Simulation of Cantilever Based Sensors for Smart Textile Applications

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What is a smart textile?

Represent a combination of active electronic components that are embedded into the textile fibre and connected to classical electronic devices or components.

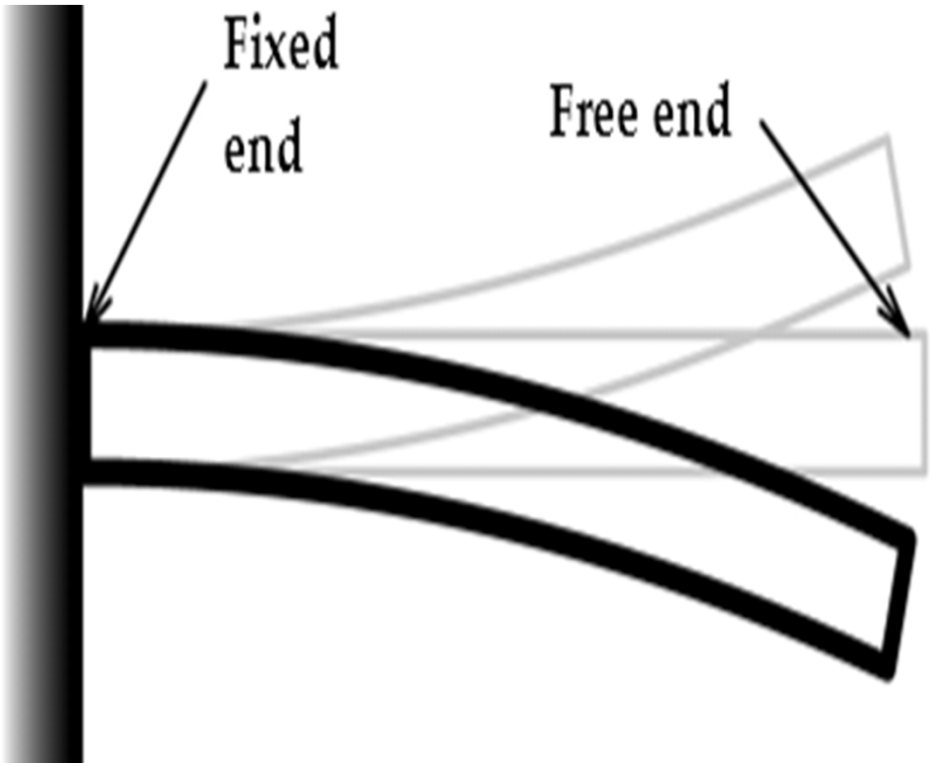
Enable the efficient collection of data with the help of biotelemetry.

1- Blood pressure sensor

2-Temperature sensor

Source: *Konstantin Astafiev (2012)"Flexible piezoelectric materials for smart textile application"*

Working principle of the cantilever beam:



*The **spring constant** in a cantilever is*

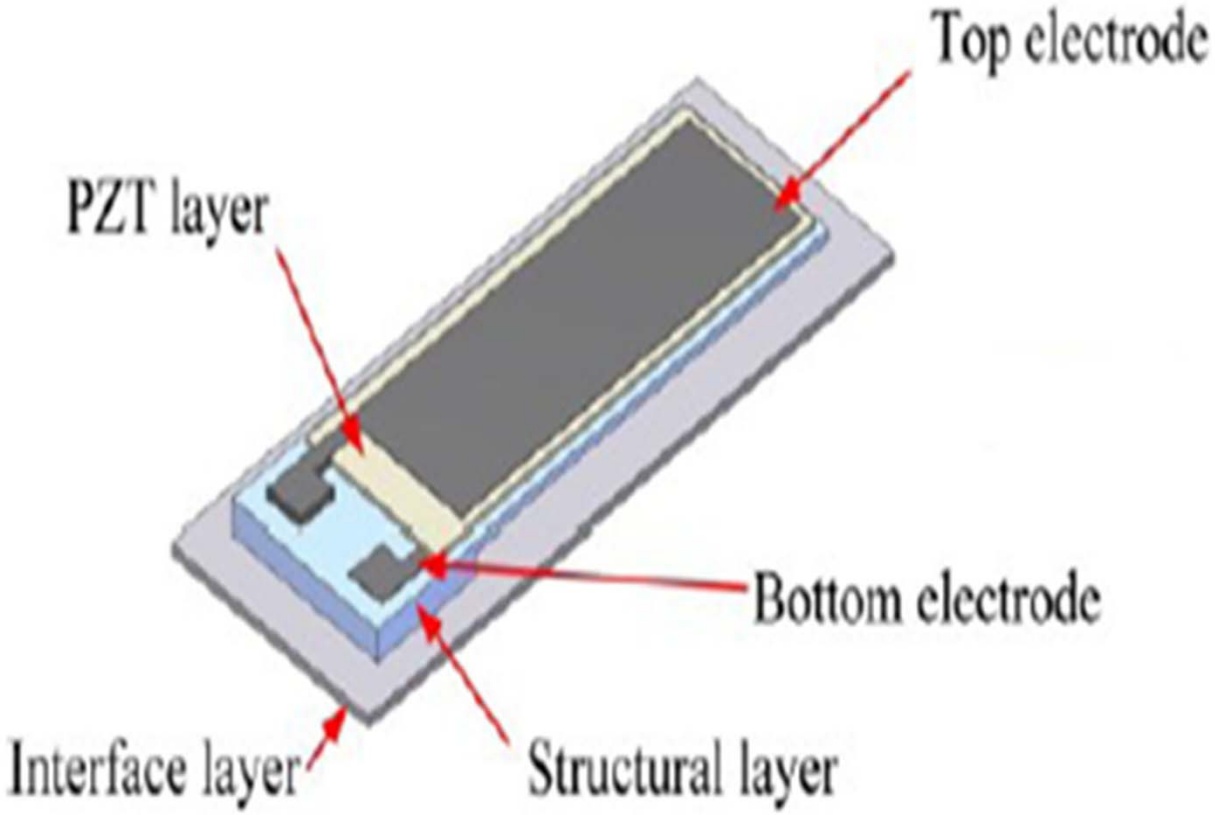
$$k = \frac{E.\,w.\,t^3}{4.\,L^3}$$

*The **surface stress** developed over the cantilever is*

$$\Delta g = \frac{E.\,\Delta h.\,t^2}{(1-v).\,L^2}$$

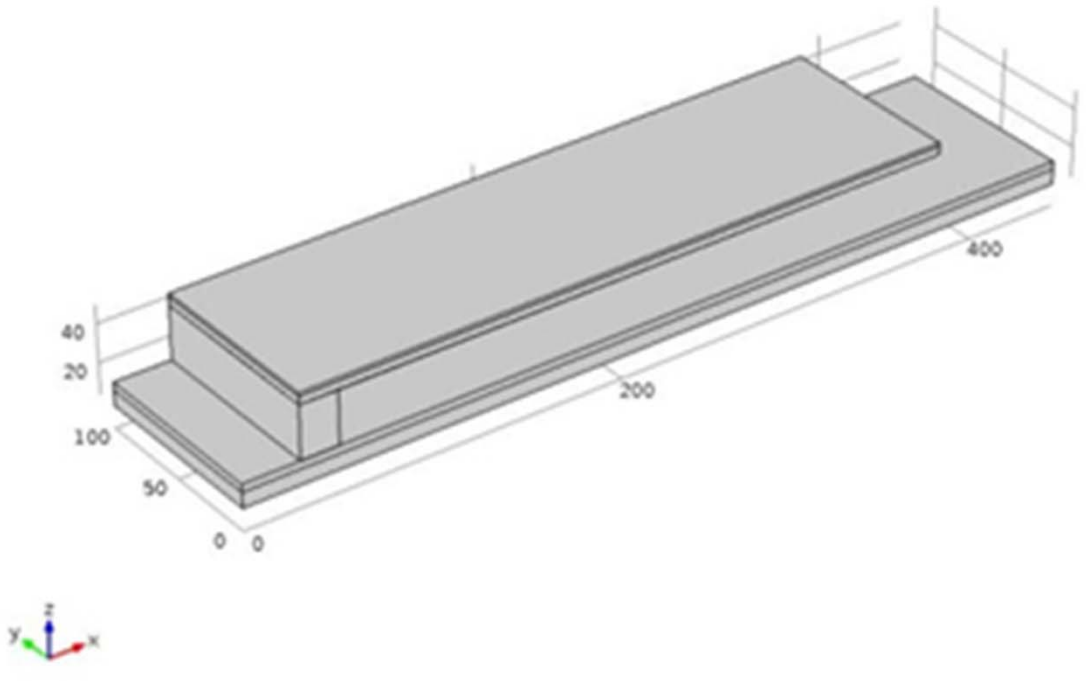
Source: *Gere, James M.; Goodno, Barry J. Mechanics of Materials (Eighth ed.). p. 1083-1087. ISBN 978-1-111-57773-5.*

3D view of the proposed cantilever sensor model:



Source: *Yang Wei (20212) " A Novel Fabrication Process to Realise Piezoelectric Cantilever Structures for Smart Fabric Sensor Applications"*

3D model of MEMS based cantilever sensor:



Physics Used: *Piezoelectric Devices*

Thermal stress

Experimental Results:

Blood Pressure Measurement:

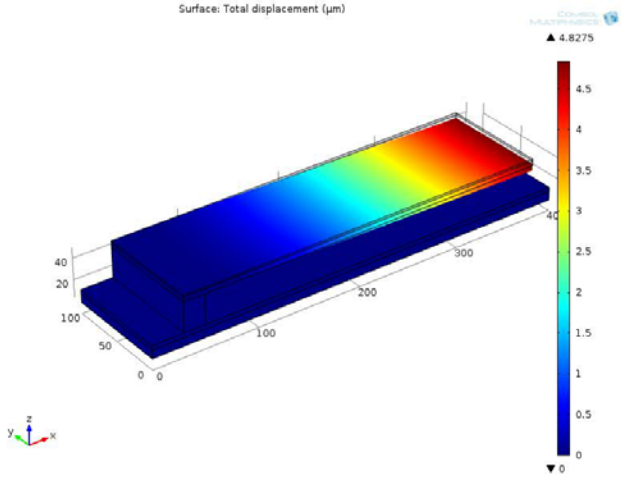
Varies between a maximum (systolic) and a minimum (diastolic) during each heart beat.

Displacement values for different piezoelectric materials at diastolic condition:

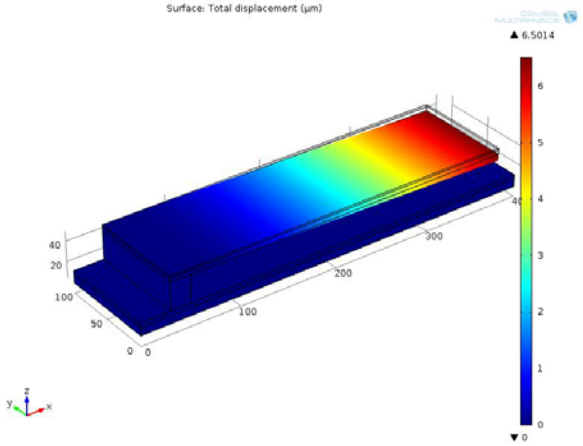
Cantilever dimensions: Length: 350µm, Width: 100µm, Thickness: 8µm

MATERIAL	MAXIMUM DISPLACEMENT FOR 80 mmHg (µm)	MAXIMUM VOLTAGE FOR 80 mmHg (V)
Barium sodium niobate	4.8275	0.2231
Bismuth germanate	6.5014	0.3476
Lead zirconate Titanate	7.5263	0.7664

Simulated displacement of blood pressure 80mmHg

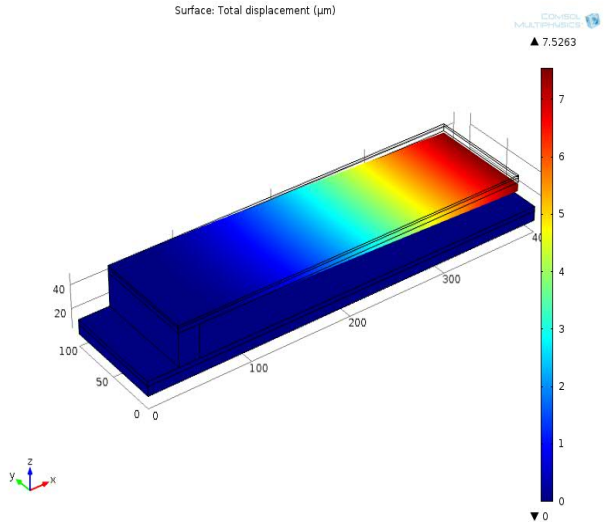


Barium sodium niobate



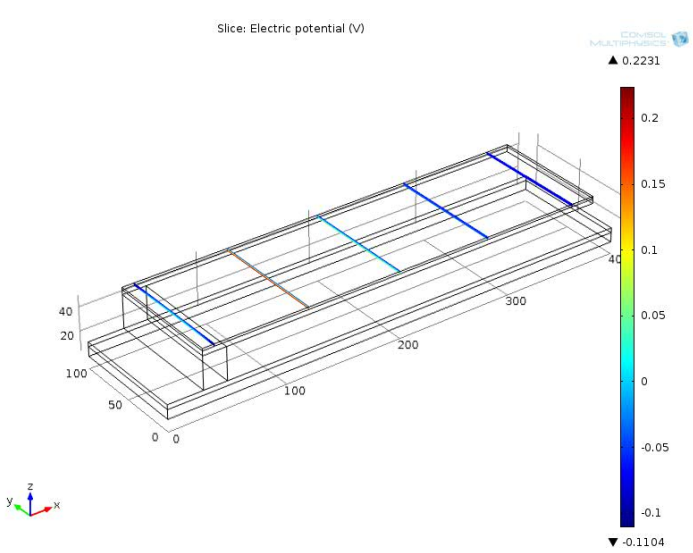
Bismuth germanate

Dimensions:
Length: 350µm,
Width: 100µm,
Thickness: 8µm

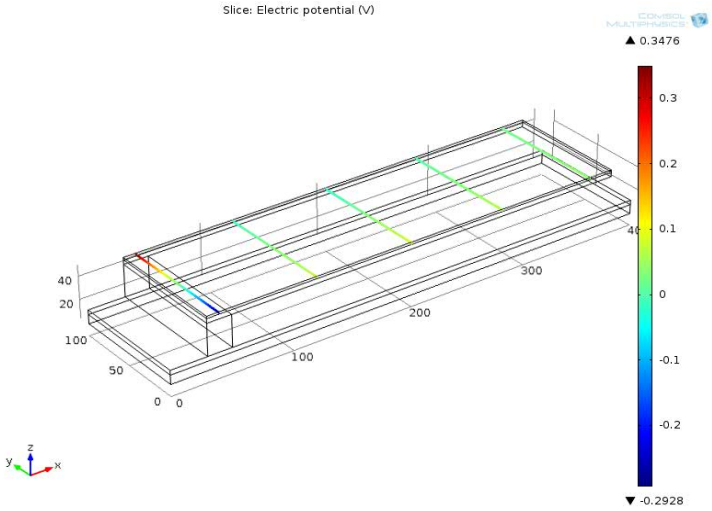


Lead zirconate titanate

Simulated electrical potential of blood pressure 80mmHg

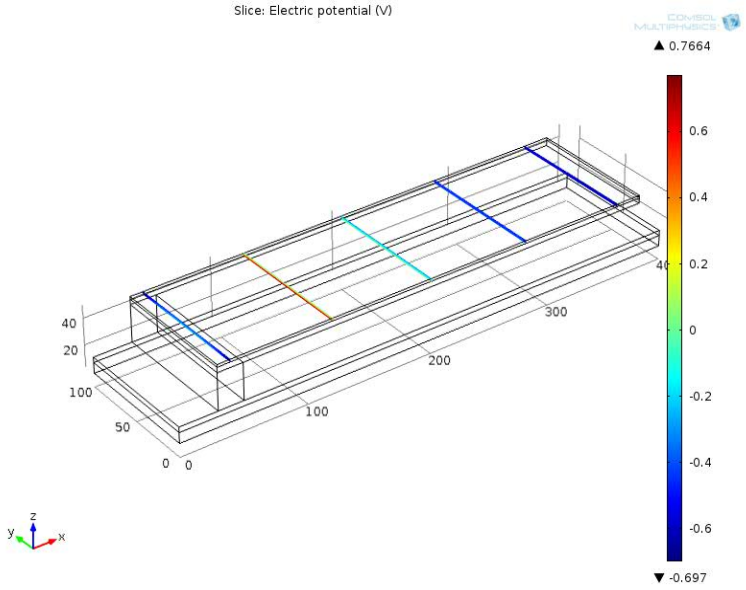


Barium sodium niobate



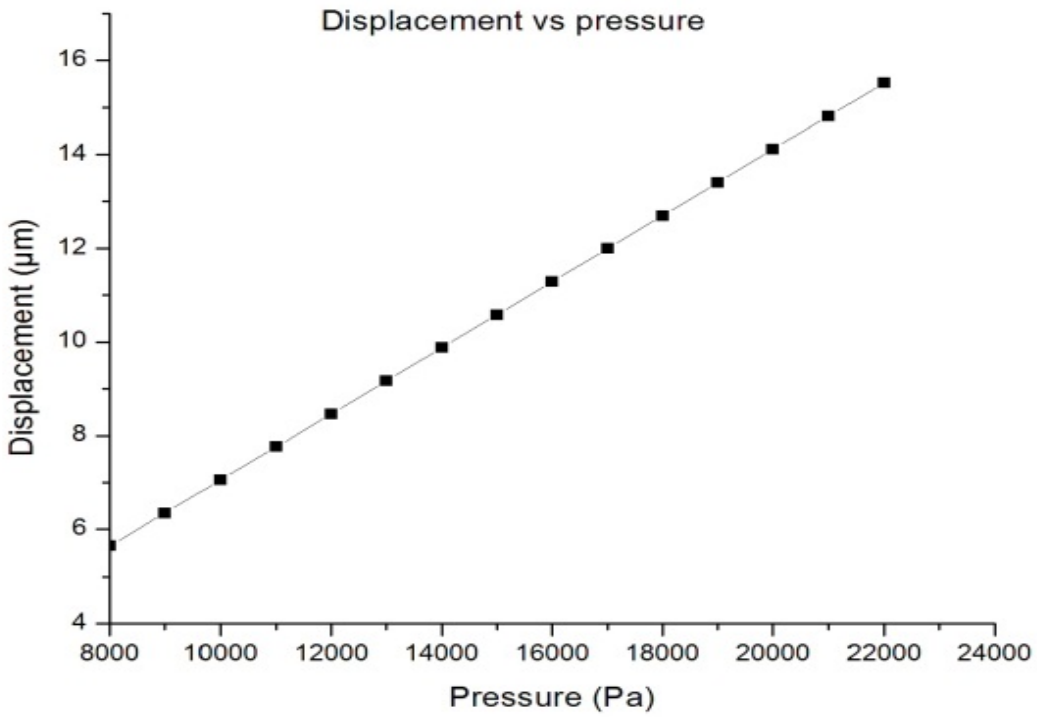
Bismuth germanate

Dimensions:
Length: 350µm,
Width: 100µm,
Thickness: 8µm



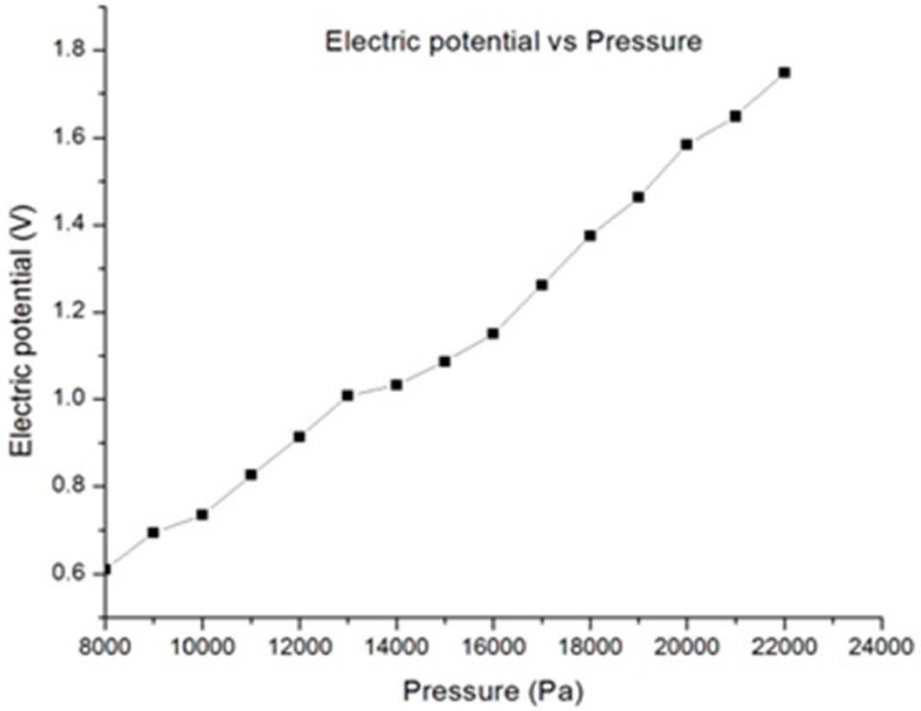
Lead zirconate titanate

Displacement vs Pressure Response of PZT based cantilever



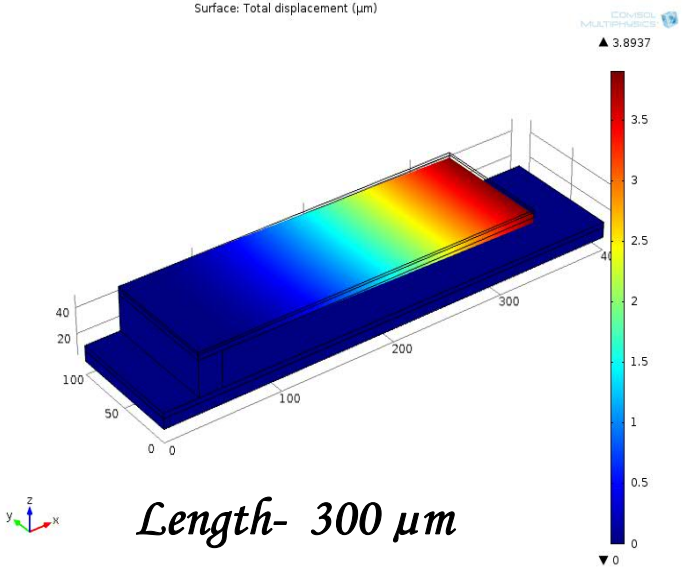
Dimensions:
Length: 350µm,
Width: 100µm,
Thickness: 8µm

Electrical potential vs Pressure Response of PZT based cantilever

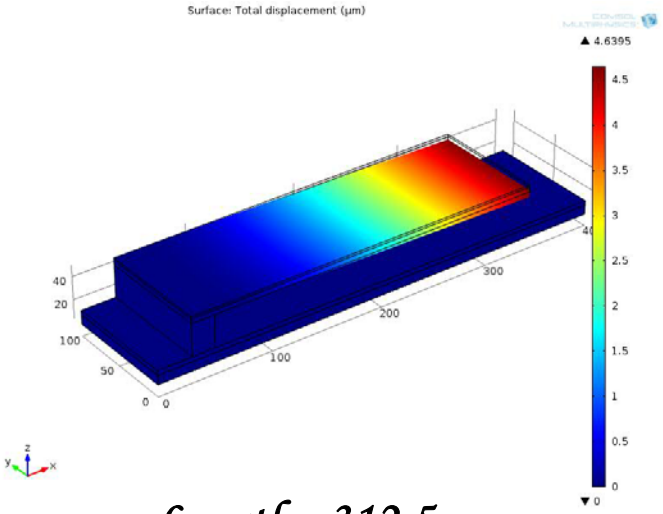


Dimensions:
Length: 350µm,
Width: 100µm,
Thickness: 8µm

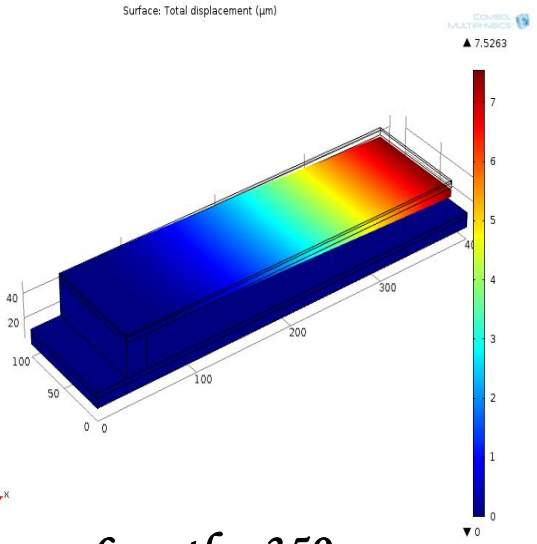
Displacement vs Length response of PZT based cantilever



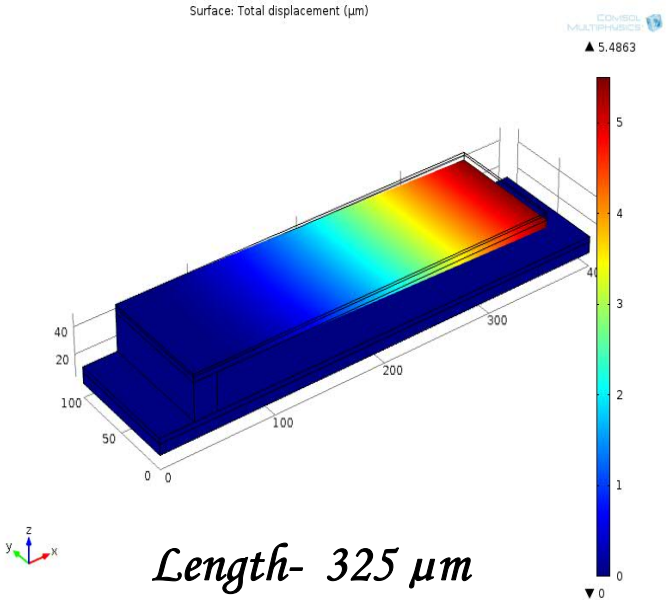
Length- 300 µm



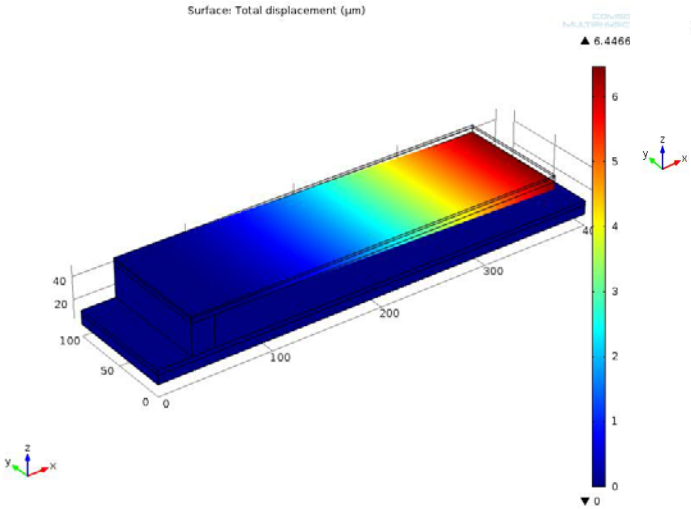
Length- 312.5µm



Length- 350µm

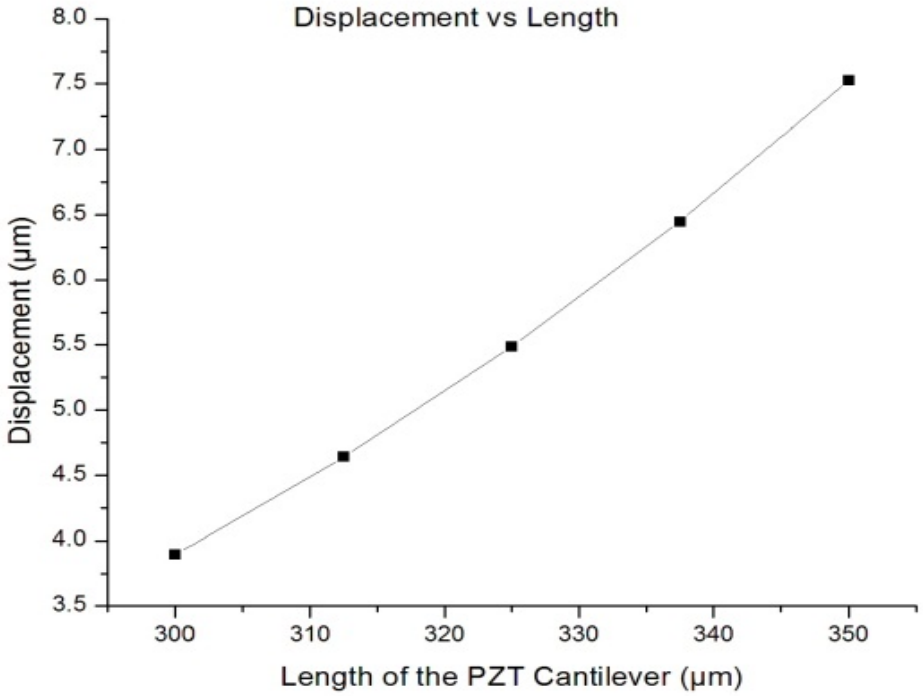


Length- 325 µm



Length- 337.5µm

Displacement vs Length response of PZT based cantilever



$$k = \frac{E.w.t^3}{4.L^3}$$

Body temperature measurement:

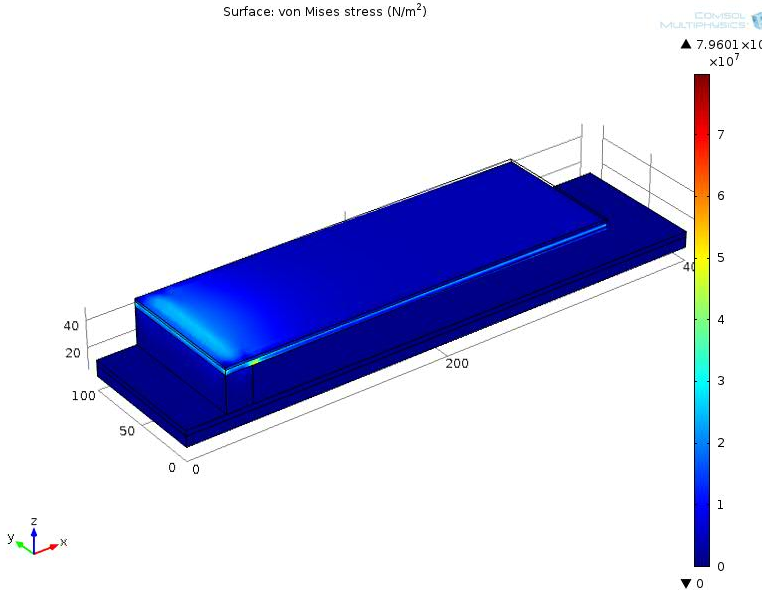
The inception of a disease is indicated by a rise in body temperature.

Stress values for different materials at normal body temperature

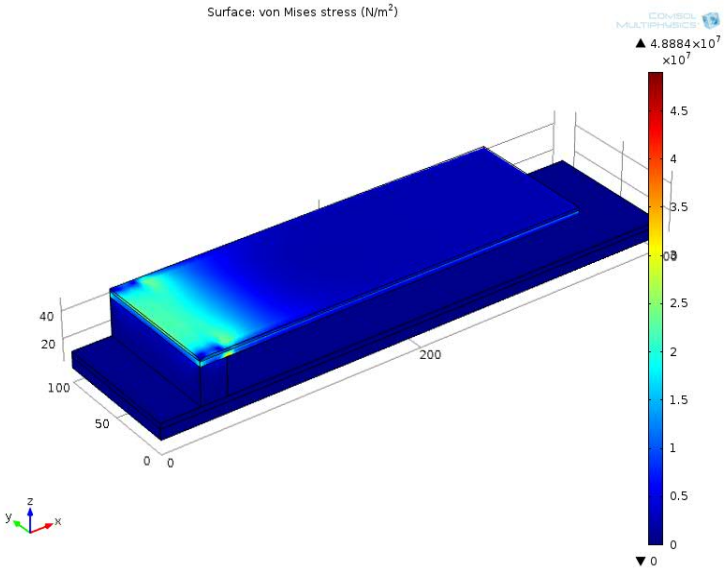
Cantilever dimensions: *Length: 300µm, Width: 100µm, Thickness: 8µm*

MATERIAL	*MAXIMUM STRESS (N/m^2)*
Au	$7.9601*10^7$
Cr	$4.884*10^7$
Cu	$1.1599*10^8$

Simulated stress for normal body temperature (37^{0}C)

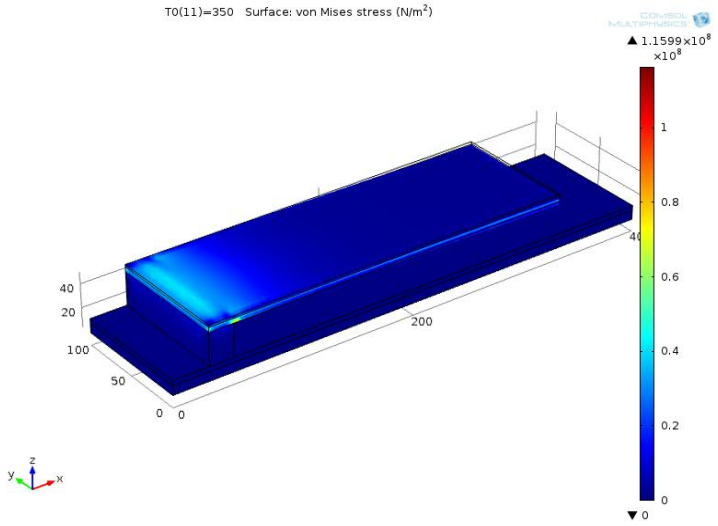


Au based cantilever



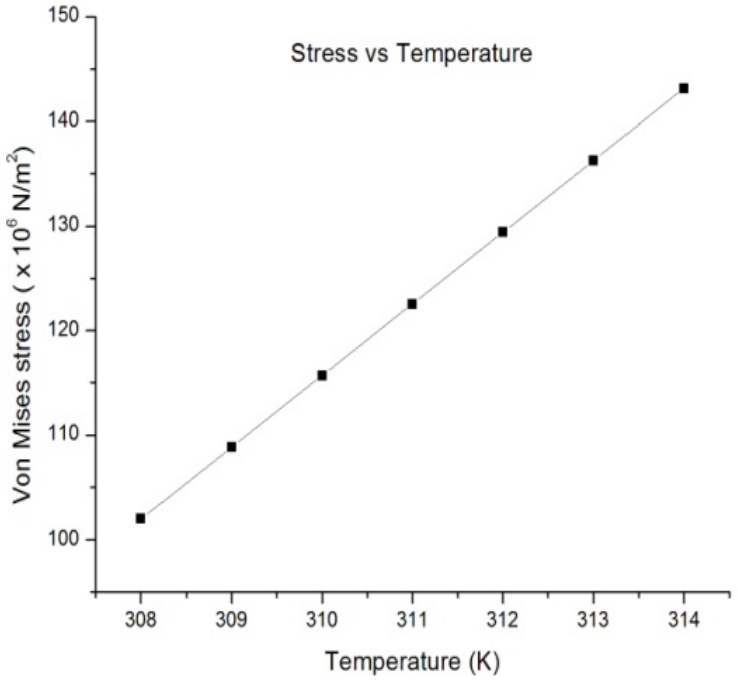
Cr based cantilever

Dimensions:
Length: 300µm,
Width: 100µm,
Thickness: 8µm



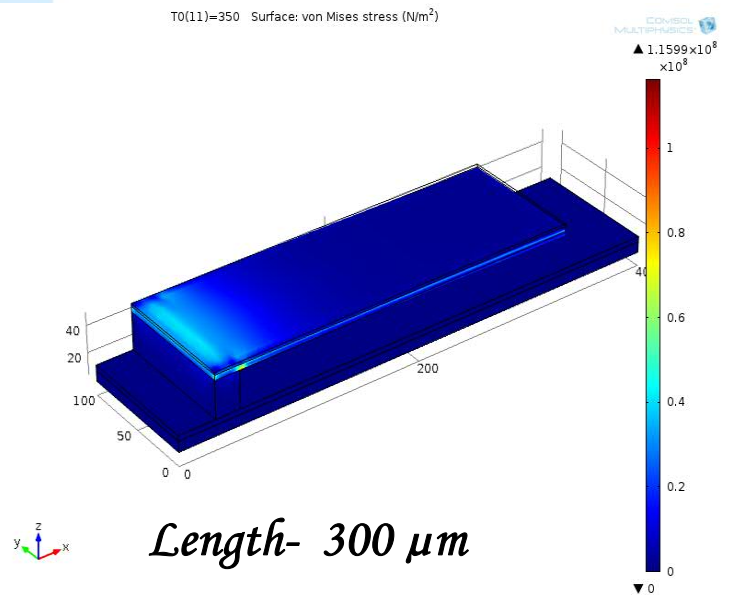
Cu based cantilever

Stress vs Temperature response of Cu based cantilever

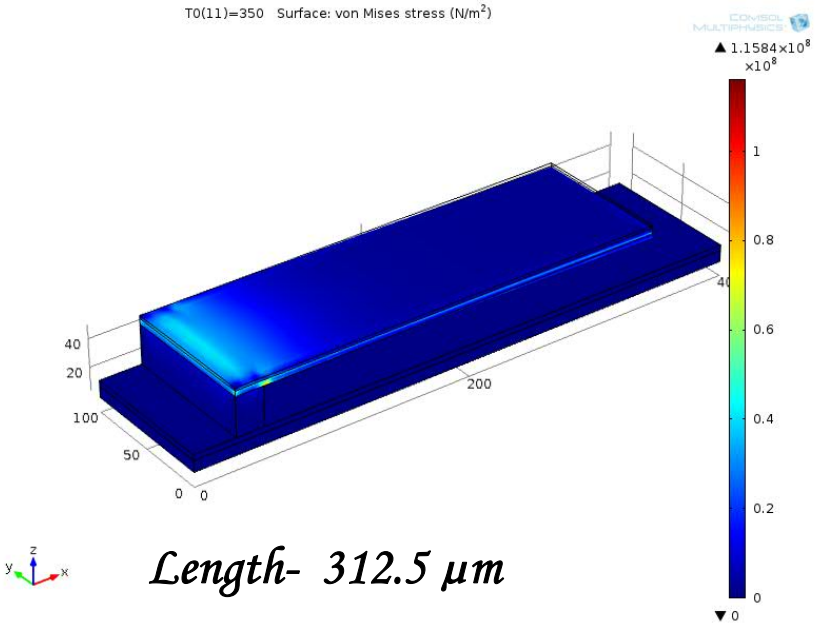


Dimensions:
Length: 300µm,
Width: 100µm,
Thickness: 8µm

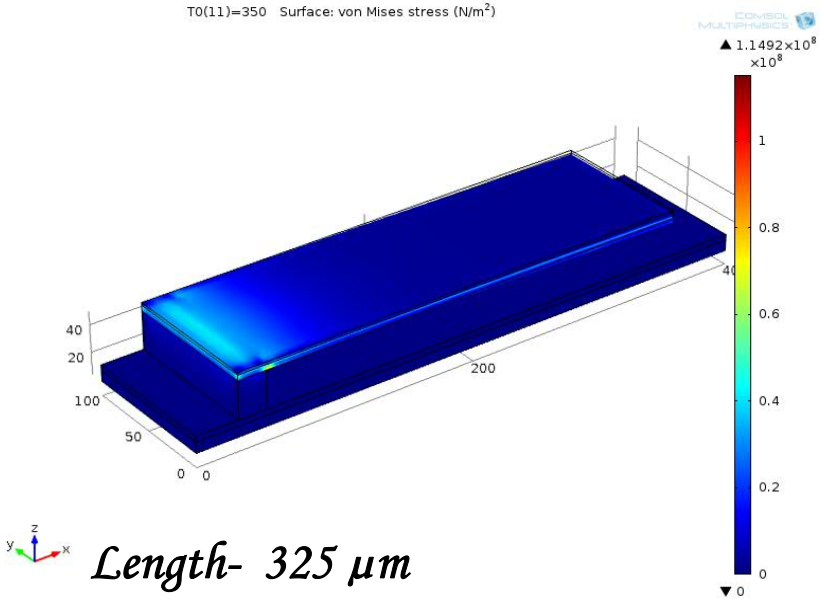
Stress vs Length response of Cu based cantilever



Length- 300 µm

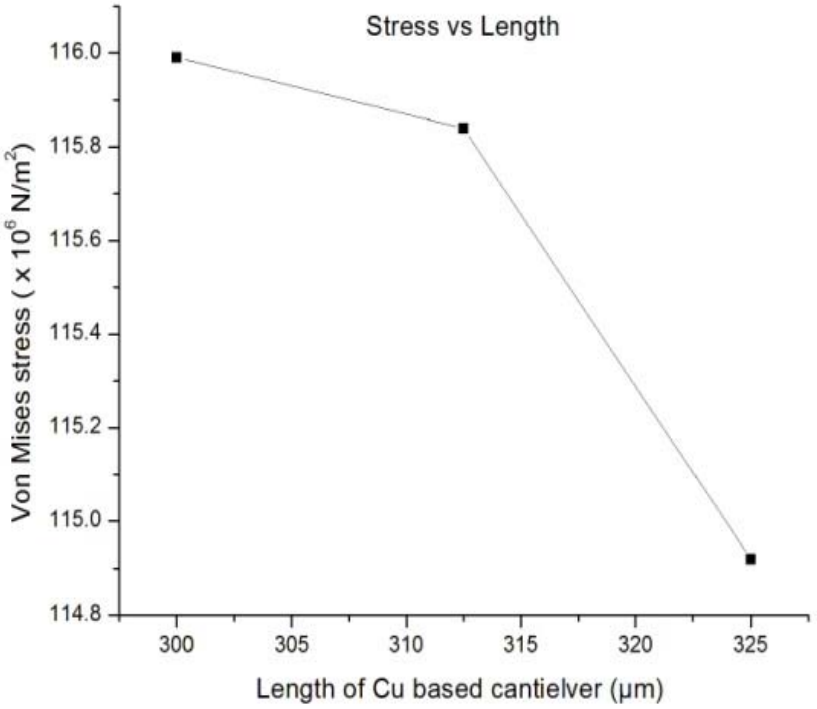


Length- 312.5 µm



Length- 325 µm

Stress vs Length response of Cu based cantilever



$$\Delta g = \frac{E.\Delta h.t^2}{(1-v).L^2}$$

Discussion & Conclusion

- *Linear sensing behaviour*
- *Lead Zirconate Titanate (PZT) - More sensitive to blood pressure variations showing a increased displacement and electric potential of 3.8935µm and 0.2753V.*
- *Copper (Cu)- a better temperature sensing element with a maximum stress of* $1.0112*10^8\ N/m^2$
- *The performance of the sensor was observed for hypothermia and hyperthermia conditions and a linear increase in stress with rise in temperature occurred*

References :

1. Shyamal Patel, A review of wearable sensors and systems with application in rehabilitation, Journal of NeuroEngineering and Rehabilitation, 9, 21(2012)

2. Philip F. Binkley, Predicting the Potential of Wearable Technology, IEEE Engineering In Medicine And Biology Magazine, (2003)

3. Sungmee Park, Smart Textiles: Wearable Electronic Systems, MRS Bulletin, (2003)


THANK YOU