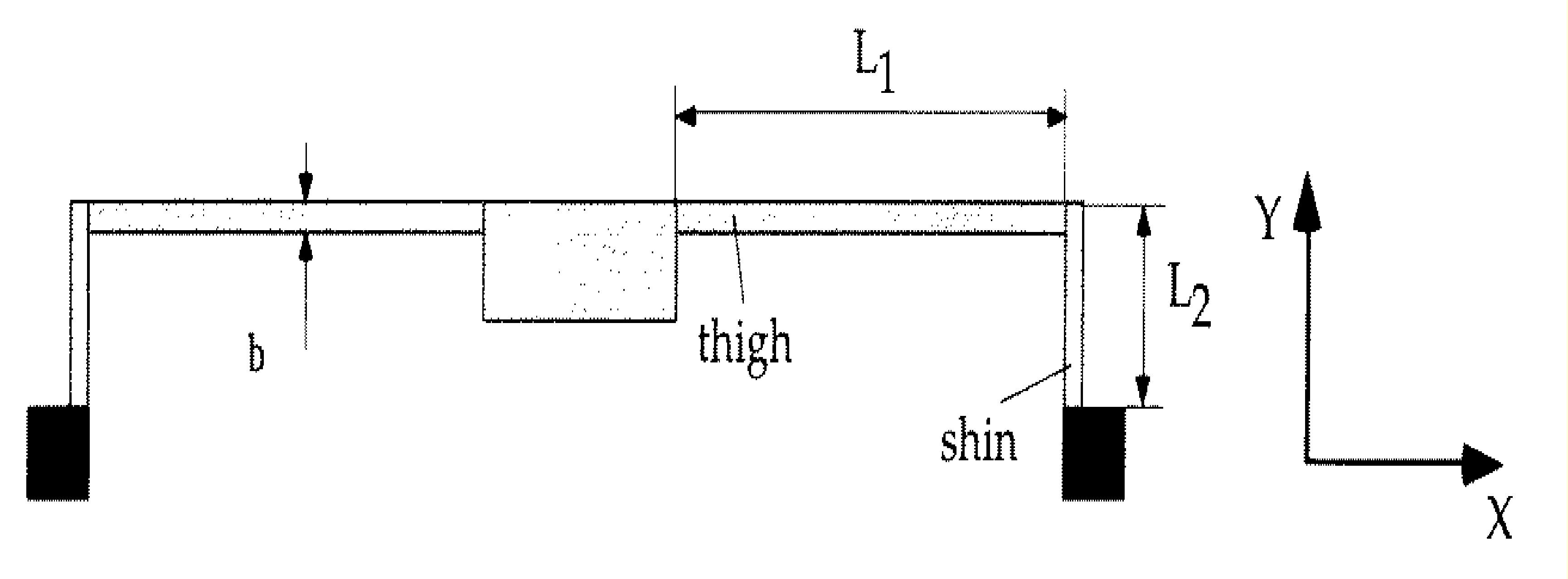
SPRING DESIGNS

1. FIXED – FIXED FLEXURE
2. CRAB LEG FLEXURE
3. FOLDED FLEXURE

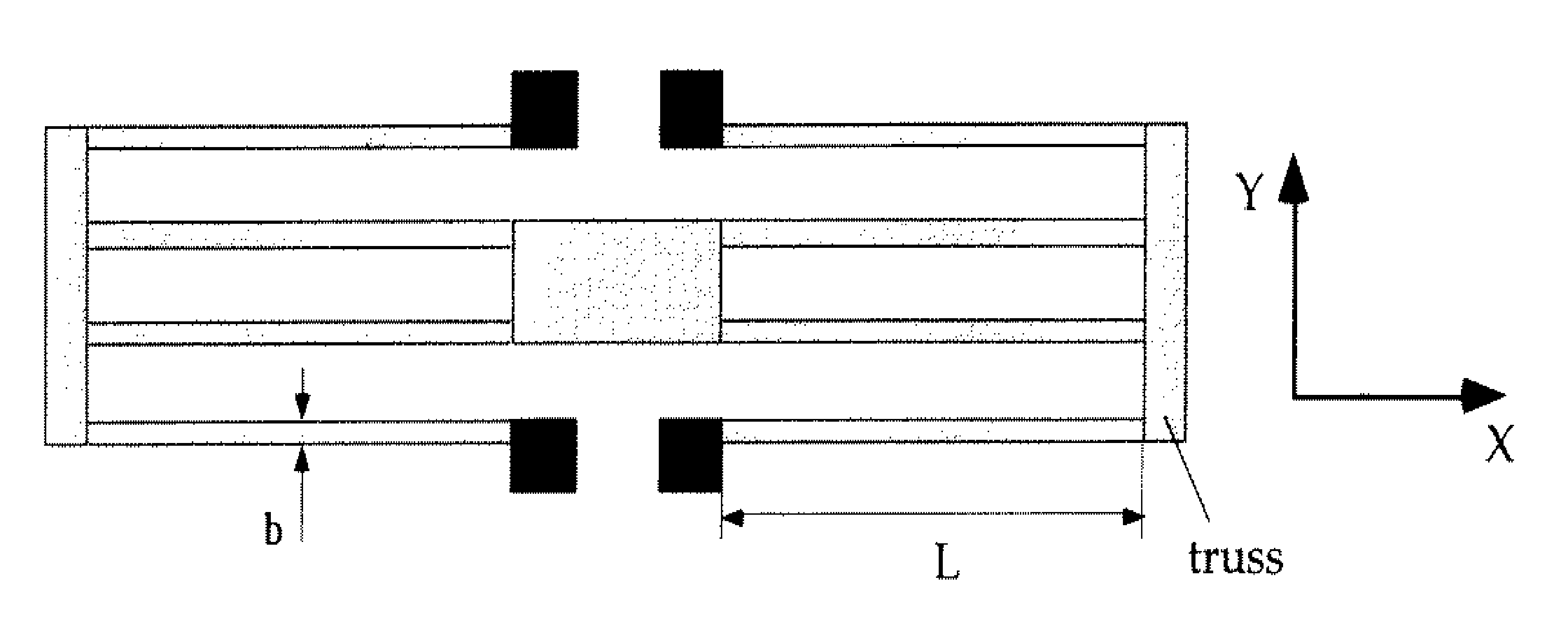
Fixed–Fixed beam.



2) Crab-Leg Flexure



3) Folded-Flexure



DIMENSIONS

1) Comb length = 30µm
2) Comb Width = 3µm
3) Gap between moving comb and fixed combs = 7µm
4) Overlapping area = 20µm
5) Spring length = 280µm
6) Spring width = 2µm
7) Gap between spring legs = 19µm
8) Thickness of Actuator = 2µm
9) No. of Moving combs = 4
10) No. of Fixed Combs = 5

NUMERICAL SIMULATIONS

1. Capacitance (C) is:

$$C = \frac{2n\varepsilon_0 t(y_0 + y)}{g}$$

y0 +y = change in overlapping area in y direction
t = thickness
g = gap spacing b/w combs
y=comb displacement
y0=initial overlap

2. Electrostatic Force (Fel) is:

$$F_{el} = \frac{n\varepsilon_0 t V^2}{g}$$

V= Actuation Voltage
n = No. of combs

3. Spring Constant (K) is:

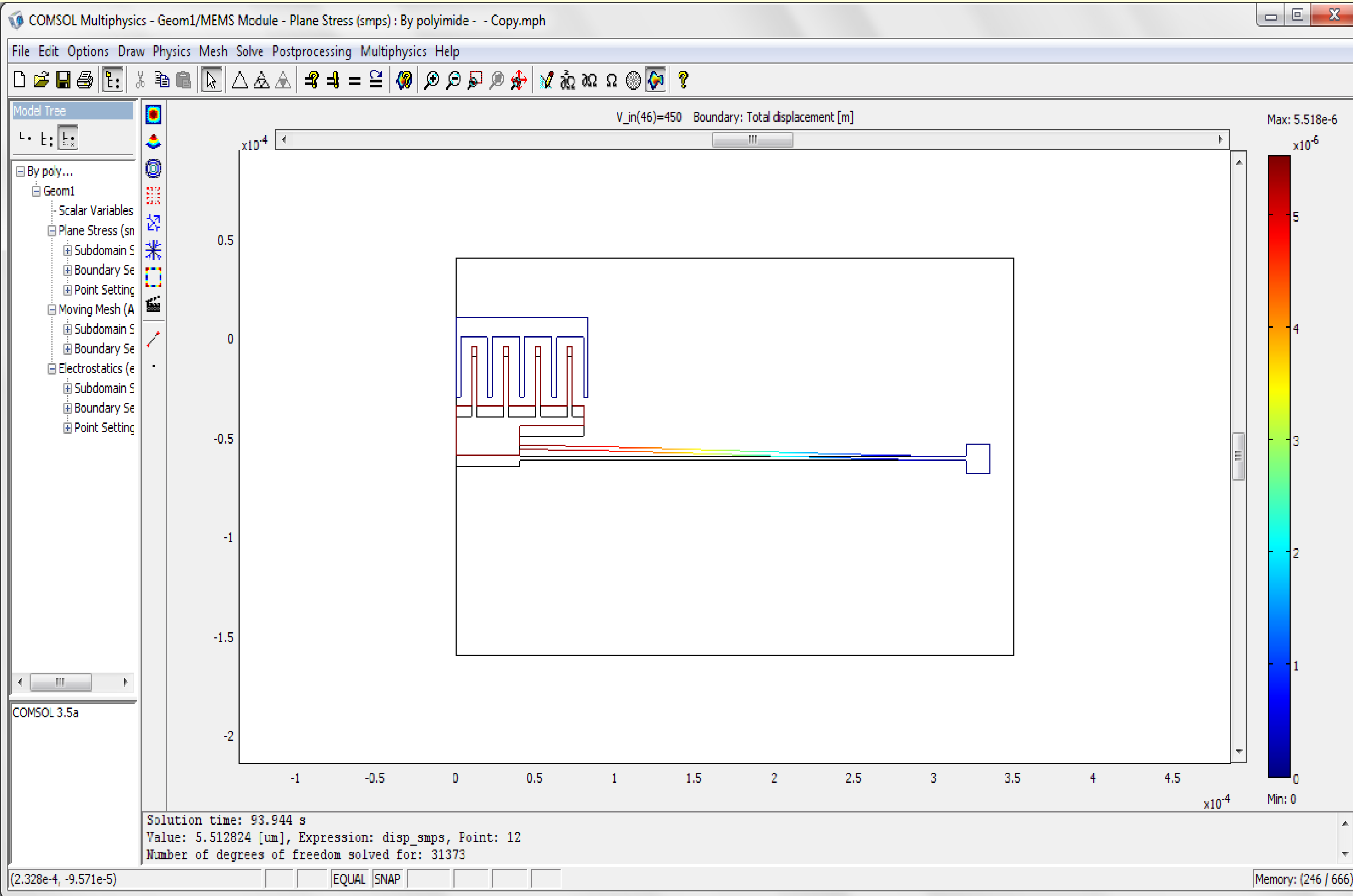
$$K = 2Et\left(\frac{W}{L}\right)^3$$

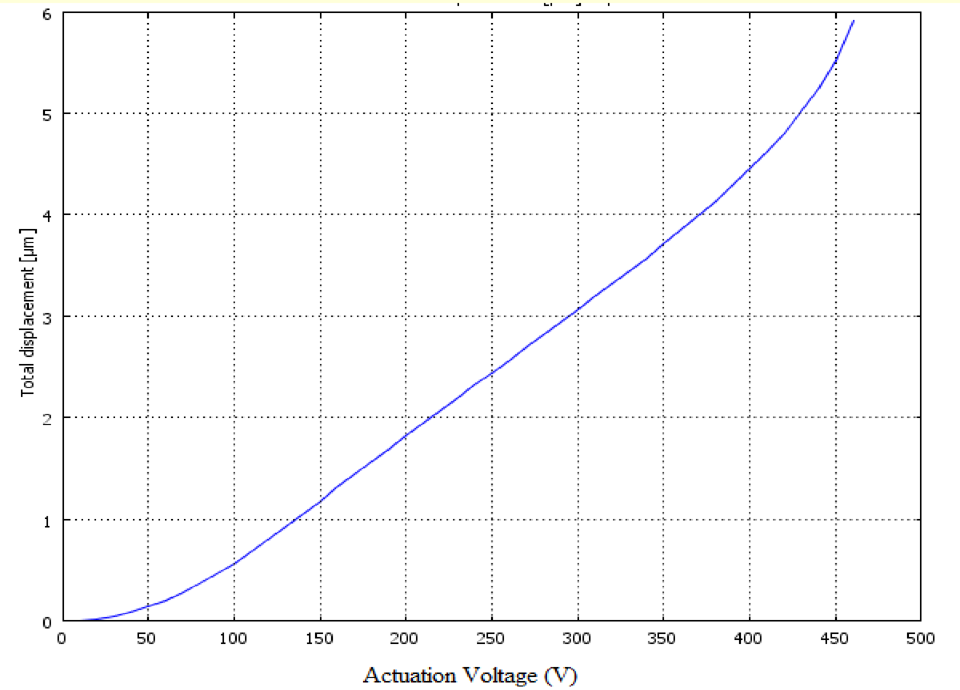
W = Width
L = Length
t = thickness

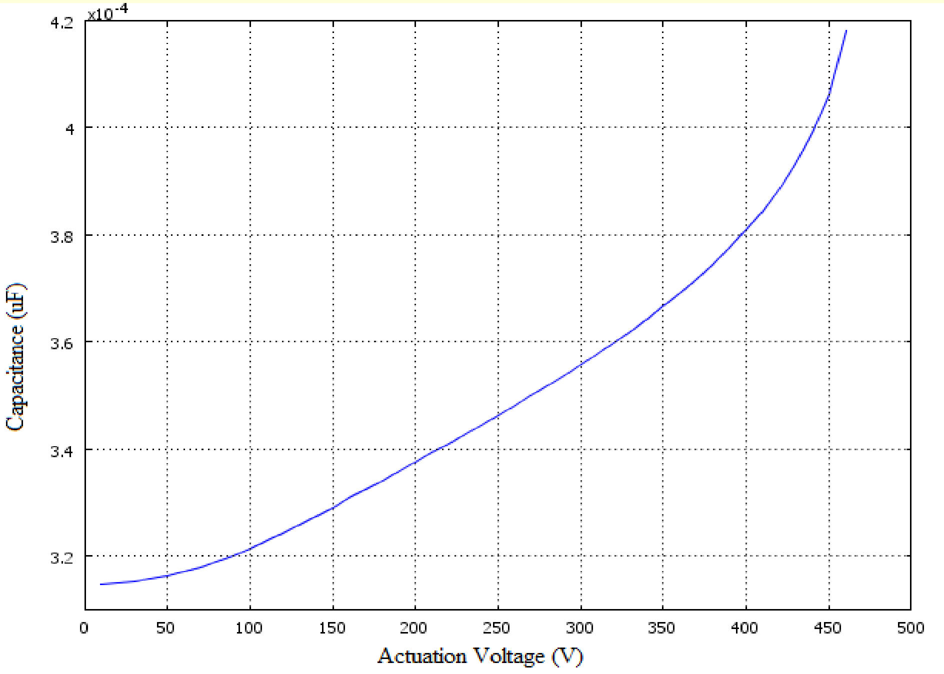
4. Displacement (Y) is:

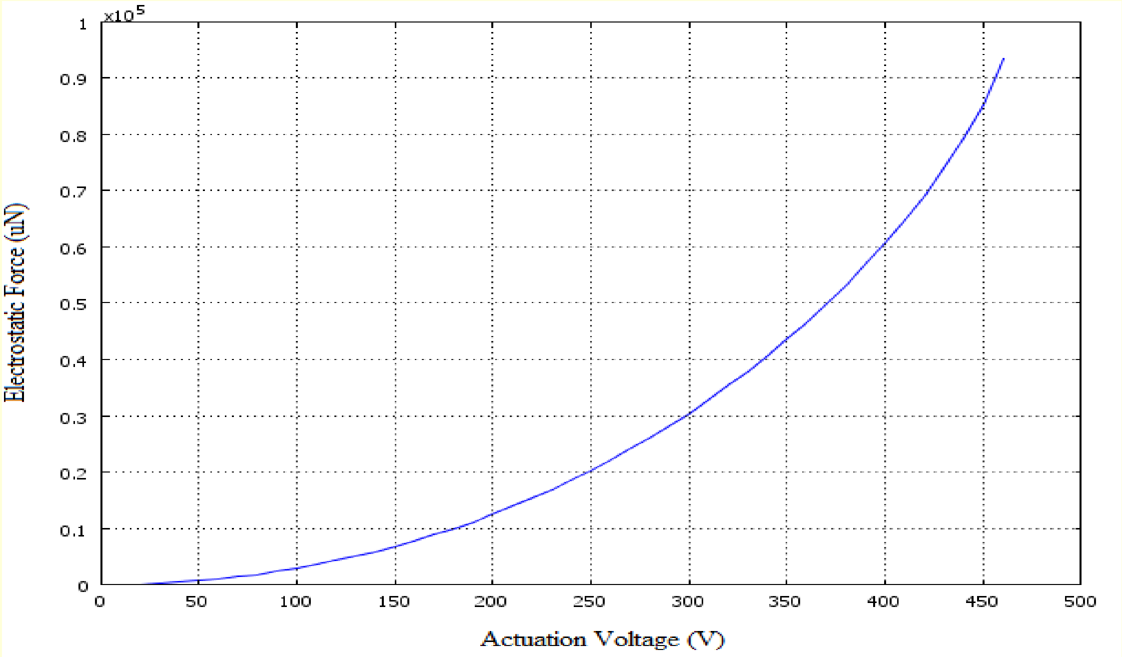
$$Y = \frac{n\varepsilon_0}{2Eg}\left(\frac{L}{W}\right)^3 V^2 = \frac{Force}{SpringConstant}$$

Simulation of Fixed-fixed Flexure

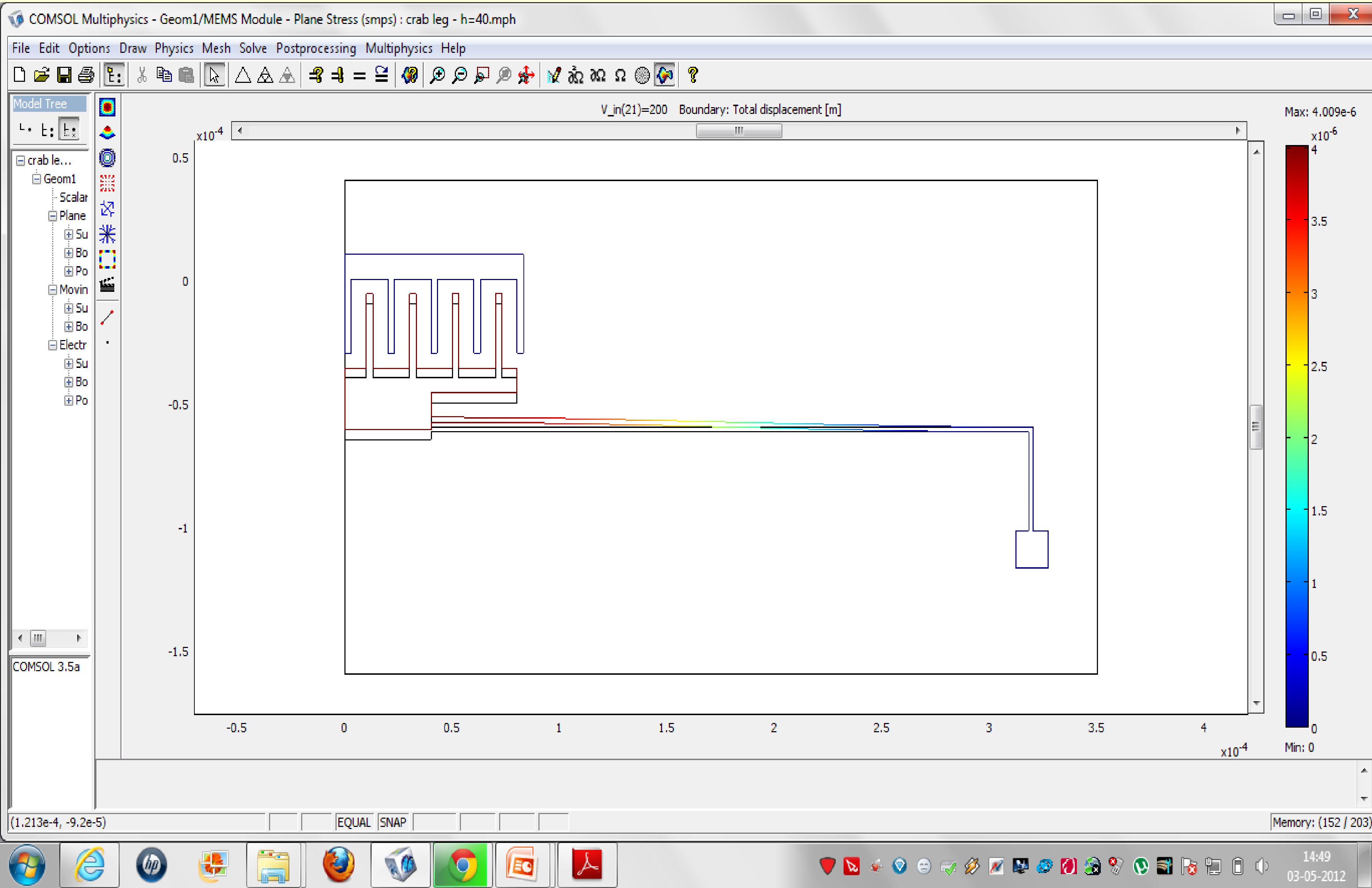


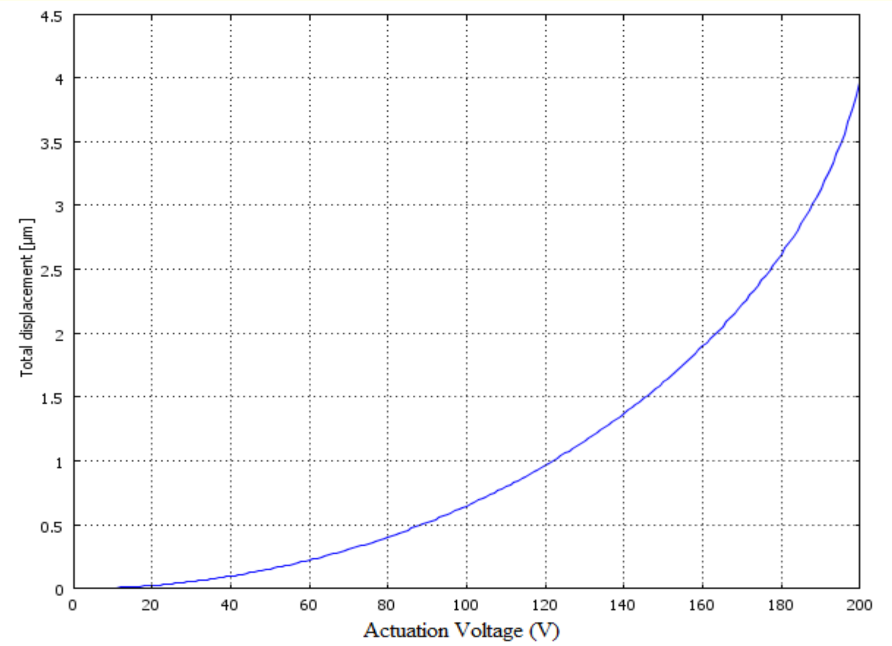

Total displacement [μm]
0
1
2
3
4
5
6
0
50
100
150
200
250
300
350
400
450
500
Actuation Voltage (V)

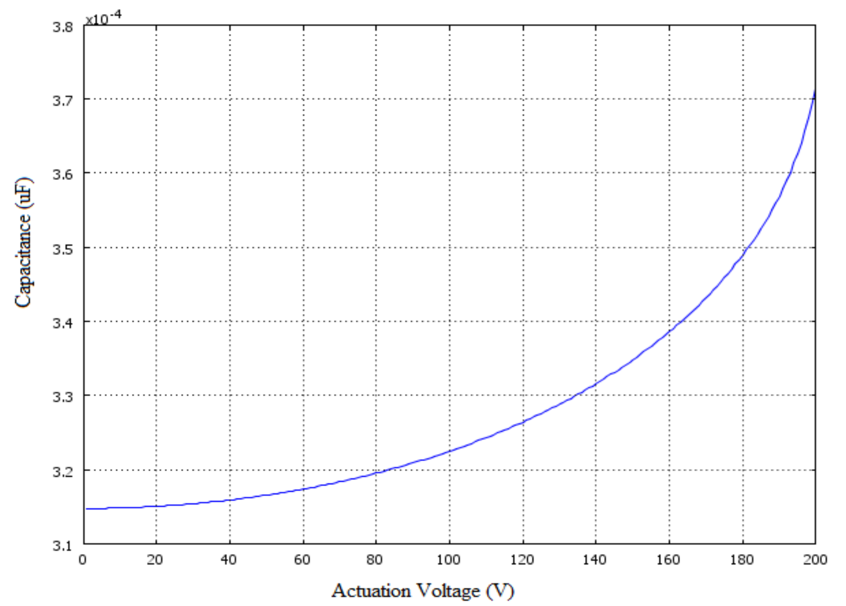

x10^-4
Capacitance (uF)
3.2
3.4
3.6
3.8
4
4.2
0
50
100
150
200
250
300
350
400
450
500
Actuation Voltage (V)

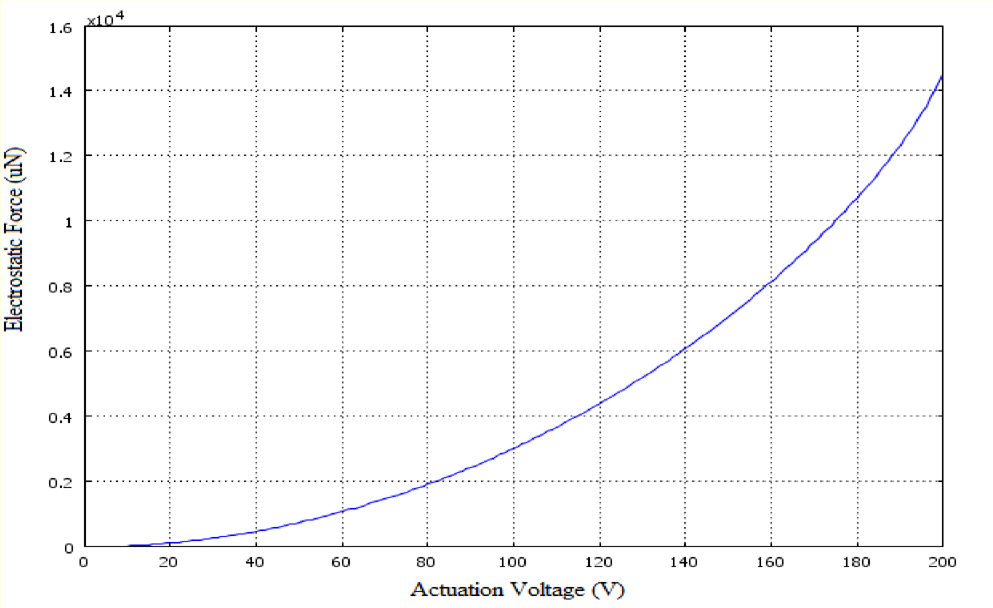

x10^5
Electrostatic Force (uN)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350
400
450
500
Actuation Voltage (V)

Simulation Of Crab Leg Flexure

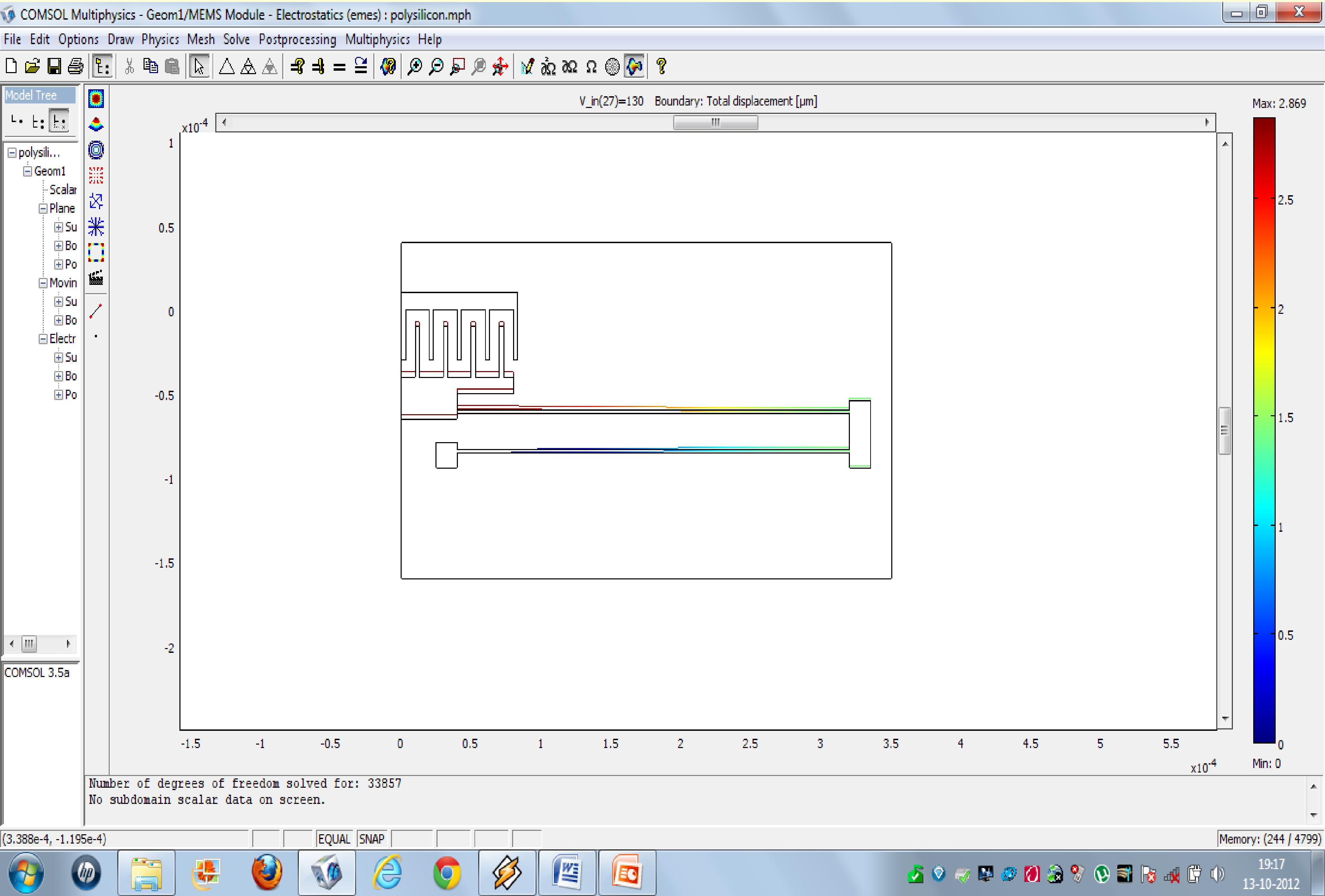


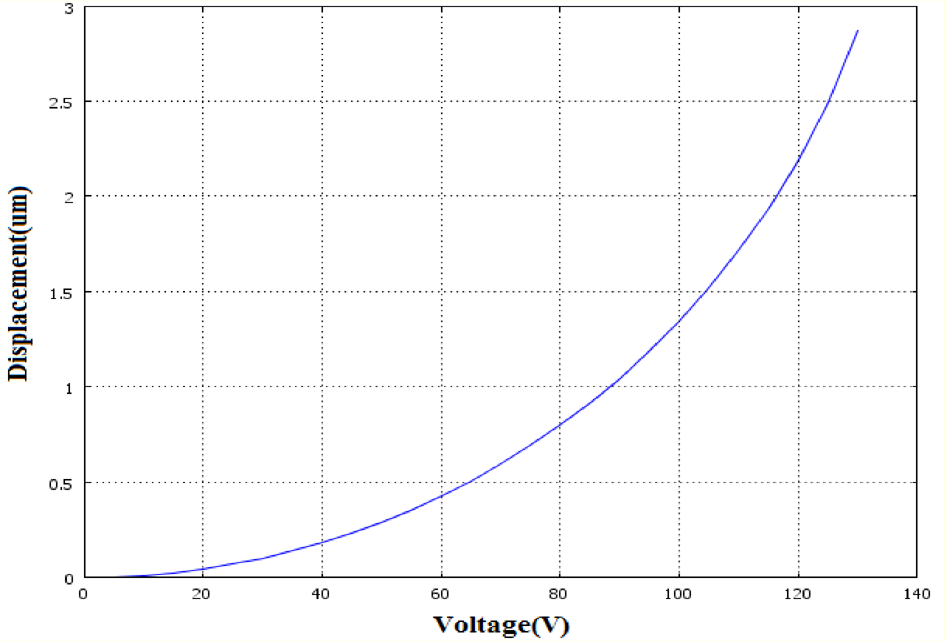

Total displacement [µm]
Actuation Voltage (V)


x10^-4
Capacitance (uF)
Actuation Voltage (V)

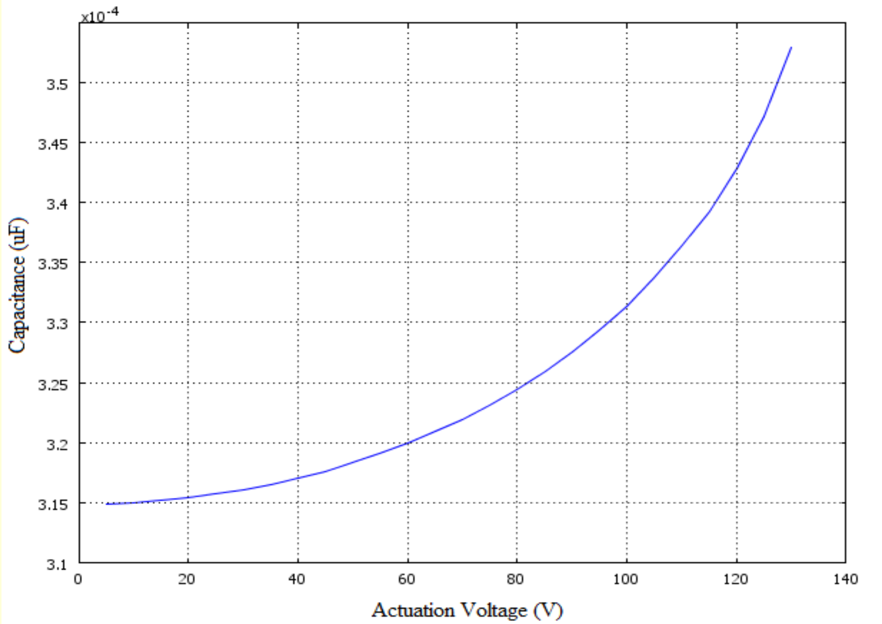

x10^4
Electrostatic Force (uN)
Actuation Voltage (V)

Simulation of Folded Flexure

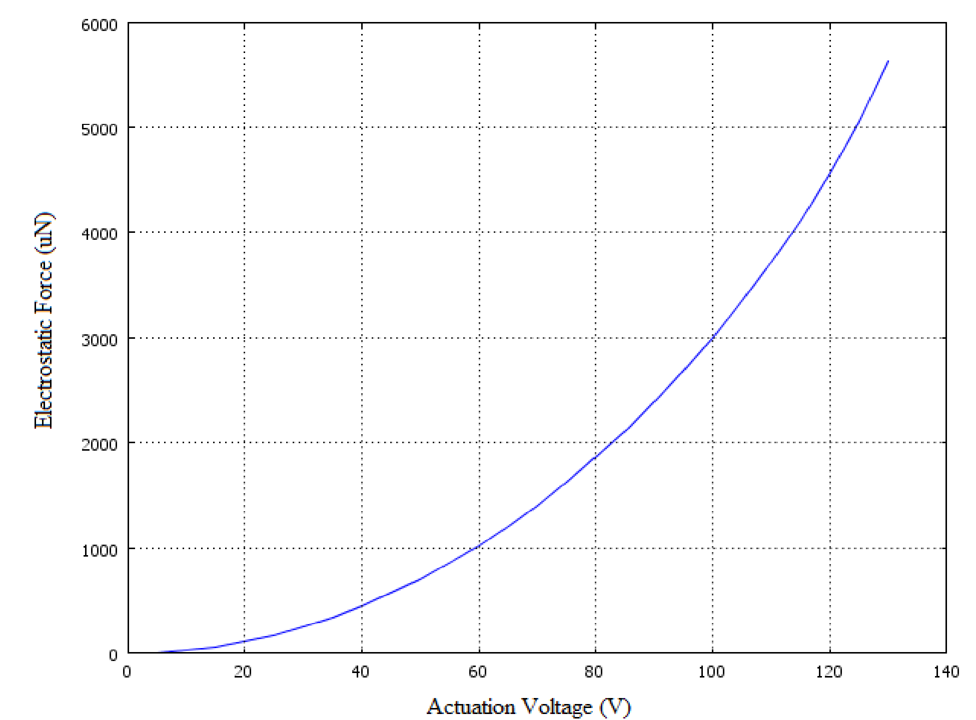




Displacement(um)
Voltage(V)
0
0.5
1
1.5
2
2.5
3
0
20
40
60
80
100
120
140

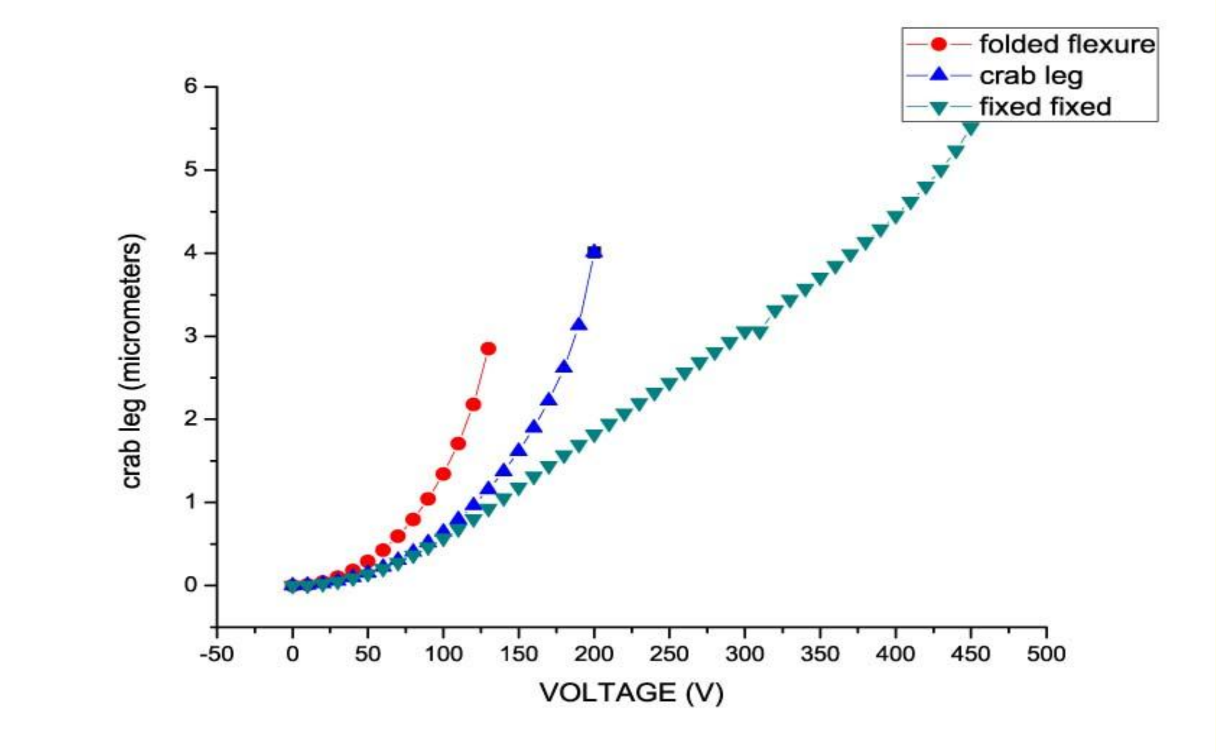


x10^-4
Capacitance (uF)
Actuation Voltage (V)
3.1
3.15
3.2
3.25
3.3
3.35
3.4
3.45
3.5
0
20
40
60
80
100
120
140

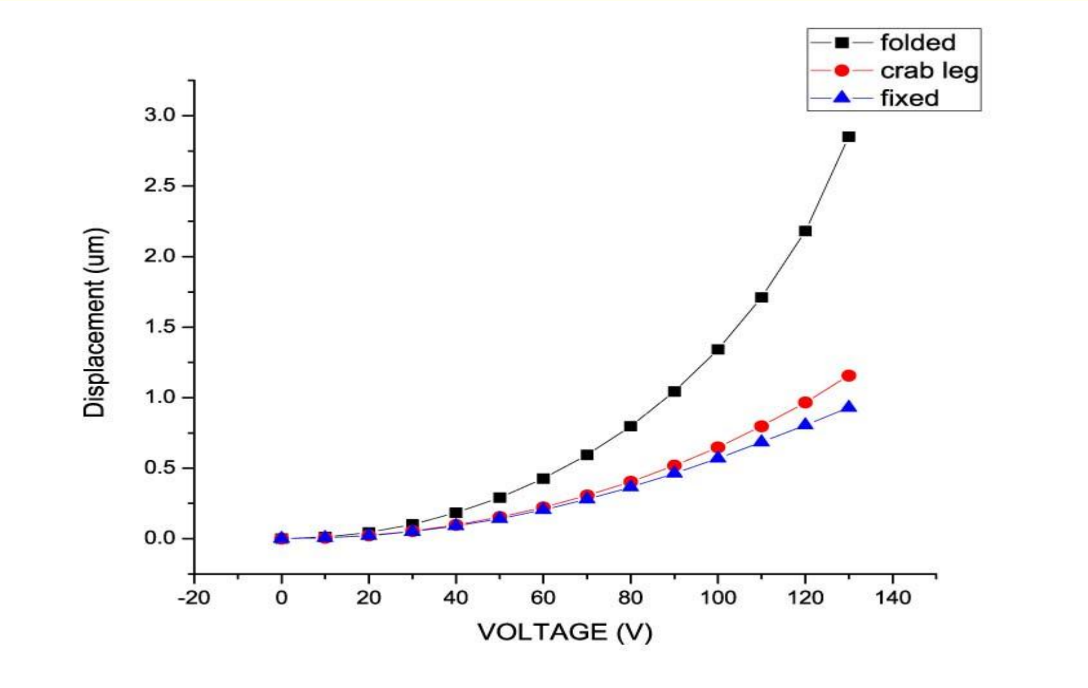


Electrostatic Force (uN)
Actuation Voltage (V)
0
1000
2000
3000
4000
5000
6000
0
20
40
60
80
100
120
140

Parameters	Different Flexures		
	Fixed-Fixed Flexure	**Crab Leg Flexure**	**Folded Flexure**
Voltage (V)	460	200	130
Displacement (μm)	5.9	4.0	2.85
Capacitance (pF)	417	372	352
Finger overlap (μm)	6	4	3
Force (N)	0.085	0.015	0.0056



Parameters	Different Flexures		
	Fixed-Fixed Flexure	Crab Leg Flexure	Folded Flexure
Voltage (V)	130V	130V	130V
Displacement (µm)	0.92	1.156	2.85
Force (N)	0.0050	0.0052	0.0056
Capacitance (pF)	326	328	352



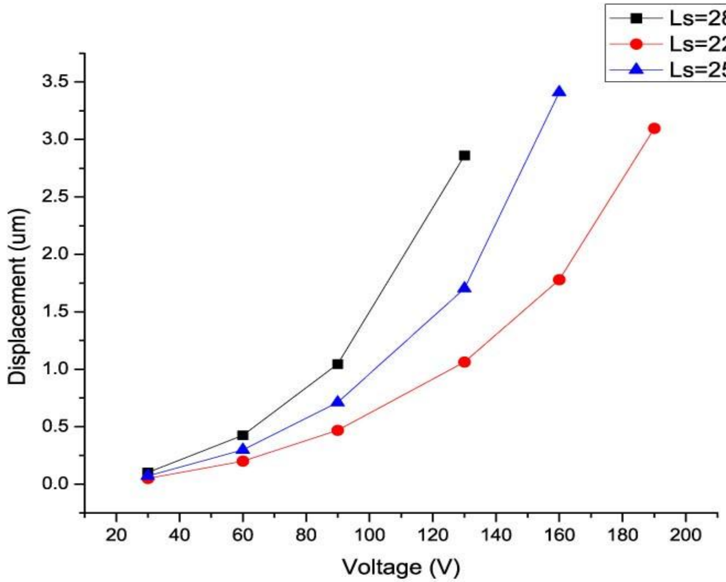
Effect of Folded Flexure Length with Displacement

- As the folded flexure length increases, spring stiffness decreases which increases displacement.

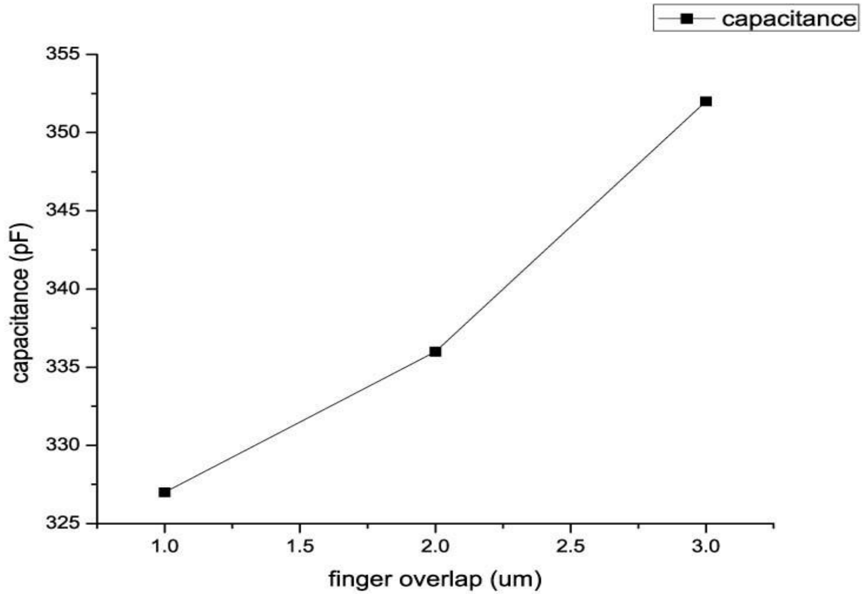
$$K = 2Et\left(\frac{W}{L}\right)^3 = \frac{Force}{Displacement}$$

Parameters by Folded Flexure Spring

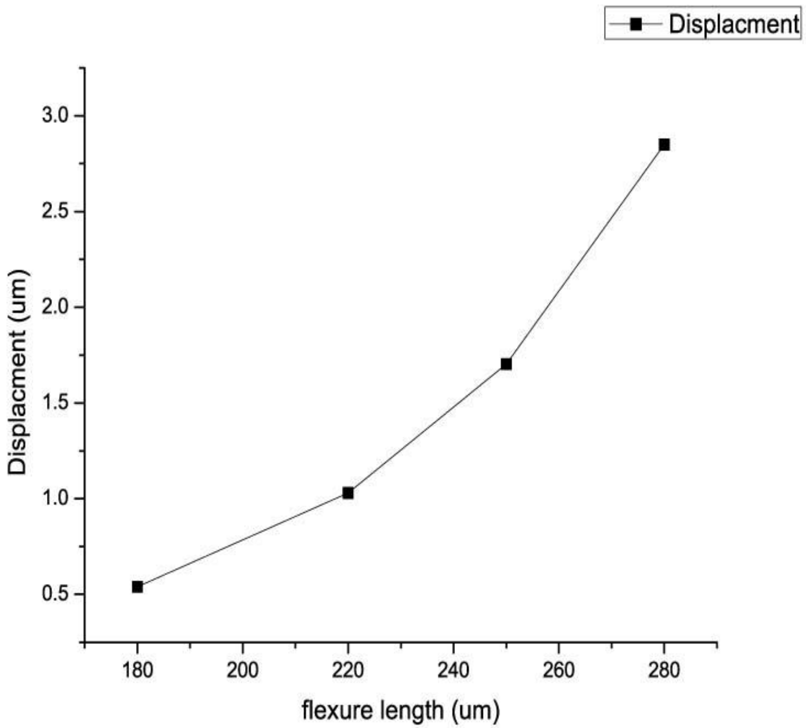
No. of Moving Fingers	4 fingers		
Spring Length(um)	280	250	220
Voltage (V)	130	130	130
Displacement (µm)	2.85	1.704	1.063
Capacitance (pF)	352	336	327
Finger Overlap(µm)	3	2	1
Force (N)	0.0056	0.0051	0.0050



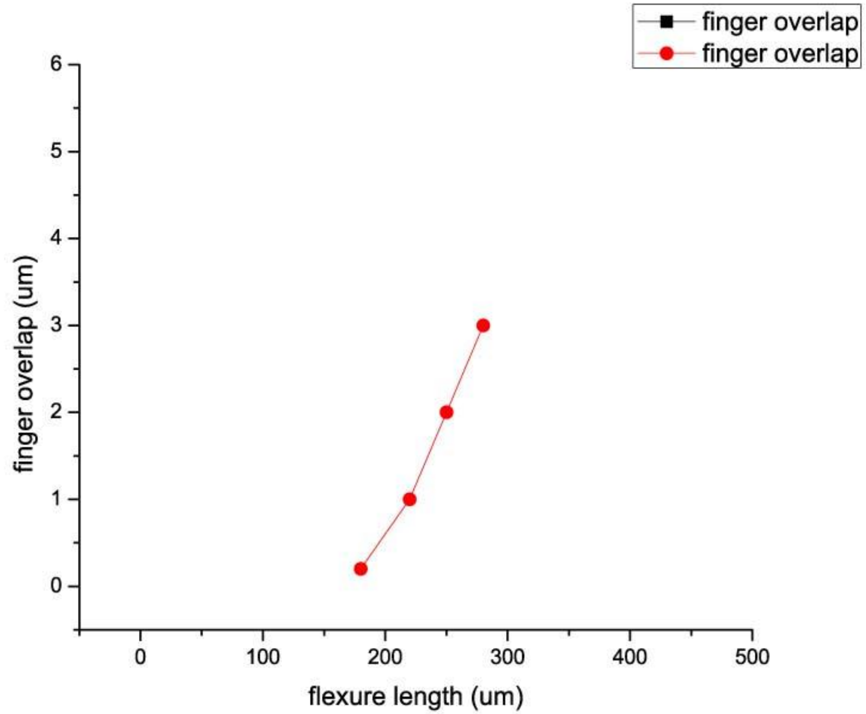
Ls=280um
Ls=220um
Ls=250um
Displacement (um)
Voltage (V)



capacitance
capacitance (pF)
finger overlap (um)



Displacment
Displacment (um)
flexure length (um)



finger overlap
finger overlap
finger overlap (um)
flexure length (um)

Thank You