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Design and Fabrication of Mems U-Shaped Cantilever

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Abstract*: MEMS are used in acceleration, flow, pressure and force sensing applications on the micro and macro levels. The fundamental part of every sensor is the transducer which converts the measurend of intrest into and interpretable output signal. The most prominent transducer is the piezoresistive cantilever which translates any signal into an electrical signal.This paper presents the deisgn and fabrication of U shaped cantilever with enhanced sensitivity and stiffness which gives better results than other cantilevers. The simulation results of the cantilevers are designed using COMSOL software. MEMS technology becomes more affordable better and easier to fabricate in increasing quantities. Each layer of fabrication process is quite complex and final fabricated product will tested and used for high end applications.

***Keywords*: Mems, Fabrication, Cantilever, Comsol**

I. INTRODUCTION

The MEMS biomass sensors are used for detecting for sensing pictograms to femtograms of weight. But these molecules have to be sensed using a cantilever with more sensitivity and stiffness. Piezo resistance is a characteristic of conductive and semiconductive materials attributed to the change of the electrical resistance with an applied stress. Piezoresistive cantilevers have been successfully commercialized especially in applications such as accelerometers AFM probes for scientific and sensing modules. The cantilever basically operates on static and dynamic modes. The static mode focuses on the change in the resistance and dynamic mode stresses on the change in the resonant frequency. Starting with deposition of the fabrications process first concentrates on the wafer deposition by polysilicon layer which is exposed to masks light and chemicals to etch holes. The next layer is sacrificial and it is also exposed to masks, light and chemicals. The light is used to harden or soften certain parts of layer so that etching process will etch the unwanted parts and give the desired shapes.

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II. LITERATURE

Research in MEMS is an interdisciplinary activity involving various engineering disciplines like mechanical, materials science, electronics and instrumentation. It is an integration of mechanical and electronic systems on the same chip at micro-scales. The MEMS systems are replacing other conventional systems because of their unique advantages like, IC technology with integrated multi-functioning, precision and improved performance, batch fabrication leading to reduced manufacturing costs and time. Miniaturization which results in portability, ruggedness, low-power consumption, developed on a mass scale, easily maintained and repaired, and less harmful to environment. The researchers of MEMS focus on different fields like design, MEMS materials, processing, fabrication, testing & calibration. Microcantilevers are popular as sensing elements in bioMEMS applications. A bio-MEMS sensor consists of a bio receptor and transducer. A biosensor utilizes chemical and biological reactions to detect and quantify a specific analyte. A biosensor, which uses mass based transduction, is called a mass sensor [1]. Mass sensors are used to detect extremely small masses of biomolecules such as proteins, viruses or even parts of DNA in the range of femtograms (10-15 gm.) to zeptograms (10-21 gm.). In all applications one of the key points for a successful solution to the problem is the availability of a detector with high sensitivity, selectivity and reproducibility to the chemical and biochemical parameters of interest. The sensitivity or minimum detectable mass depends on the ratio between the mass and the resonant frequency of the beam. Generally, the resonant frequency increases and the mass decreases when the dimensions are decreased. Thus, a straightforward approach to enhance sensitivity is to decrease the dimensions of the beam. In microcantilever biosensors, the cantilever transduces the recognition event from its receptor - immobilized surface (for example, a DNA probe and an antigen or antibody) into a mechanical response (for example, static displacement and resonance frequency). Microcantilever provides an alternative technology that overcomes this limitation. One face of the cantilever is coated with a functionalizing layer, which is highly specific to a particular analyte. This layer acts as the sensing element. When the cantilever is brought into contact with the corresponding analyte, the interaction between the functionalizing layer and the analyte causes a change of free energy, which results in a change of surface stress. The difference between the stresses of the functionalized and non-functionalized layers causes the cantilever to deflect.

Thus, the cantilever transduces a chemical reaction into a mechanical response. Measurement of this deflection provides a rapid indication of the analyte concentration.

III. FINITE ELEMENT ANALYSIS OF U SHAPED PIEZORESISTIVE CANTILEVER

A U shaped cantilever is designed with insulation layers with the following dimensions.

U -shape	Length (µm)	Width (µm)	Thickness (µm)	Material
Layer 1	200	100	0.65	SiO2
Layer 2	200	100	0.7	PolySi
Layer 3	200	100	0.65	SiO2

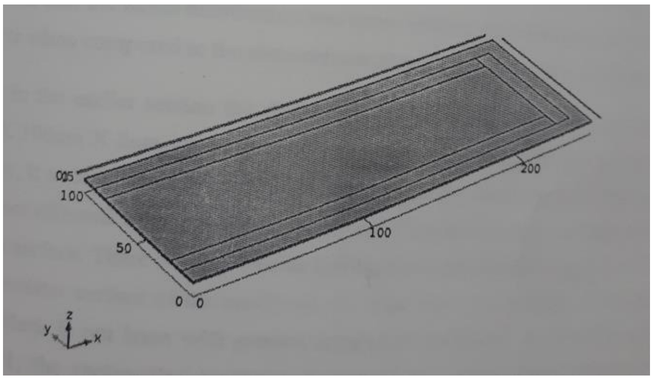

Fig.1 U shaped cantilever

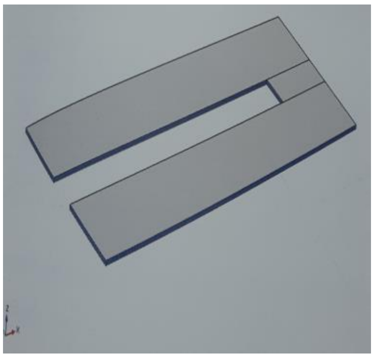

Fig.2 Simulated U shaped cantilever

The width 100µm includes the air gap between the two legs.The proposed U shaped cantilever has 3 layers. The middle layer is the sensing piezoresistive layer while top and bottom are the sensing surfaces on which the analytes which are deposited to create deflection in the cantilever to produce stress which can be sensed with more sensitivity and stiffness.[2]

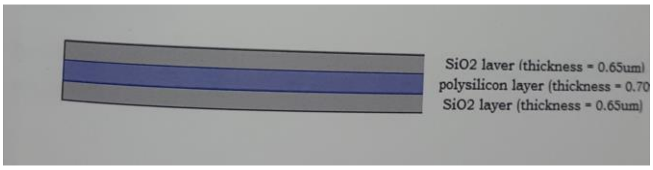

Fig.3 Dimensions of cantilever

IV. FABRICATION

Microcantilever fabrication involves the process of wafer cleaning, wet oxidation, Lithography, oxide etching and silicon etching.

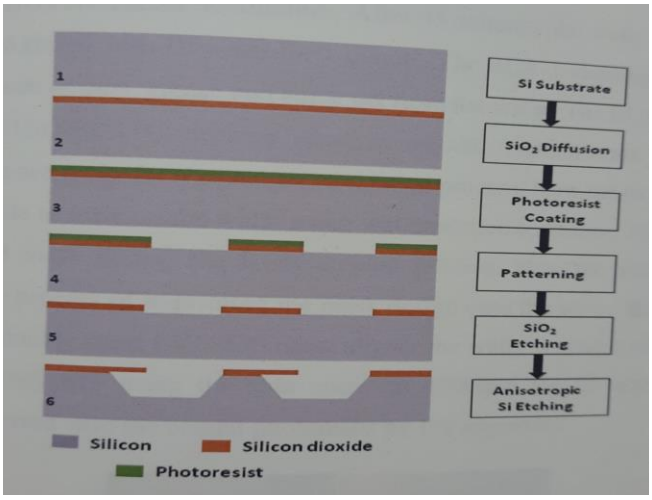

Fig.4 Fabrication process

The first step in microcantilever fabrication is wafer cleaning. Intially the wafer is cleaned in Deionised water then it is put in RCA-I solution for 15 minutes. After 15 minutes the wafer is removed from the solution and rinsed with DI water for 1 minute. The RCA-I cleaning removes surface contaminants such as dust, grease and silica gel from the water. The RCA-II cleaning removes metallic contaminants from the wafer. Now the wafer is ready for thermal wet oxidation process. Now the oxide layer of 2µm thickness is made to form on the wafer using wet oxidation technique. This oxide layer is used as a hard mask during KOH etching process. Now the wafer is ready for lithography, the process of imprinting the mask design onto the wafer [3]. Before putting the wafer onto the double sided EVG620 mask aligner the wafer is coated with positive tone photoresist Shipley 813 using spin coater at 400rpm for 40 seconds. The mask pattern is transferred onto the coated photoresist by UV exposure.

The celvin software is used for imprinting the mask structures.

Fig.5 Mask Imprinting

The pattern is then developed in a MF26A developer solution for 1 min and rinsed with DI water followed by nitrogen drying. The released microcantilevers can be observed under high resolution microscope[4].

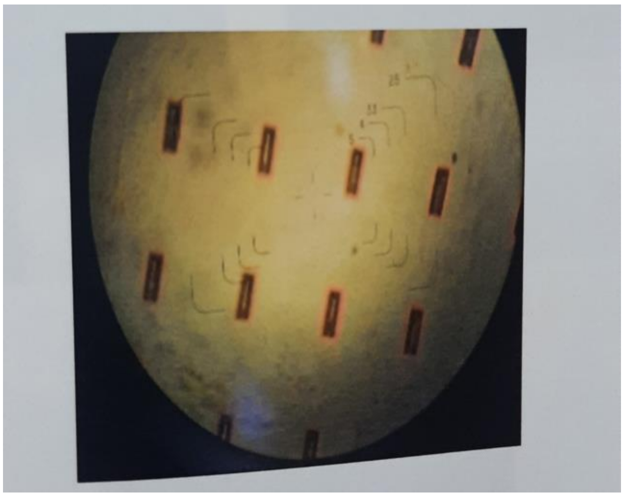

Fig.6 Cantilever structures

The mask Alignment set up is as follows:

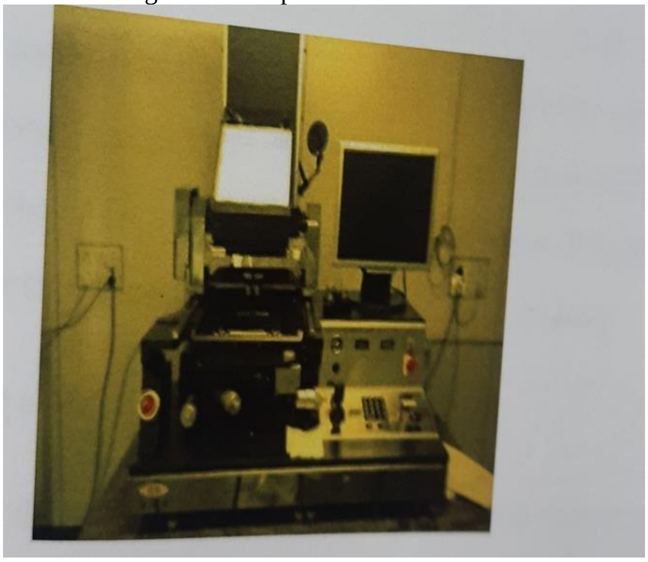

Fig.7 Mask Alignment

HWCVD is a new technique which is used to deposit thin layer of polycrystalline silicon on substrate [5]. The reactant gases Silane, diborane and hydrogen thermally decomposed at the surface of resistively heated filament whose temperature range of 1500-2000ºC to form radical. The recipe used in HWCVD is as follows.

Base pressure = $1.76e^{-6}$
Gas pressure = $1.1e^{-1}$
Substrate temperature = 300ºCelsius
Filament temperature = 1850º Celsius
Ratio of gases SiH4:B2H6:H2= 1:5:10
Voltage = 22.7v
Current = 13.7Amp
Process time = 30 min.

Lithography was done to transfer the pattern on full wafer. After that dry cleaning was done in STS RIE for removing polysilicon from unwanted region.

Gases used SF6 = 25sccm
Chamber pressure = 100mtorr
RF power = 150 watts
Etching time = 30 seconds

The fabricated cantilever was released by removing the sacrificial layer with BHF 5:1.While releasing the cantilever the color change was observed. Also to verify the etching results contact angle measurement of the sample was done. In contact angle measurement angle was found to be greater than 90º which means hydrophobic in nature sio2 is removed completely.

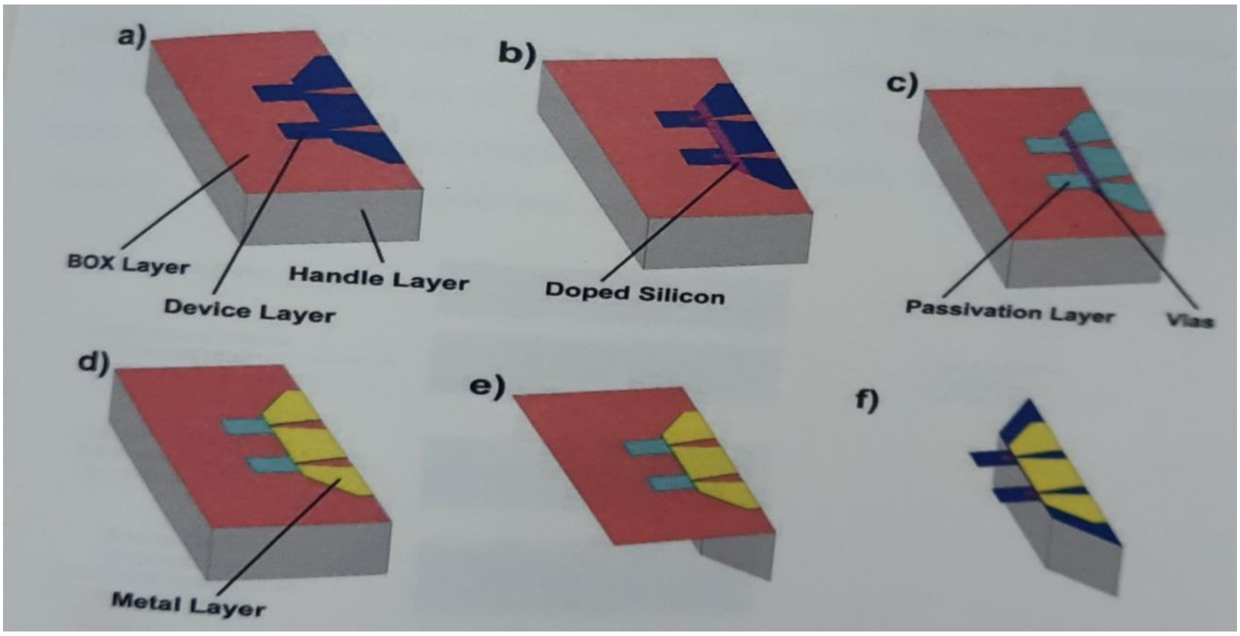

Fig.8 Lithography

V. CONCLUSION

This paper presented the design and fabrication of the cantilever. The design of U shaped cantilever is designed and simulated using COMSOL software and it is observed that u shaped cantilevers with 3 layers has given an enhanced sensitivity. The change in the resistance due to the stress induced has given the cantilever deflection. The cantilever is fabricated with different process and these cantilevers can be used further in different application

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Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	If applicable and having more than 01 authors: All authors have individual partnerships in this article. The first author has worked on the design of cantilevers and the second author has worked on the fabrication technologies and the third author has worked on mathematical works on the cantilever.

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Dr. K. Durga Aparna has completed her Ph.D from Andhra University under DST women scientist scheme. Her area of research is in MEMS. She has attended Hands on training workshop her in IIT BOMBAY. She has attended many workshops and trainings in various institutions and published papers in various research journals. She has 13 years of teaching experience in Department of Electronics, Instrumentation, Physics and currently she working as a Lecturer in Department of Electronics and Physics in PRISM Degree College, Visakhapatnam.

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