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MODELING OF PIEZORESISTIVE CANTILEVERS FOR CHEMICAL SENSING

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Abstract— **This paper presents and analytical model to provide good results for cantilevers with point load at free end and to describe the micro cantilevers with surface stress. It has been shown that the width of the cantilever has to be increased to optimize the sensitivity. The placement of the piezoresistor was found to be in the centre of the cantilevers clamped end and the area of the piezoresitor should be minimized.**

Keywords— **Piezoresistor, cantilevers, sensitivity, Surface stress**

I. INTRODUCTION

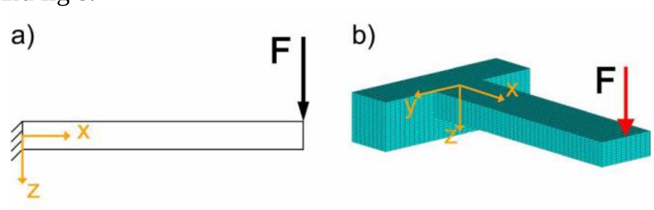
In a piezoresistive cantilever the detecting resistors, called piezoresistors, are placed at potentially high-stress points of the cantilever beam; as long as the cantilever deflection is negligible compared to its length, the resistance of piezoresistors changes linearly with the deflection. The considerable advantages of this scheme are the implementation of the detection mechanism within the cantilever, CMOS integration capability, and the possibility of making large cantilever arrays. Piezoresistance is a characteristic of conductive and semi conductive materials, attributed to the change of the electrical resistance with an applied stress (strain). The phenomenon of the resistance change of metallic wires with elastic strain has been investigated since the mid-19th century, after the pioneering works of Thomson1 followed by, particularly, Bridgman‘s works on the Piezoresistance measurements of polycrystalline materials . In the mid-20th century, after the theoretical modelling of the energy level structure in diamond crystals (e.g., silicon and diamond), it was predicted that the energy gap between the valence and conduction bands would increase with the decrease of the atomic spacing and, therefore, with pressure. This prediction was confirmed by observation of the resistance change of p-n junctions with pressure in germanium, and especially by Smith‘s work on the Piezoresistance effect in germanium and silicon. Being the dominant material in the semiconductor industry, silicon has been comprehensively studied as a prominent piezoresistive material. Also, besides crystalline silicon, the Piezoresistive properties of other microelectronic materials have been exploited and characterized, such as poly-Si, GaAs, GaN, SiC, poly-C, and amorphous materials. In addition, with the development of non-conventional micro-fabrication techniques, the Piezoresistance effect in carbon nanotubes and thin metal films has been recently investigated. These materials are demonstrated to be viable alternatives in piezoresistive detection.

II. DESIGN OF PIEZORESISTIVE FORCE SENSING CANTILEVERS

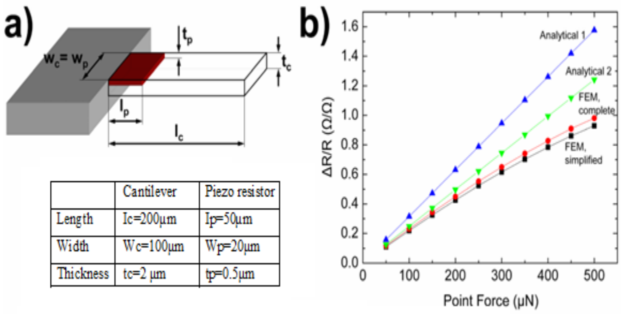
The measuring point loads at the free end; design criteria for cantilever sensors are discussed. The design of cantilevers and the analytical models are done using COMSOL Multiphysics software. The cantilever and piezoresistor dimensions are shown in table 1.

	Cantilever	Piezoresistor
Length	200µm	50 µm
Width	100 µm	20 µm
Thickness	2 µm	0.5 µm

The schematic of the cantilever with point load at the free end and the analytical model and Finite model are shown in fig a and fig b.



The chosen cantilver and piezoresistor dimensions for the comparision of different models and the relative resistance change over point force at cantilever free end calculated by three different models are shown in fig a. and fig.b.

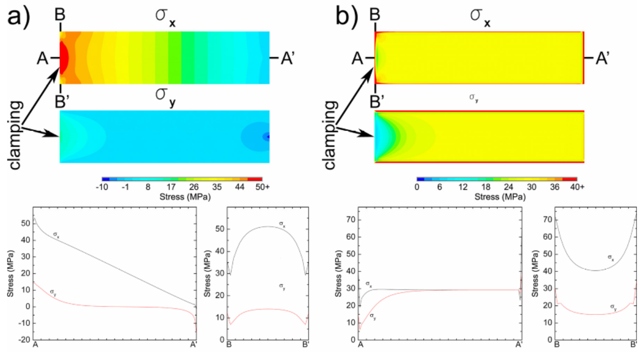


	Cantilever	Piezo resistor
Length	lc=200µm	lp=50µm
Width	Wc=100µm	Wp=20µm
Thickness	tc=2 µm	tp=0.5µm

The deviation of FEM solutions from the linear behaviour is caused by geometric linearities at large tip deflections 47.0µm at 500µN is accounted in this type of analysis. The two FEM solutions differ by no more than 5.3% which indicates that stress difference is good. So the force sensing cantilevers should be made thin and long and the piezoresistior area should be short and thin and as close to the clamped base.

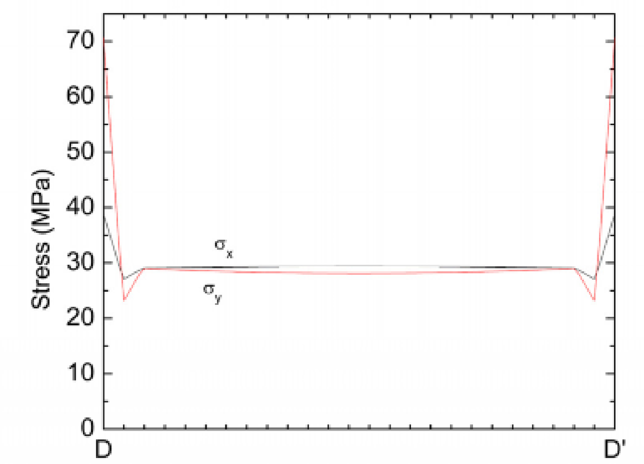
III. DESIGN OF PIEZORESISTIVE SURFACE SENSING CANTILEVERS

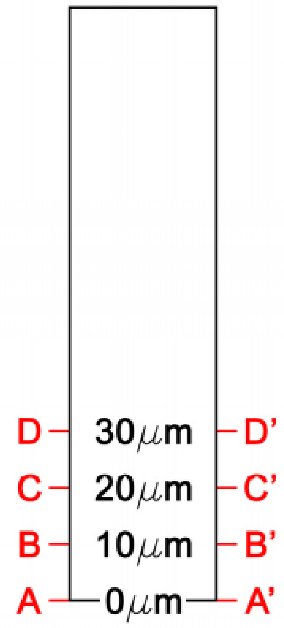
The stress distribution in a cantilever with surface stress is similar to that of a cantilever with a given tip deflection. The stress distributions of a cantilever with a point force at free end and surface stress on the top surface are shown in the figs.

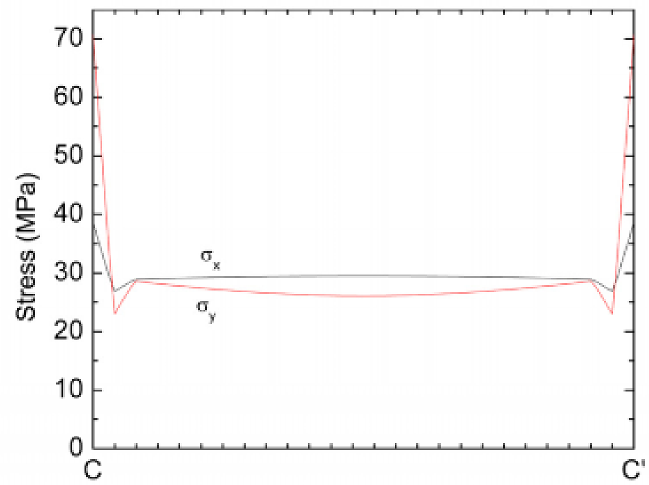


The two loading cases comparison clearly displays that the stress distributions within the cantilever and thus the piezoresistive output signal are very dissimilar. While the point force causes a stress distribution with a linearly decreasing stress in x-direction and a stress of much smaller magnitude in y-direction, this is not the case for the cantilever surface stress loading.

The distribution of stresses closes to the surface in x-and y-direction for different cross sections of a cantielver with surface stress is shown in the figs below.







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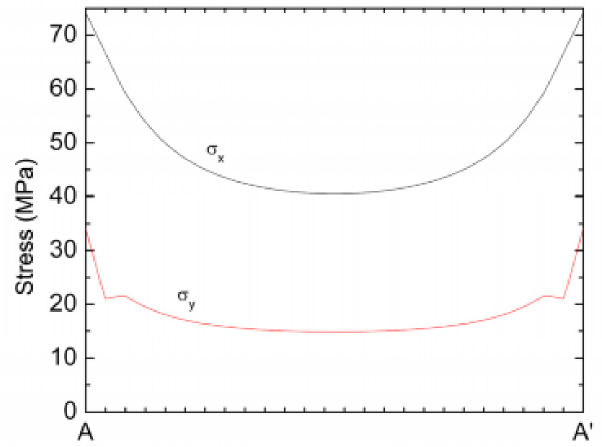
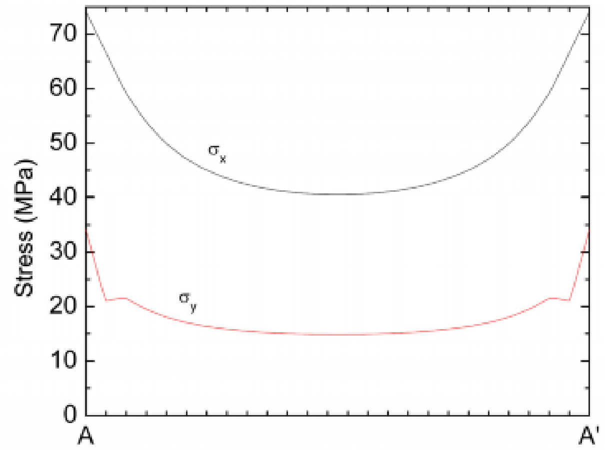
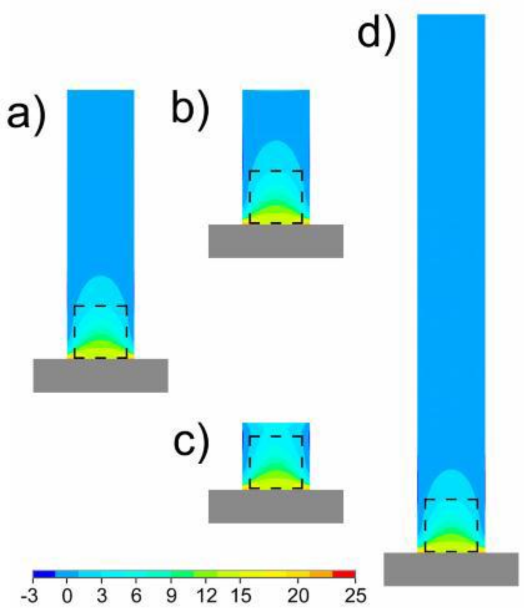
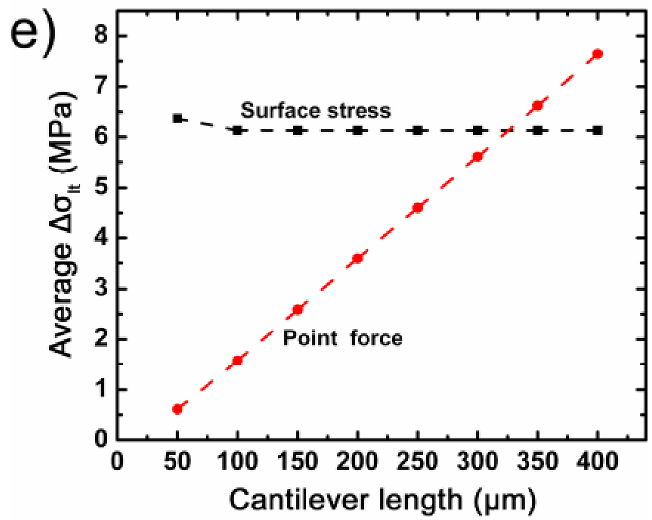


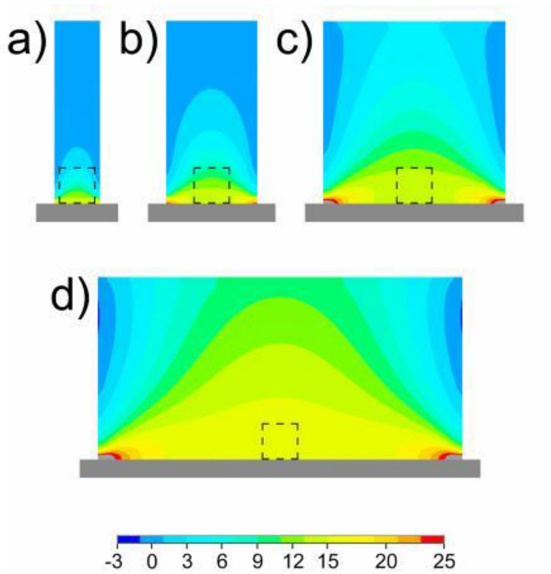


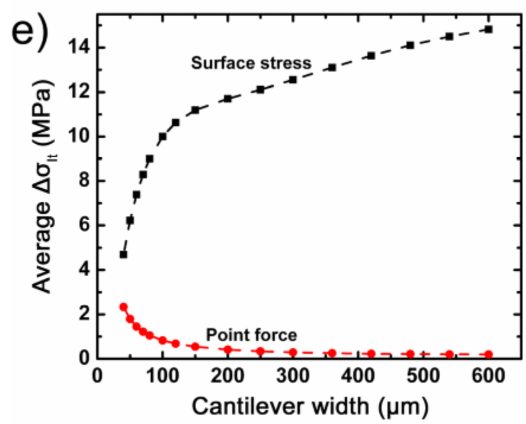
The stress difference with surface stress loading on the top surface with width 50µm and length 200,100, 50 and 400µm and the graph of average stress and cantilever length is shown below.





The stress difference with surface stress loading on the top surface with width 50µm and length 200,100, 50 and 400µm and the graph of average stress and cantilever width is shown below.





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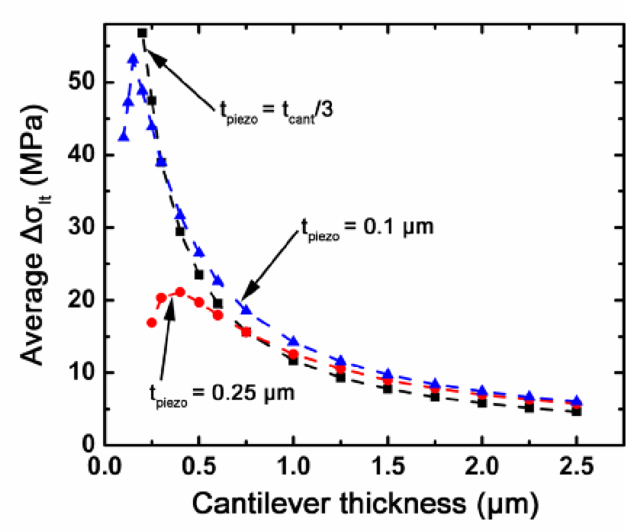

The above figure compares the piezoresistor thickness of 0.1 and 0.25µm and the one in which the piezoresistior thickness is one third of the cantilever thickness. The relationship is inversely proportional.

IV. CONCLUSION

Thus this paper presented the process for understanding the micro cantilevers for chemical sensing was familiarized. In many cases, the piezoresistor thickness is constrained by the fabrication process. In this case, the cantilever thickness should be chosen so that the piezoresistor is about two thirds of the cantilever thickness. In contrast to the case of a cantilever with a point load at the free end, when the piezoresistor thickness is close to the total thickness of the cantilever the sensitivity does not decrease intensely.

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