Frequency softening of an electrostatically actuated beam structure

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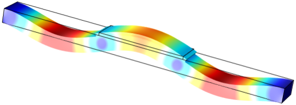

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Outline

Introduction

Background
- Objective
- Theory
- Testing the simulation

Methodology
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- Simulation of Si_3N_4 resonantor

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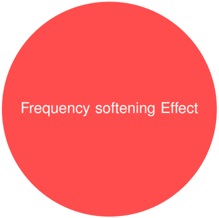
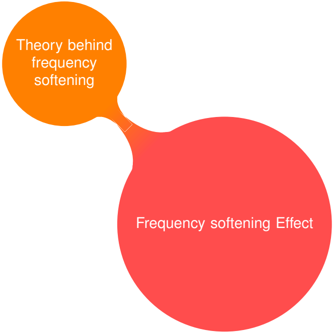
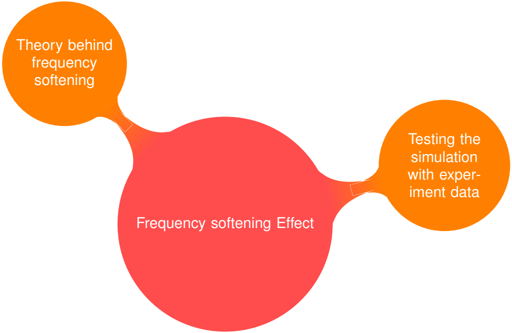
Overview



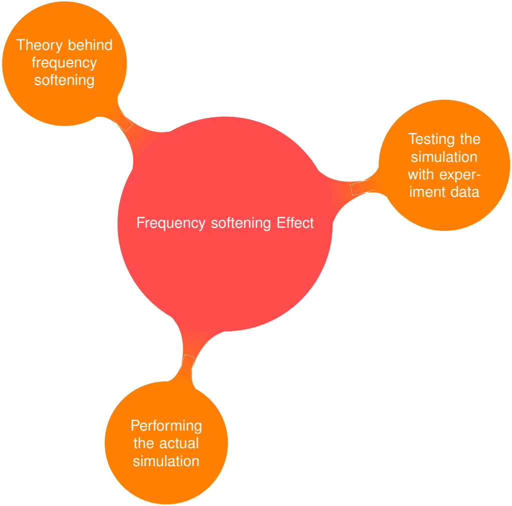
Overview


Theory behind frequency softening
Frequency softening Effect

Overview


Theory behind frequency softening
Frequency softening Effect
Testing the simulation with exper-iment data

Overview


Frequency softening Effect
Theory behind frequency softening
Testing the simulation with exper- iment data
Performing the actual simulation

THEORY [1]

- potential energy of resonator

$$V(x) = \frac{1}{2}kx^2 - \frac{C}{d+x}$$

here $C = Aq^2/4\pi\epsilon$

$$\frac{dV}{dx} = kx + \frac{C}{(d+x)^2} = 0$$

- Taylor series expansion about x_0

$$V(x) \simeq V(x_0) + \frac{1}{2}(k - \frac{2C}{(d+x_0)^3})x^2 + \frac{C}{(d+x_0)^4}x^3 - \frac{C}{(d+x_0)^5}x^4 + ...$$
$$= V(x_0) + \frac{1}{2}kx^2 + \frac{1}{3}\beta x^3 + \frac{1}{4}\alpha x^4$$

- The force equation will look like

$$m\ddot{x} + Kx + \beta x^2 + \alpha x^3 = 0$$

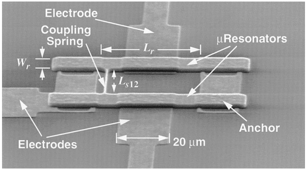
where K is the new effective stiffness constant which is less than k. i.e.

$$K = k - \frac{2C}{(d+x_0)^3}$$

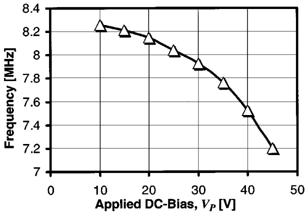
and

$$f_{res} = \sqrt{\frac{K}{m_{eff}}}$$

TESTING THE SIMULATION [2][1]



(a) SEM image of the resonator(Frank D. Bannon et al 2000)



(b) Frequency shift of the resonator

(c) Model of the resonator

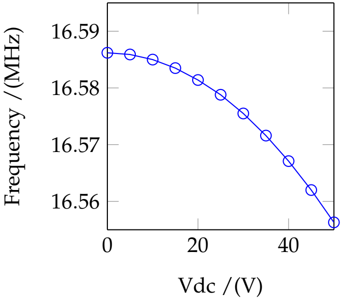
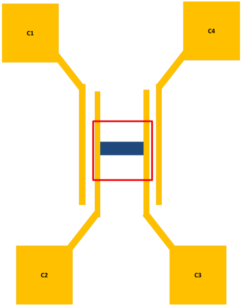


Figure : Comparision of the simulation result with the experimental result

STUDY TO PERFORM

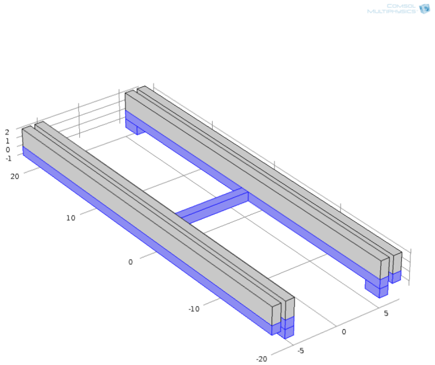


(a) Front view of the device

(b) Side of the device

Figure : Schematic of the resonator

SIMULATION OF Si_3N_4 RESONATOR



- Dimension of the Si_3N_4 beam is 10 $\mu m \times 1\ \mu m \times 1\ \mu m$.
- Dimension of the PolySi pads are 40 $\mu m \times 1\ \mu m \times 2\ \mu m$.

Simulation of Si_3N_4 resonator...

- MATERIALS
  - Beam is made of Si_3N_4 .
  - Contact Pads are made up of PolySi.
  - surrounding is air.
- Electromechanics and Study
  - The beam is in contact with the inner pads which are suspended over 40 μm.
  - The finite elements mesh are fine triangular structures.
  - inner pads are grounded.
  - outer pads at potential Vdc and swept from 0V to 400 V.
  - Egeinfrequency analysis is done.

EIGEN FREQUENCIES STUDY

- Change of resonance frequency with applied DC voltage across the pads.

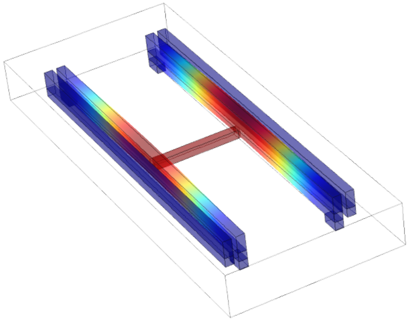
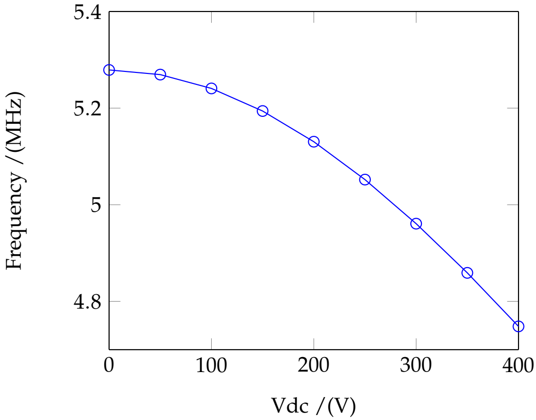


Figure : Deformation of the resonator applied dc voltage, above figure is for $Vdc = 150V$

Eigen frequencies Study

- Chnage resonance frequency With applied DC voltage across the pads.



REFERENCES

- Ron Lifshitz and M. C. Cross, ”Nonlinear Dynamics of Nanomechanical and Micromechanical Resonators”, 2008
- Frank D. Bannon et al., ”High Q HF Microelectromechanical Filters”, IEEE 35,4 2000

Thank you