Simulation of Static mode and Dynamic mode of microcantilever Structures

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Abstract —*This Microcantilevers are the most simplified MEMS (Micro-electo mechanical systems) based devices. Diverse applications of microcantilevers in the field of sensors have been explored by many researchers. This paper presents the simulation of microcantilever and observed sensitivity for static mode of deflection and dynamic mode of deflections. Simulations of microcantilever made up of single crystal silicon and gold as sensing layer using FEM (finite element method) with COMSOL Multiphysics was done.*

Keywords - *Microcantilever; static mode; dynamic mode; Eigen frequency; Simulation; MEMS.*

I. INTRODUCTION

Now a days, micro Electro Mechanical Systems (MEMS) have shown tremendous growth in sensing research. MEMS based microcantilever has been proven as an outstanding platform for extremely sensitive chemical and biological sensors. Conventional biological and chemical sensors required regular maintenance,   extensive packaging and complex electronic interfacing, also they are expensive and bulky. The microcantilever based sensors are low cost, easy to fabricate, more sensitive, requires low analyte and it gives quick response. The target molecules can be detected in atmosphere, gaseous as well as in liquid medium. Many previous researches reported that piezoresistive microcantilever with polysilicon as a piezoresistive layer improves the cantilever sensitivity. These researches provided thorough understanding and strong foundation on silicon based microcantilevers. These researches provided thorough understanding and strong foundation on silicon based microcantilevers.

II. THERIOTICAL CONSIDERATION

A. MICROCANTILEVER BASED SENSING TECHNIQUES

A cantilever is a simplest mechanical structure, which is fixed at one end and free to move at the other end. Microcantilever is a microfabricated rectangular bar shaped structure, and has a thickness much smaller than its length or width. To serve as a sensor, cantilever has to be coated with a sensing layer to detect change in mass by static or dynamic method. Interaction of sensing molecules with surface causes bending of the microcantilever. This is called as static method. In dynamic method the resonant frequency of the cantilever depends on the mass of the cantilever and the resonant frequency drops as the mass increases. The change in static cantilever deflection or change in vibrational amplitude is detected by optical method, peizoresistive method, piezoelectric method and capacitive method.
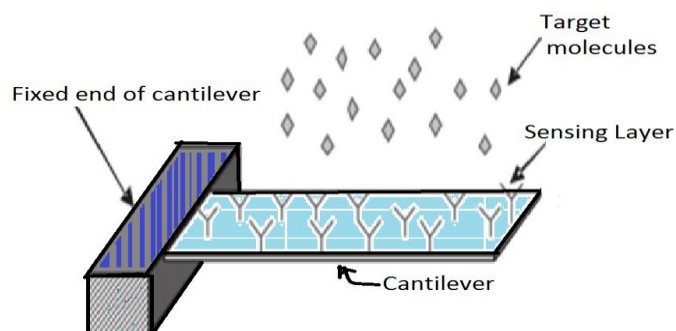

Figure 1. Microcantilever based sensor

B. DESIGN PARAMETERS

Two commonly used approaches for the operation of microcantilever for sensing applications are Adsorption-induced Deflection (Static mode) and Resonant Frequency Shift-based Approach (Dynamic mode). Two equations are key to understand the behavior of MEMS cantilevers. The first is Stoney's formula and second is the resonant frequency of the oscillating cantilever. The stoney's formula which relates microcantilevers deflection Δz to applied surface stress σ is describe as

$$\Delta Z = \frac{3(1-v)L^2}{Eh^2}\sigma$$

Where,

    E = Young's modulus of the cantilever material,
    L = Length of the cantilever beam,
    T = Thickness of the cantilever beam,
    σ = surface stress,
   υ = Poisson's ratio.

In dynamic mode the resonant frequency of oscillating cantilever is given by the formula

$$w = \sqrt{(K/m)}$$

Where, K is spring constant and m is effective mass of cantilever.

In the geometry of the microcantilever, Silicon is used as structural layer of the cantilever. Gold material is deposited at the free end of the cantilever and it acts as a sensing layer. The simulation is run by COMSOL Multiphysics.

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Length of Microcantilever	100μm
Width of Microcantilever	20μm
Thickness of Microcantilever	2μm
area of sensing layer	40μm^2
Thickness of sensing layer	1μm
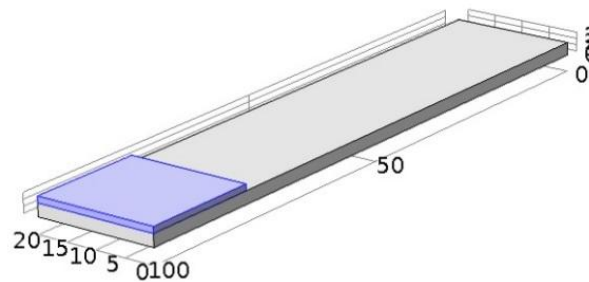
Figure 2. Geometry of cantilever

III. SIMULATION RESULT

    One end of the cantilever beam is fixed constraint. Gravity is applied to the whole system. Sensing layer deposited on the free end shows higher sensitivity than full length of deposition on cantilever. Figure (3) shows higher stress at the fixed end of cantilever
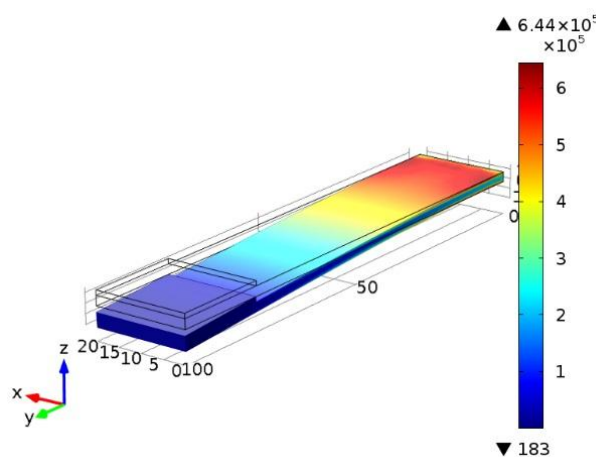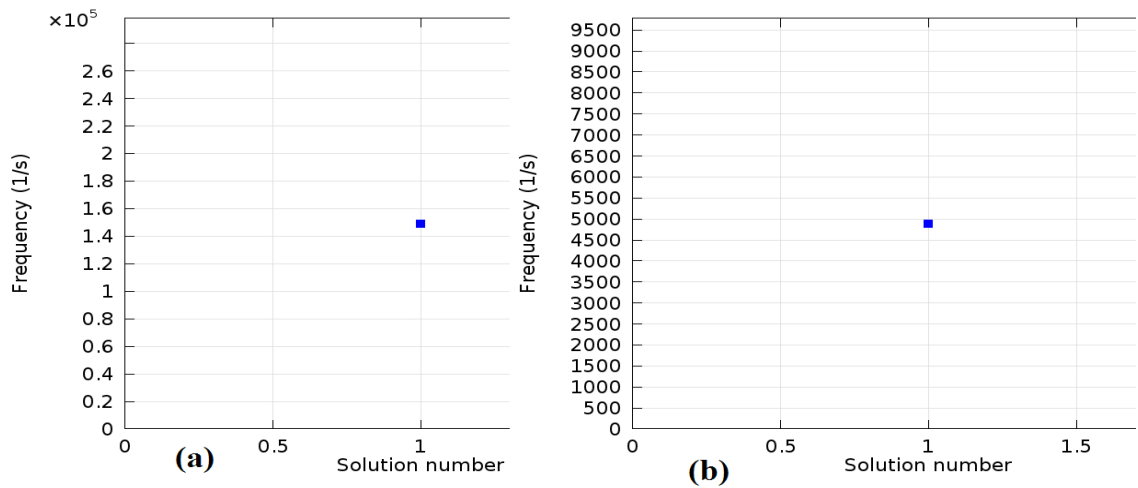

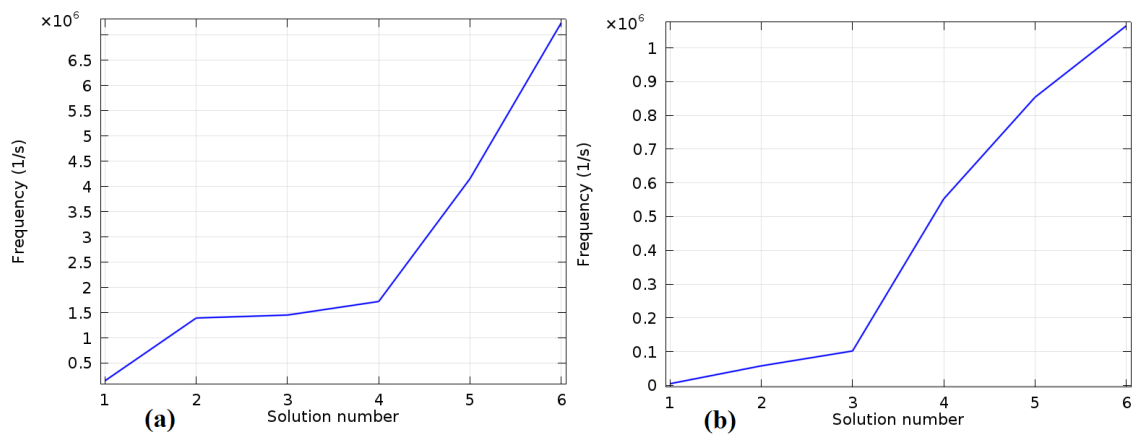*Figure 3. von mises stress of cantilever*
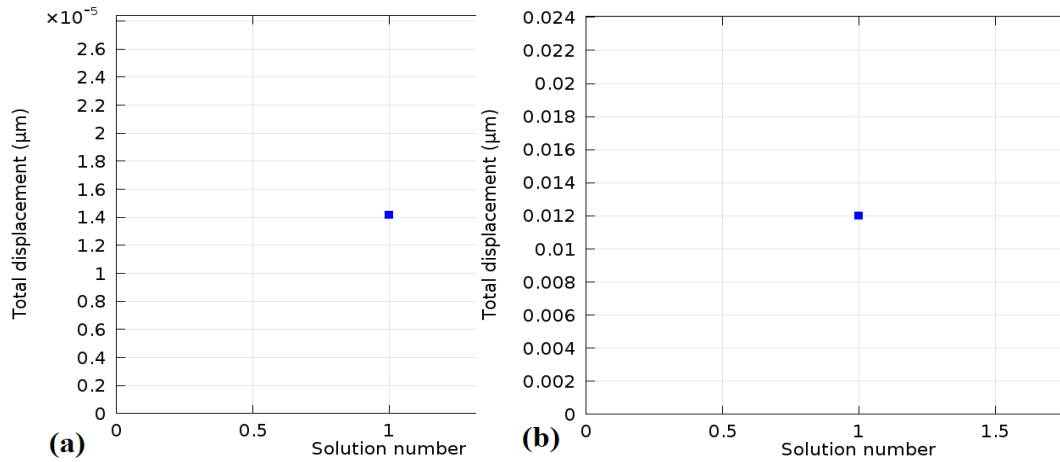
Figure 4. Displacement of cantilever for (a) non-added mass (b) added mass

Total displacement of the cantilever when Mass is not added and when mass is added is shown in Figure (4). It shows that cantilever is more sensitive for small mass change.

Figure 5. Eigen Frequency (a) non added mass (b) added mass

Figure 6. All Eigen frequency for (a) non added mass (b) added mass

Figure (5) and figure (6) shows Eigen frequency change when mass is not added and when mass is added on the cantilever surface. Small change in mass is sufficient to considerably change the eigen frequency. Dynamic method is more sensitive for mass change than static method.

IV. CONCLUSION

Tiny dimension of the cantilever shows very high sensitivity. Cantilever with optimized geometry gives better deflection results. Dynamic mode of deflection and static mode of deflection is observed with finite element method. Simulation results show that dynamic mode of the cantilever shows more mass change than static mode. Promising materials used for structural layer shows higher deflection for small mass change. The static mode specifically targets the force sensitivity of piezoresistive cantilevers, the dynamic mode can be used for improving the resonance quality of rectangular cantilevers in general, regardless of the implemented sensing schemes.

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