Design of piezoelectric cantilevers

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MAE 656: Advanced computer aided design

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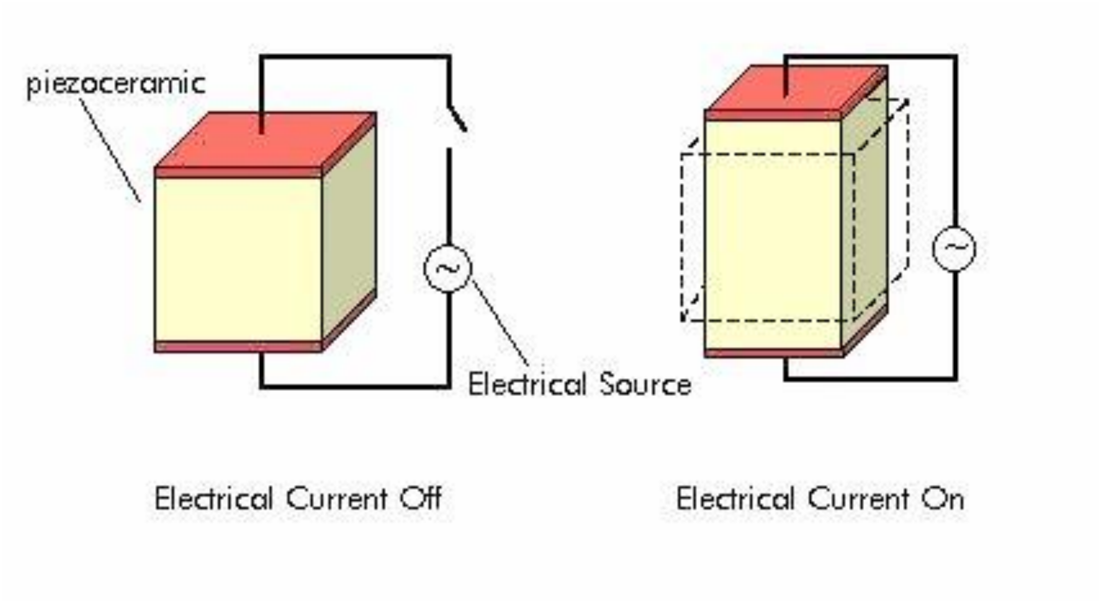
Presentation

- Description of the problem solved
- Description of the numerical model
- Results obtained with the numerical model
- Conclusions and summary

Description of the problem solved

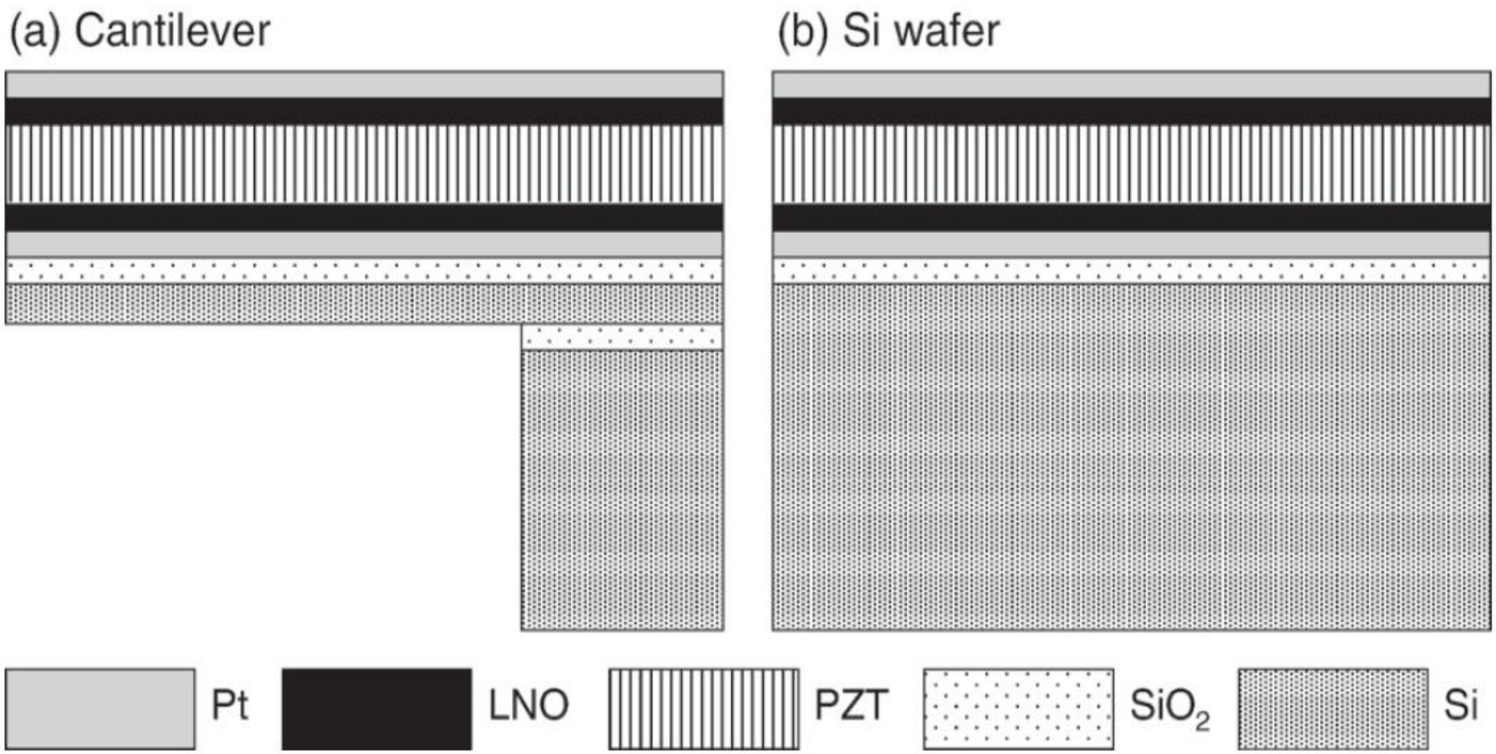
Description of the problem solved

- Piezoelectric materials:



Description of the problem solved

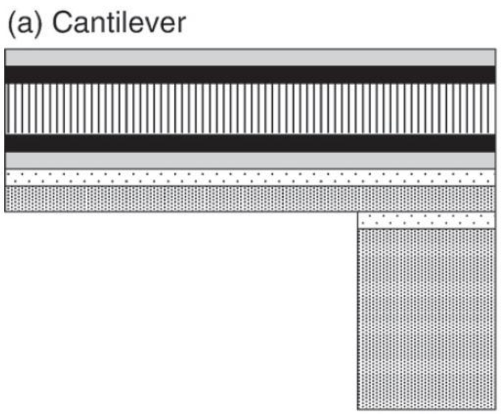
- Piezoelectric cantilevers:



[5]

Description of the problem solved

- Applications for this cantilevers:
  - Accelerometers [1].
  - AFM cantilevers [2].
  - Harvesters [3].
- In all this applications the mechanical resonance frequency is a key parameter.



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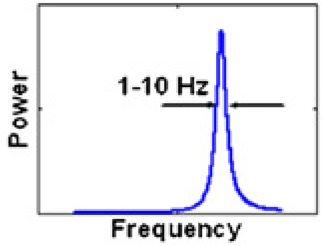


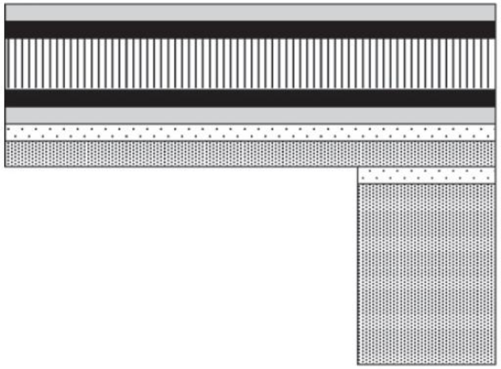
Description of the problem solved

- The goal of this project is to develop a design criterion.
  - Evaluate the change in stresses when the length and the width is changed.
  - Advantage: the resonance frequency can be tuned without increasing the internal loads.

Description of the problem solved

- Fabrication of the cantilever:
  - The thickness of the films is defined by the process.

(a) Cantilever



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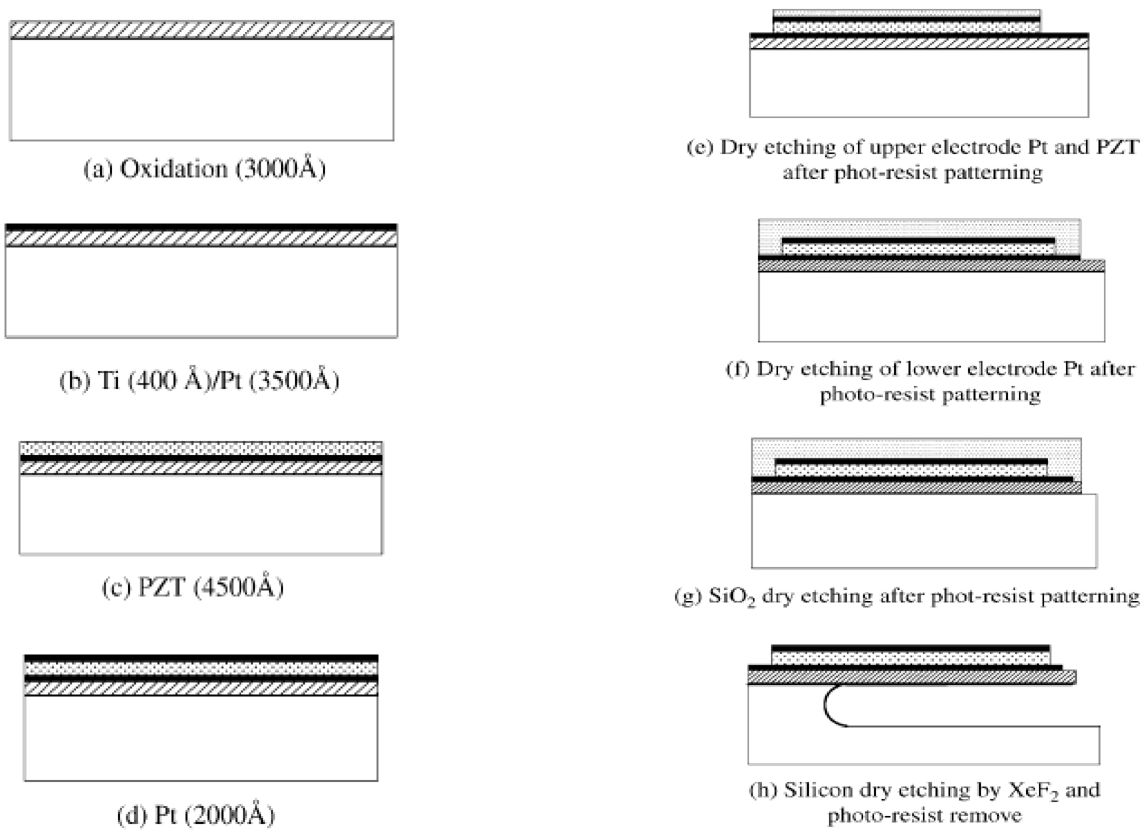
Material	Thickness (nm)
Pt	175
LNO	115
PZT	960
LNO	200
Pt/Ti	175/5
SiO2	540

Description of the problem solved

- Fabrication of the cantilever:



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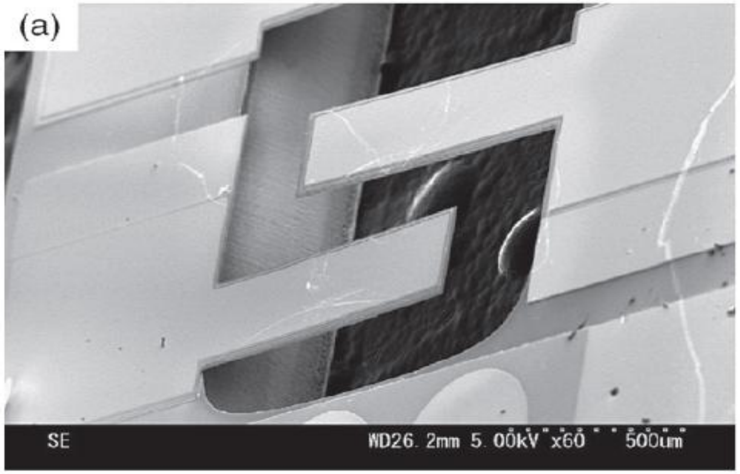
Description of the problem solved

- In this project the cantilever made by Kobayashi et.al. [5] will be modeled to know what are the stresses that the materials can support without breaking.



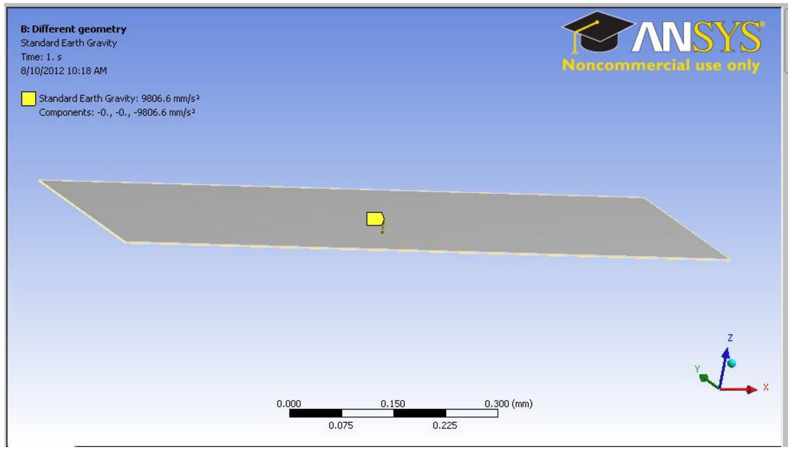
[5]

Cantilever dimensions: 270x1000µm

Description of the numerical model

Description of the numerical model

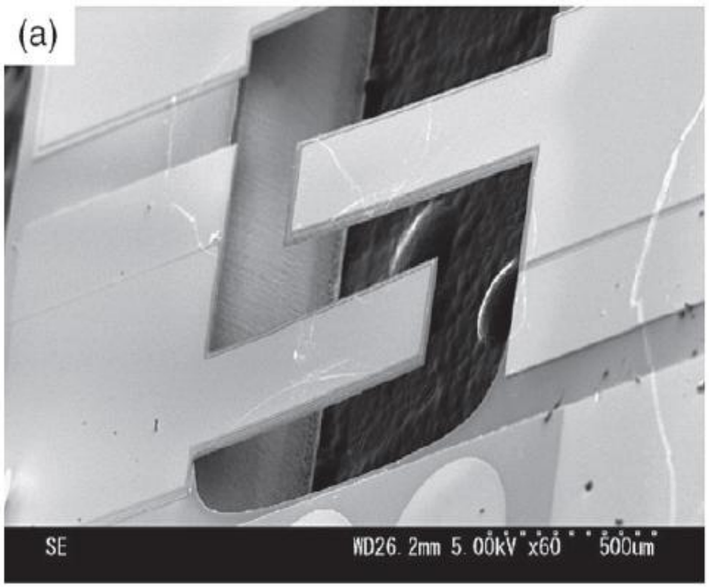
- Loads over the cantilever:
  - Gravitational.
  - Process loads*.
  - Loads during the application*.

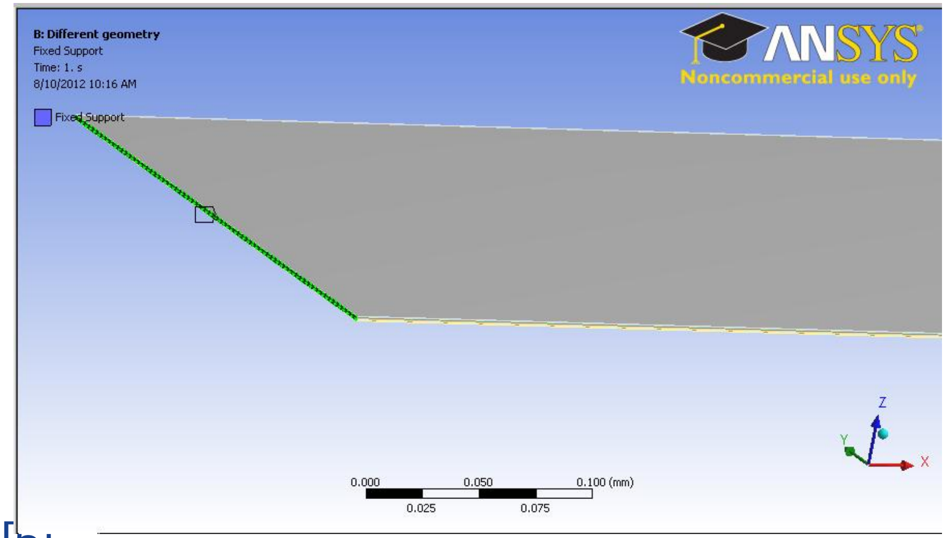


*: not considered in this work

Description of the numerical model

- Support:
  - The cantilever will be supported in the lateral faces.





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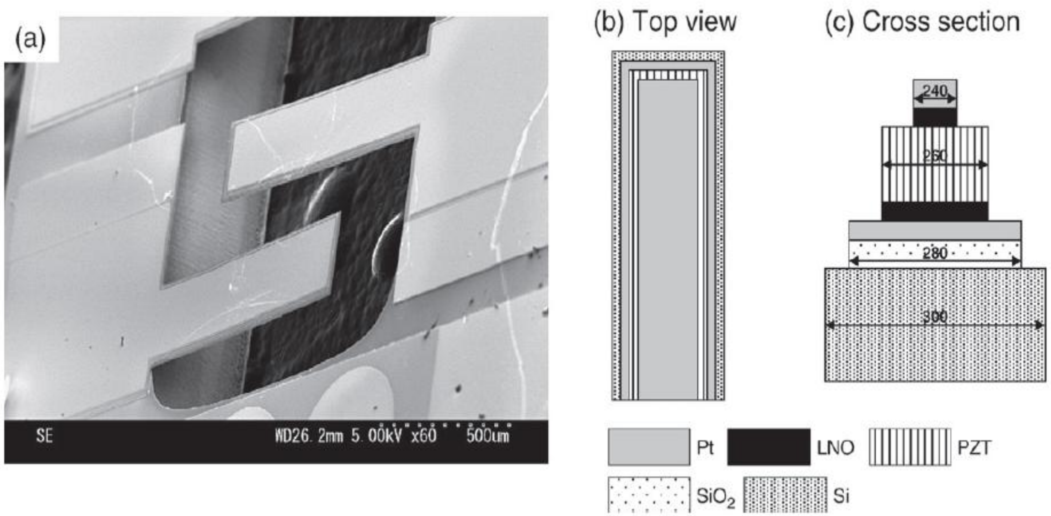
Description of the numerical model

- Geometry approximation:
  - Only one width and length will be used for all the layers.
  - The Ti layer (5nm) won't be modeled because is an adhesion layer.



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Description of the numerical model

- 3D Modeling:
  - In this case we are in the limit were 3D modeling can be used because the smallest lamina dimensions are 1000x270x0.1µm.

Description of the numerical model

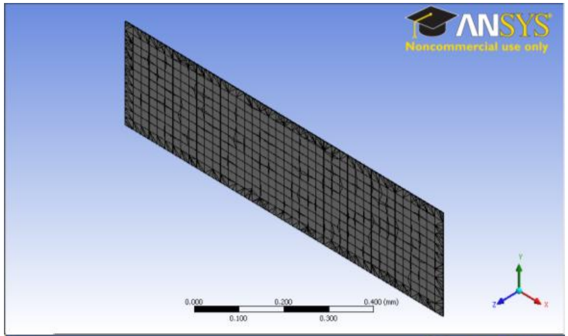
Materials properties:

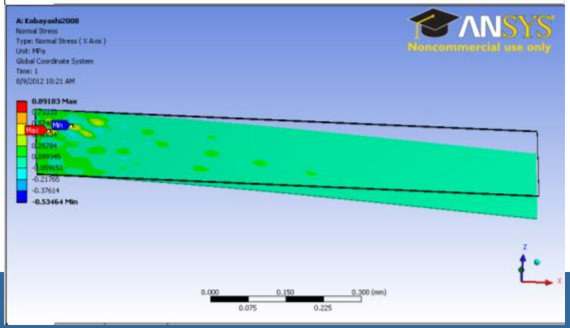
	Density (g/cm3)	Elastic Modulus (Gpa)	Poisson's ratio	Ref.
SiO_2	2.2	69	0.17	[7]
Pt	21.44	164.6	0.396	[8]
LNO	4.8	69*	0.17*	[9]
PZT	7.6	101	0.3	[10]

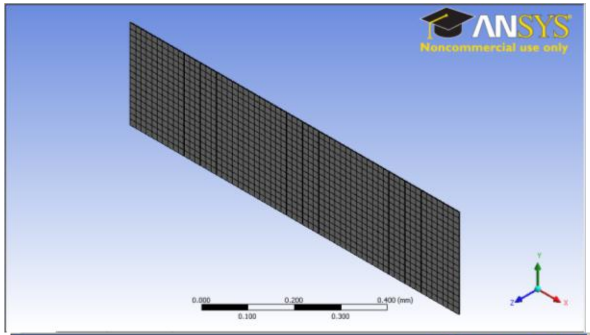
*the properties of LNO couldn't be found and they were replaced for the SiO_2 properties.

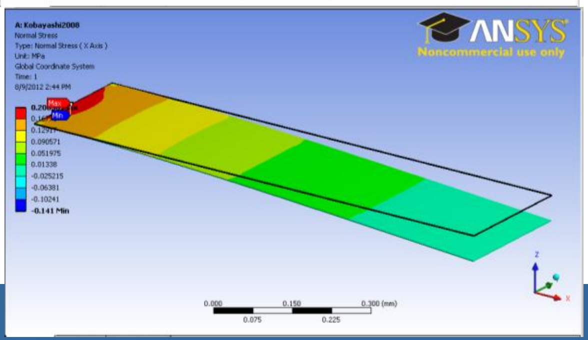
Description of the numerical model

- Meshing:
  - First the automatic meshing.
  - Secondly, mapping and face sizing.









Description of the numerical model

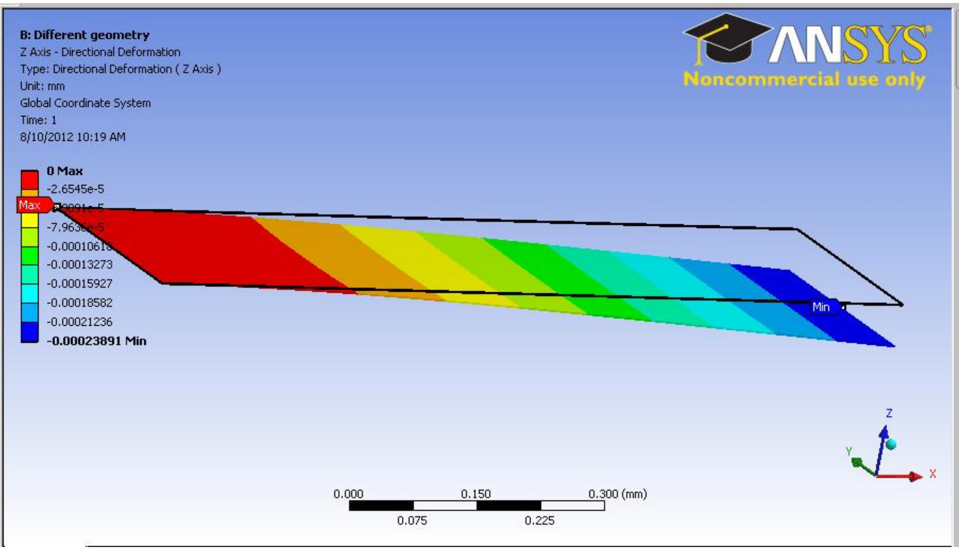
- Meshing:
  - Convergence study: problem with the aspect ratio of the elements (Thickness: 0.1µm). e.g. 16x16x0.1µm

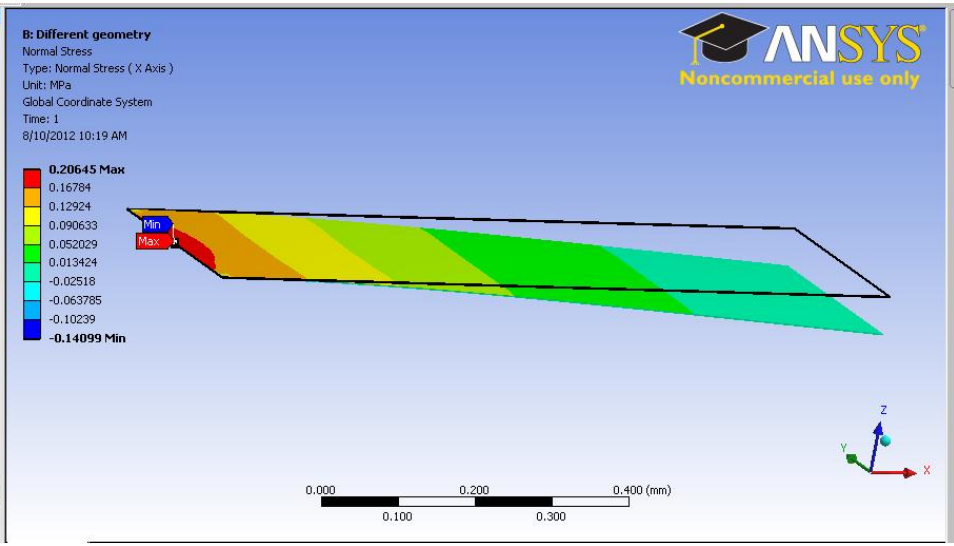
Upper size of the square nodes (µm)	Amount of nodes	Directional deformation (µm)	Maximum stress in X direction (Mpa)	Minimum stress in X direction (Mpa)
16	29572	2.38E-01	0.2063	0.141
17	27001	2.39E-01	0.2063	0.14095
18	24113	2.39E-01	0.20621	0.14087
19	21387	2.39E-01	0.20631	0.14092
20	20193	2.39E-01	0.20645	0.141
21	18081	2.39E-01	0.20629	0.14088
22	15733	2.38E-01	0.20598	0.14064

Results obtained with the numerical model

Results obtained with the numerical model

❖Deformation and stresses:



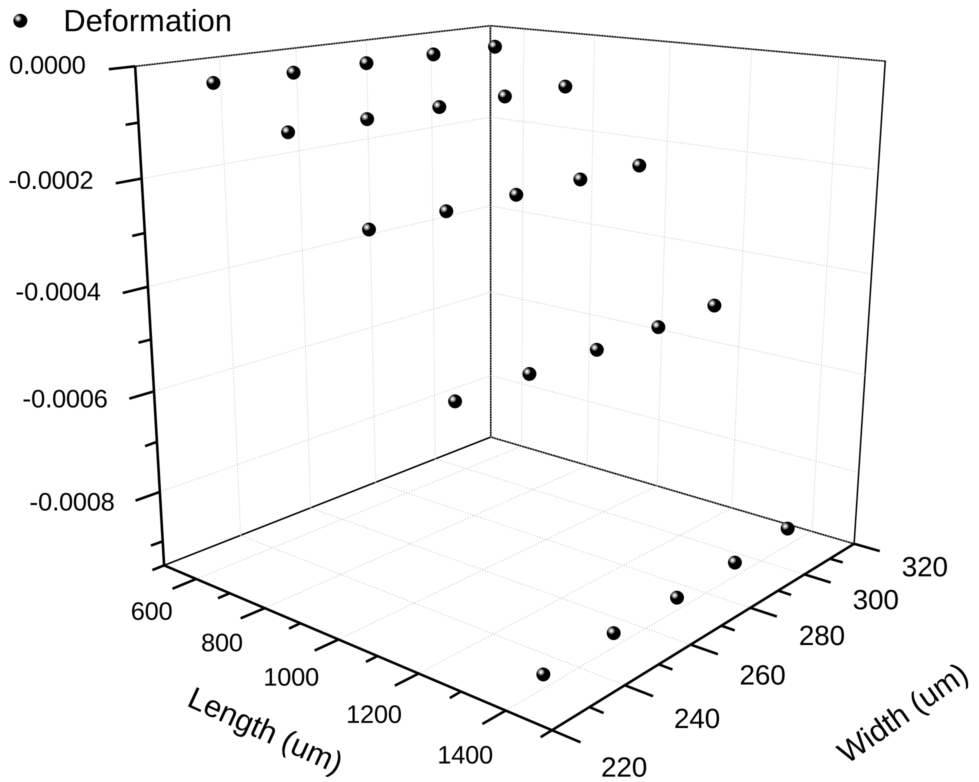


Results obtained with the numerical model

- As explained before different lengths and widths were used and the deformation and stresses were calculated:
  - Lengths varied from 600 to 1400 µm.
  - Widths varied from 230 to 310 µm.

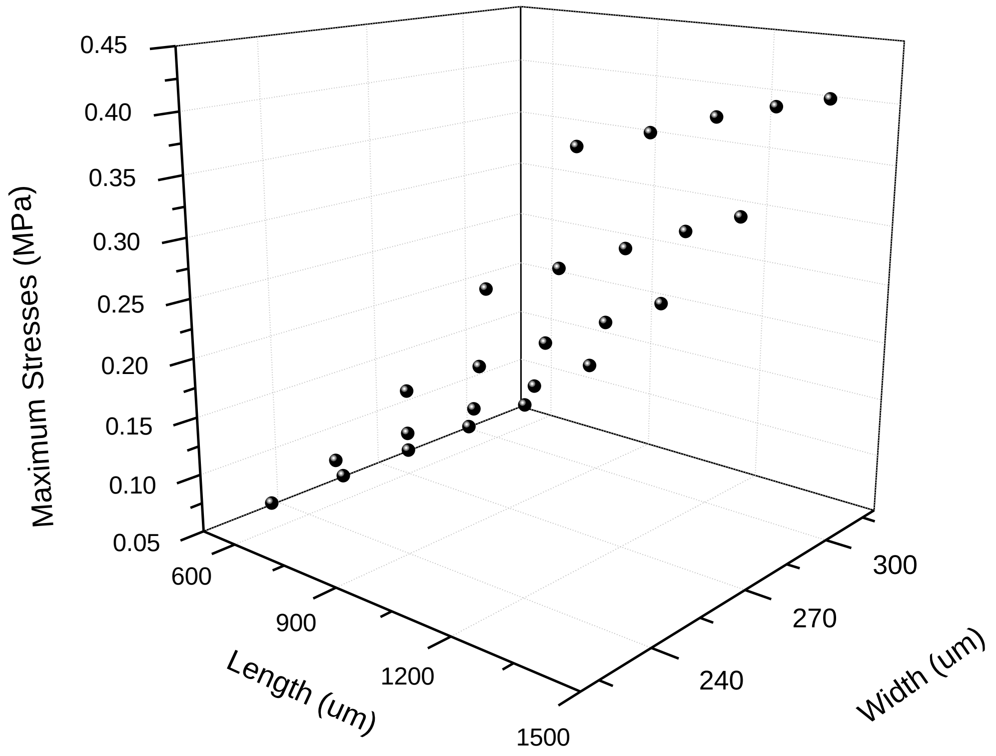
Results obtained with the numerical model

- Deformation obtained for different geometries:



Results obtained with the numerical model

- Stresses obtained for different geometries:



Results obtained with the numerical model

- Future work:
  - Develop a shell model to validate the results obtained.

Conclusions and summary

Conclusions and summary

- The working mechanism and applications of piezoelectric cantilevers was explained.
- The fabrication processes was summarized in order to know the real applied loads.

Conclusions and summary

- A model of the cantilever designed by Kobayashi et.al. [5] was made and the meshing was verified.
- Approximations made:
  - Applied loads.
  - Materials used.
  - Geometry (width and Ti layer).

Conclusions and summary

- A design criterion to change the resonance frequency was developed:
  - The width doesn't have a significant influence in the internal stresses or the deformation.
  - The internal stresses and the deformations increase when the length increase.

References

[1]: Sensors and Actuators, A92 (2001) 156-160.

[2]: Sensors and Actuators, A72 (1999) 179-188.

[3]: Applied Physics Letters, V84 N16 (2004) 3187-3189.

[4]: Meas. Sci. Technol. 17 (2006) R175-R195.

[5]: Thin Solid Films 516 (2008) 5272-5276.

[6]: Sensors and Actuators A117 (2005) 1-7

[7]: IEEE Transactions on electron devices,Vol.ED25,No.10,Oct1978, p.1249.

[8]: Platinum Metals Rev., 2001, 45, (2), 74-82.

[9]: A. Yamada, Journal of power Sources 119-121 (2003) 232-238.

[10]: Mat. Res. Soc. Symp. Proc. Vol. 687, 2002 Materials Research Society.


Thank You !