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Optimizing the Design of Polymer Based Unimorph Actuator using COMSOL Multiphysics

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Outline

- Why polymer based unimorph actuator.
- Our unimorph actuator.
- Governing Equations.
- Tools used for simulation.
- Results and discussion.
- Conclusion.

Polymer Based Unimorph Actuator

- Compared to bimorph and multilayer structures, simple structure and easy assembly.

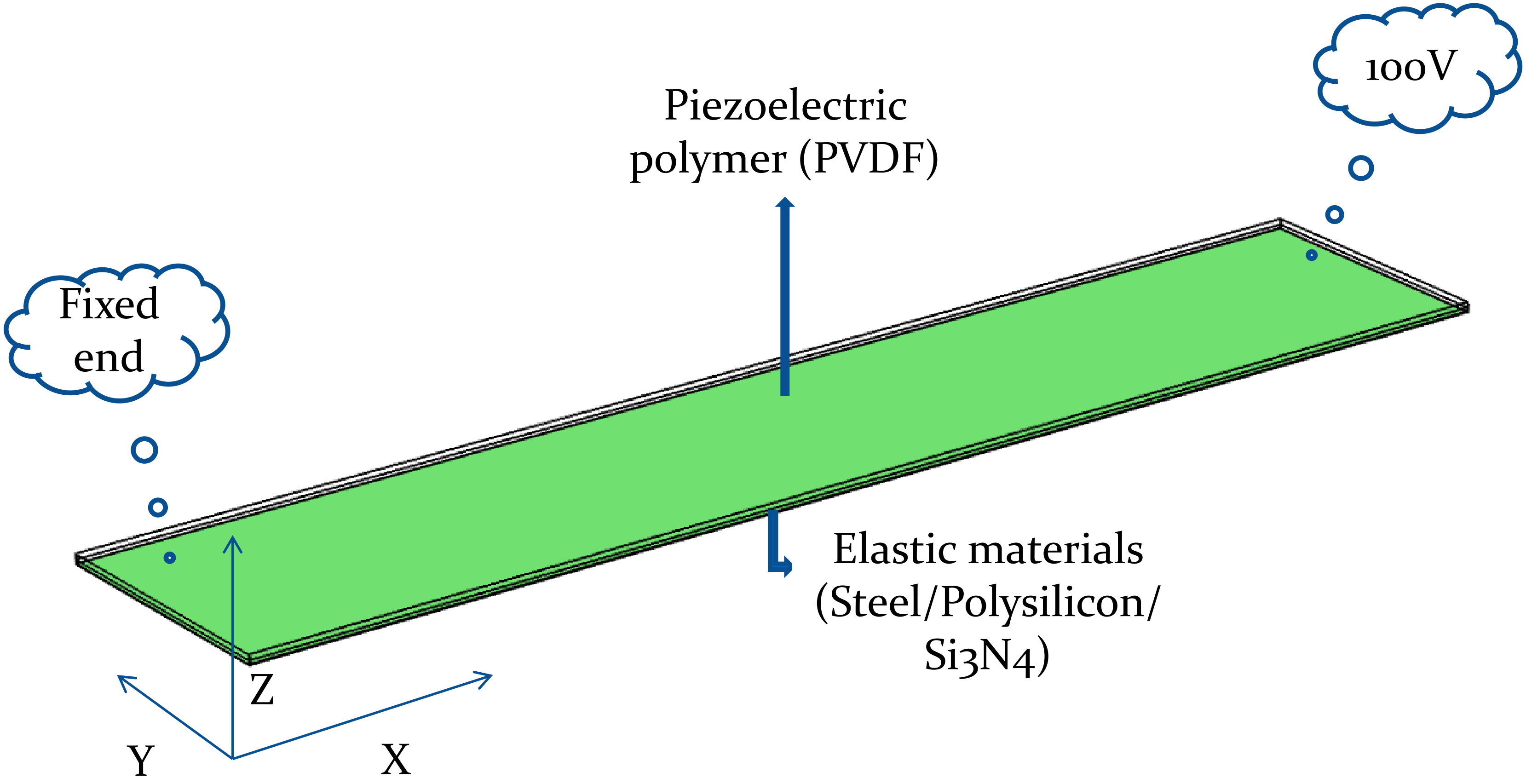
- Aeronautical applications - flexibility, durability and light weight material with high degree of robustness.

  piezoelectric ceramics - brittle and heavier

  Solution- piezoelectric polymers. PVDF is the most preferred polymer.

- Tip deflection depends on its geometrical dimensions and material properties etc. need to optimize the design parameters .

Piezoelectric Unimorph configuration taken.



Governing equations

- Converse piezoelectric effect:

$$\{S\} = \left[s^{E}\right]\{T\} + [d^{t}]\{E\}$$

Mechanical strain vector

elastic compliance tensor at constant electric field

Mechanical stress vector

Transverse piezoelectric coefficient tensor

Electric field vector

- Mechanical behaviour of rectangular beam made up of some elastic material say (Steel/ Polysilicon/ Si_3N_4):

$$\delta = W\, l^3 / (4 b d^3\, Y)$$

Tip deflection

Acting load

Length

Width

Thickness

Elastic modulus

Tools used for computation

- Comsol Multiphysics Version 4.2 .

- An analytical relation for the deflection of a piezoelectric Unimorph cantilever Beam:

$$\delta = \frac{3L^2}{2t} \cdot \frac{2AB(1+B)^2}{A^2B^4 + 2A(2B+3B^2+2B^3)+1} . d_{31}E_3$$

Where A: Ratio of elastic modulus of elastic material over elastic modulus of piezoelectric material

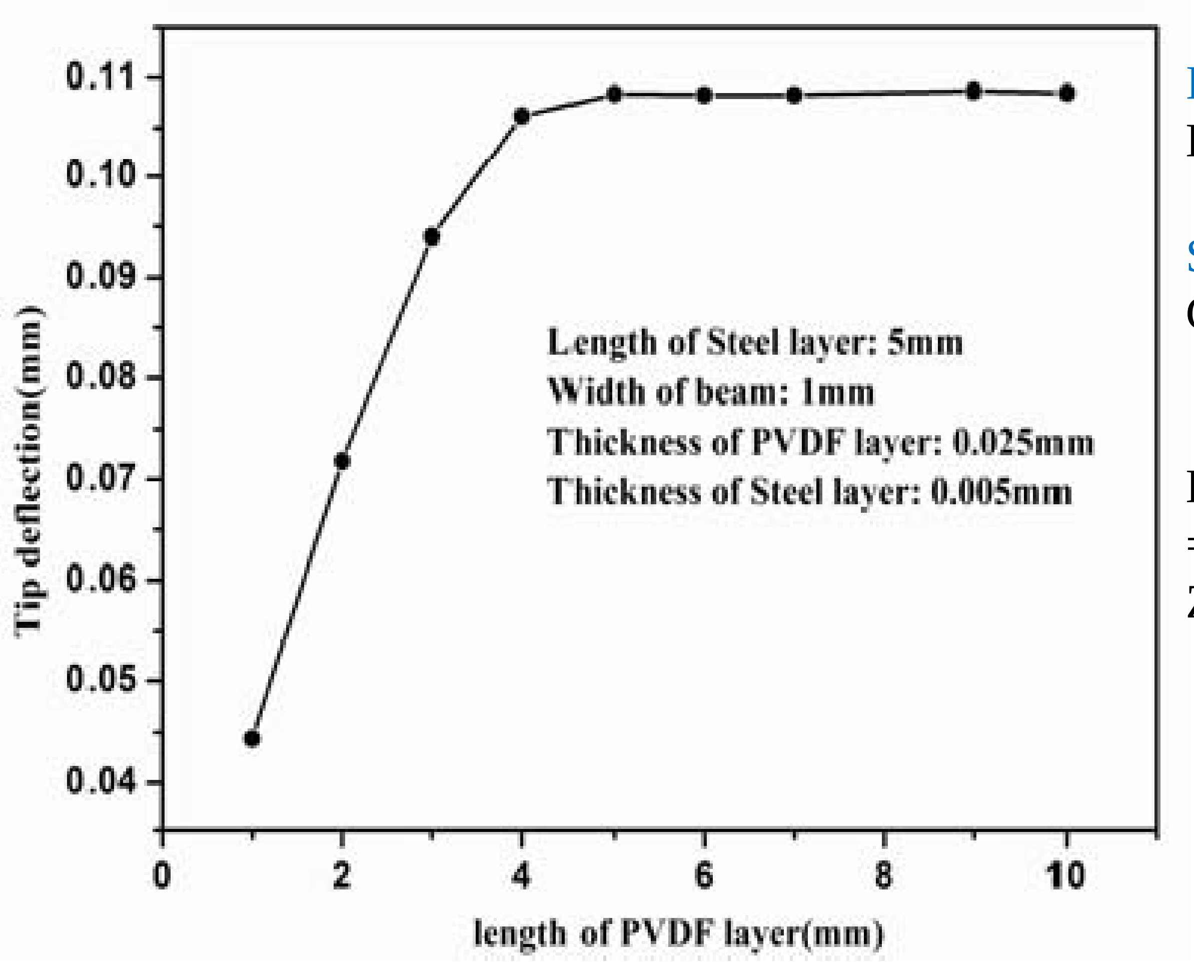
B: Ratio of thickness of elastic material over thickness of piezoelectric material.

L: Length of the cantilever beam.

d_{31}: Piezoelectric coupling coefficient.

E_3 : Applied electric field in 3rd direction

Variation in the tip deflection of the beam with the length of the PVDF layer

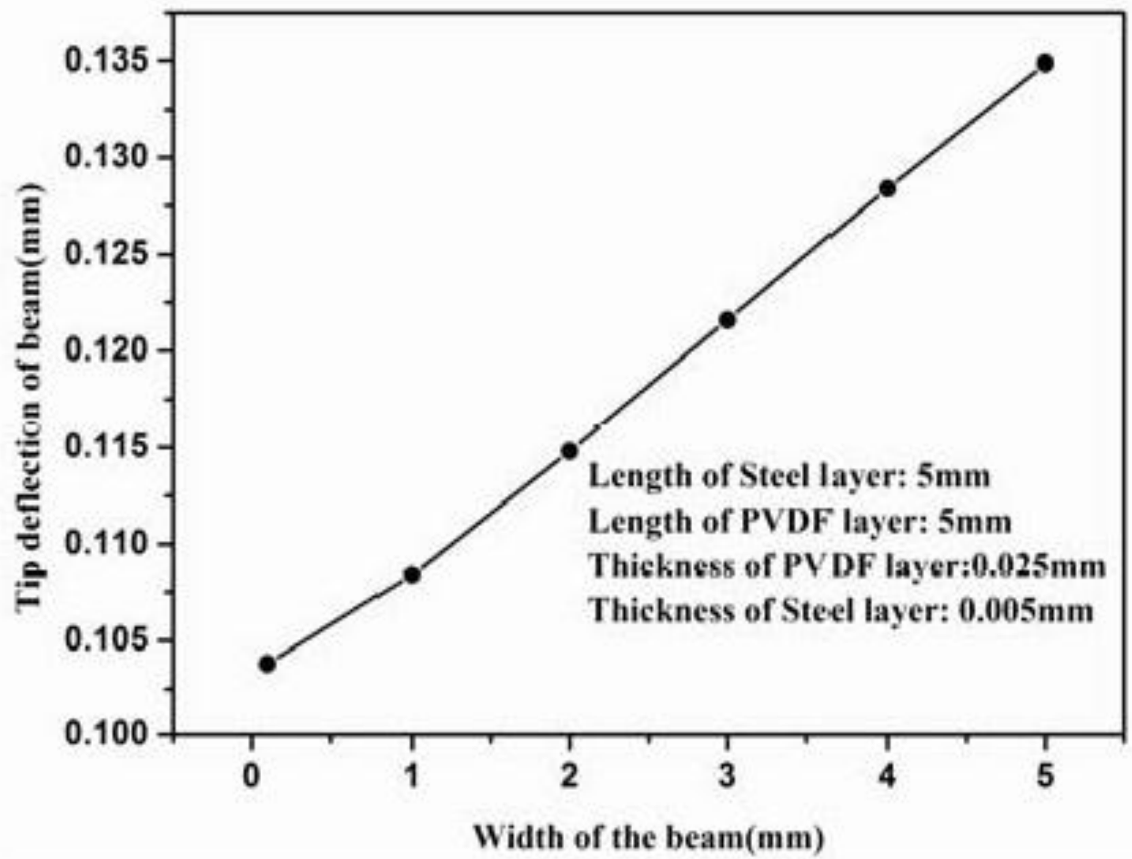


Increase:
Load and length effect

Saturation:
Converse piezoelectric effect
=>strain along X direction.

Elastic behaviour of substrate
=>bending deformation along
Z direction.

Variation in the tip deflection of the beam with the width of cantilever



Insignificant increase:

-Tip deflection $\alpha \dfrac{1}{I_{rectangular}}$

$I_{rectangular}$ α width (↑)

-Tip deflection α load

Load α width (↑)

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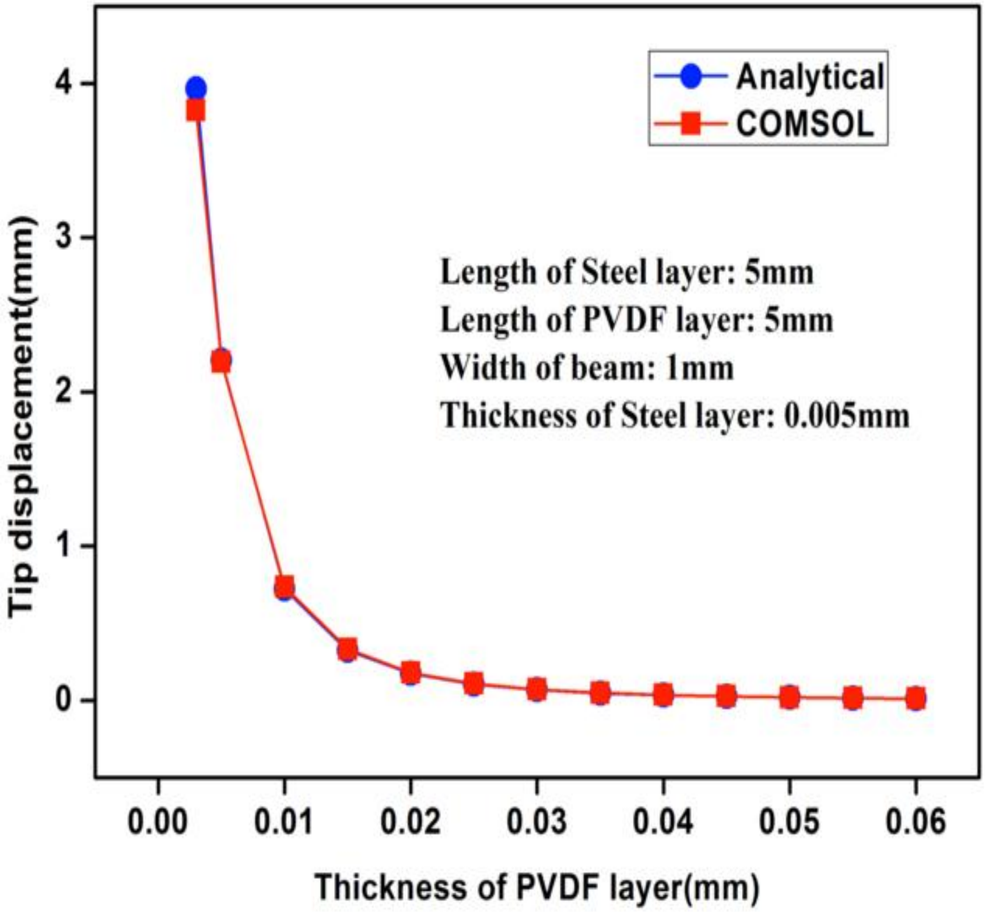
Variation in the tip deflection of the beam with the thickness of PVDF layer



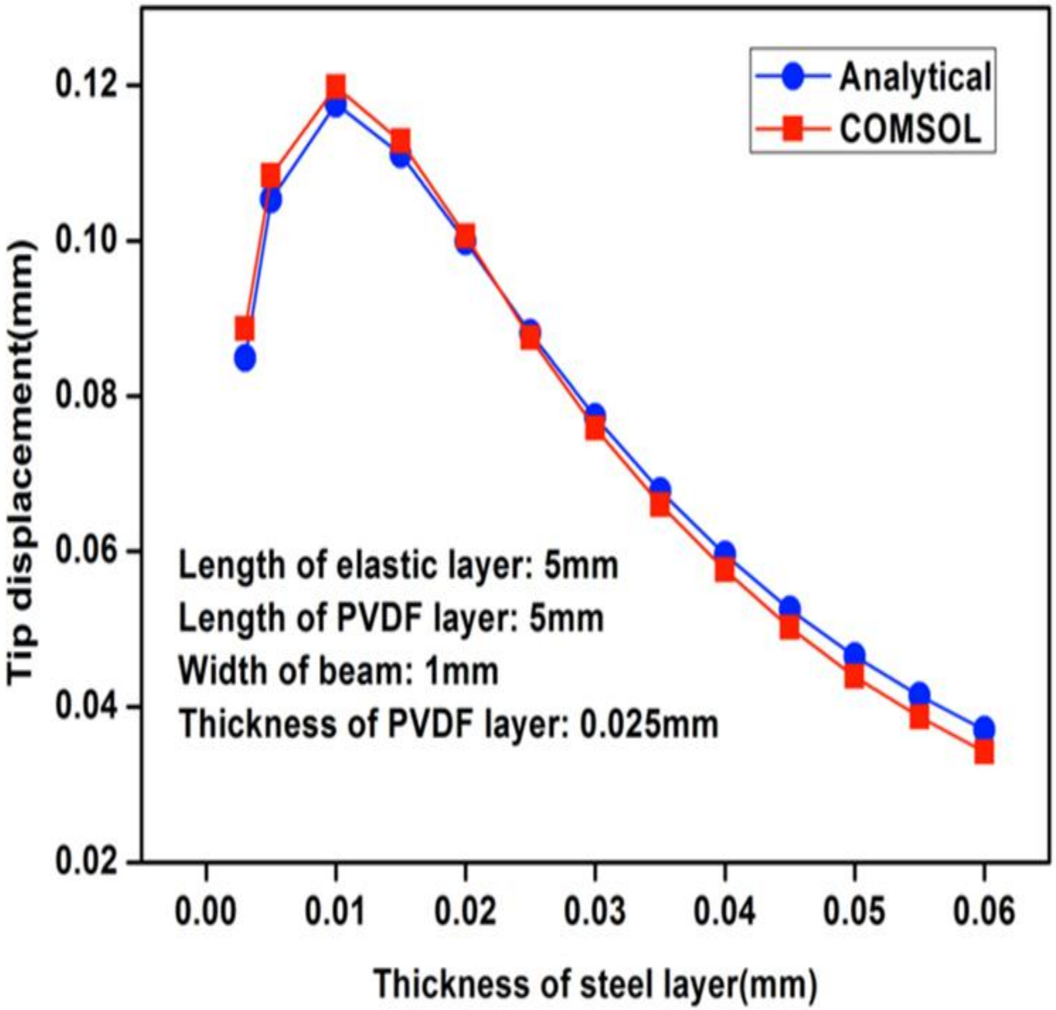
Increase:

- Strain α Electric field α thickness(⬇)

- Tip deflection $\alpha \dfrac{1}{I_{rectangular}}$

$I_{rectangular} \, \alpha$ Thickness (⬇)

Variation in the tip deflection of the beam with the thickness of steel layer



Increase:

-Tip deflection $\alpha \dfrac{1}{I_{rectangular}}$

$I_{rectangular} \; \alpha$ Thickness (⬇)

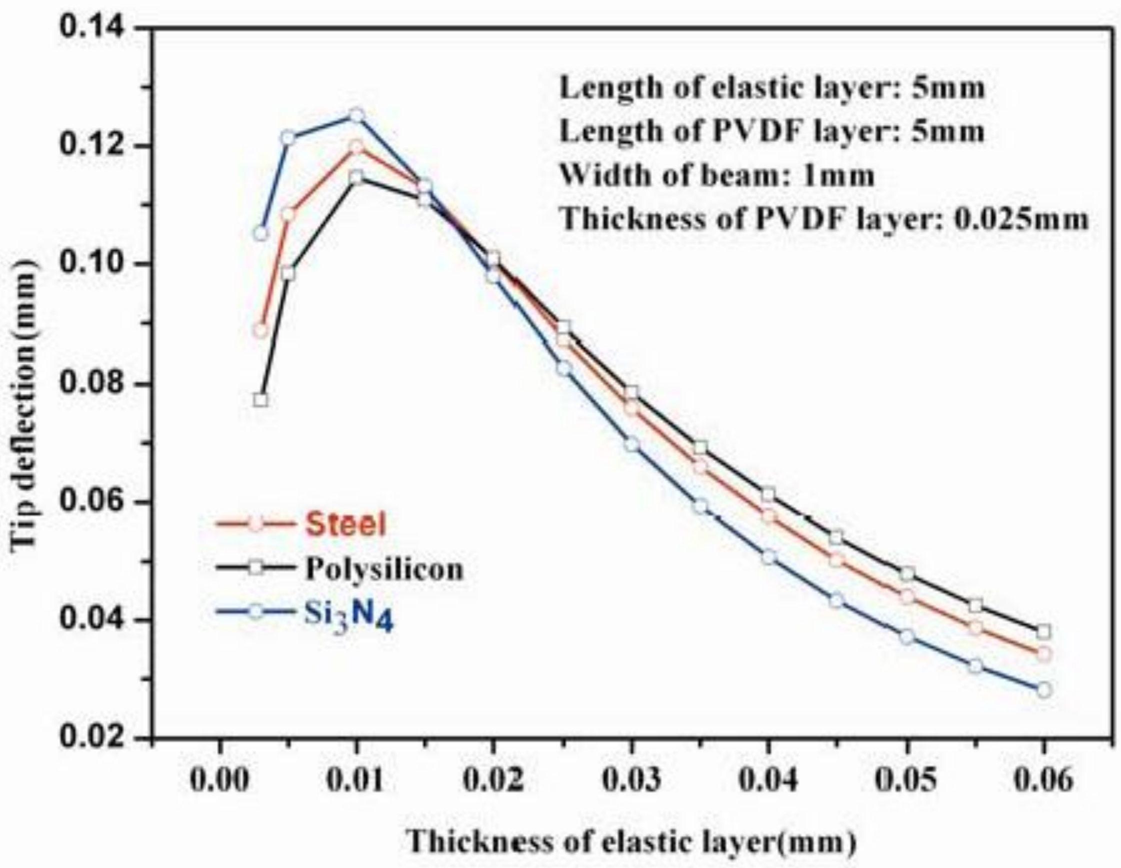
Decrease:

-Tip deflection α Load

Load αThickness(⬇)

-Less bending in third direction due to thin elastic layer.

Variation in the tip deflection of the beam with thickness for three different materials



Anamoly:

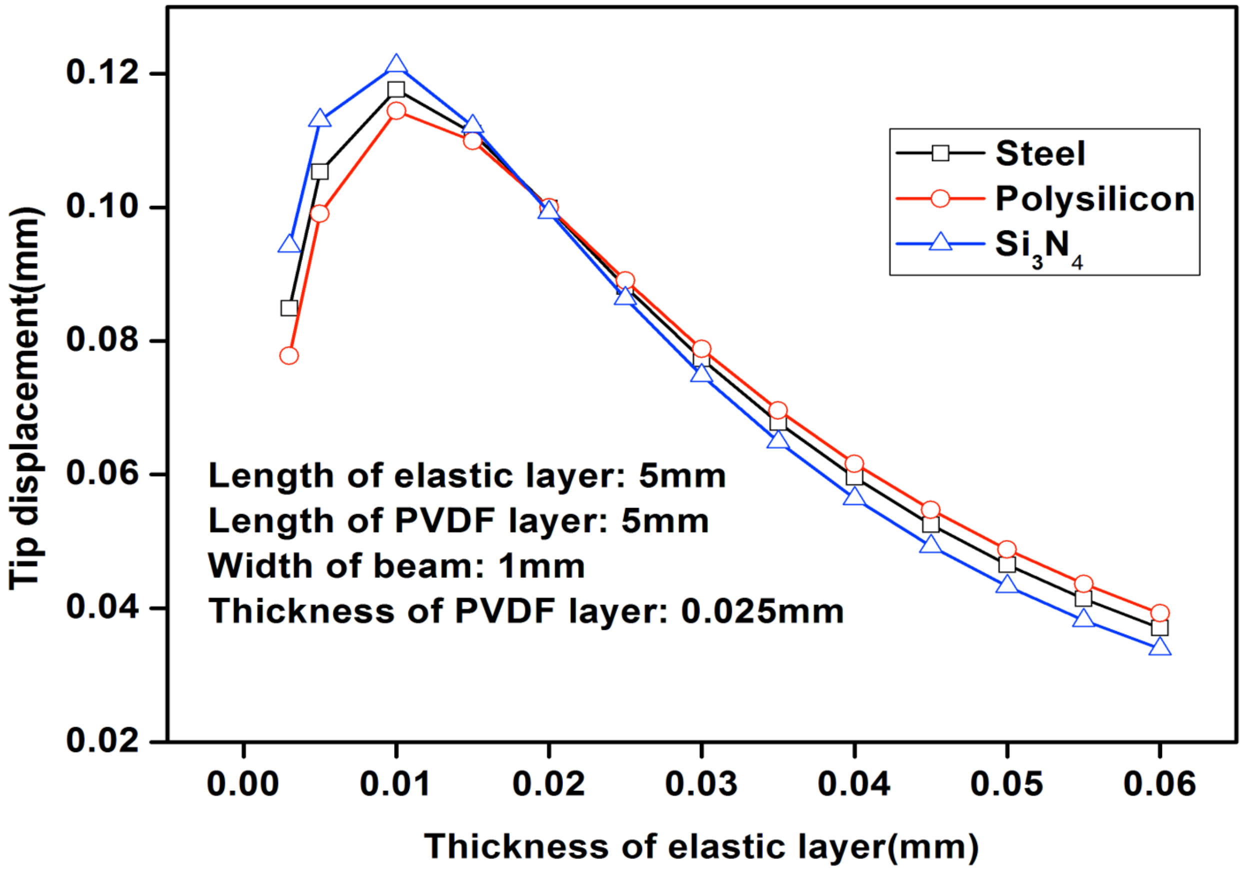
-Tip deflection α elastic modulus.

Elastic modulus:

Si_3N_4>Steel>Polysilicon.

-For thin elastic layer elastic modulus of piezoelectric layer (<elastic layer) is also going to decide the Unimorph bending.

Variation in the tip deflection of the unimorph cantilever beam with dimension for three different materials using some analytical relations.



Conclusions

-Length of the piezoelectric layer >= length of nonpiezoelectric elastic layer.

-PVDF thickness more effective design parameter as compared to thickness of passive layer. The lesser the thickness of the piezoelectric layer, higher is the deflection.

-Tip displacement for Si_3N_4 layer is maximum as compared to polysilicon and stainless steel being chosen as passive layer.

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THANK YOU