MEMS based Force Sensor for structural mechanics Interpretation in Micro devices

S. Praveen Kumar[1], T. Aravind[1], Karman Frances Raj George Maria Selvam[3], Prudhviraj Kuncha[2], Mahiz Mathi P[1*]

[1]Department of Electronics and Communication Engineering, Saveetha Engineering College, Chennai, India.
[2]IBM, Hyderabad, India.
[3]Department of ETIT, Technische Universitat, Chemnitz, Germany.
***Corresponding author: E-Mail: mahizmathi.p@gmail.com**

ABSTRACT

A novel MEMS based piezoelectric force sensor system is proposed in this article to detect the mechanical impact generated out of the particular system. The force sensor systems are implanted to have a continuous monitoring of the device and to analyses the basic mechanical factors like fatigue analyses, stress, strain, and displacements. The force sensor apart from the monitoring of device also helps to predict the load stability of the system which is presented in this article with Yield point criteria analyses. The sensor system proposed is composed of Lead titanium Zircon ate material of Grade 2. These continuous monitoring is carried out with respect to the generated potential out of the piezo-electric devices. The entire structural and potential simulation carried out with COMSOL Multi-physics Software.

KEY WORDS: Piezoelectric Force Sensor System, COMSOL multi-physics software, Grade 2 Lead titanium zirconate.

1. INTRODUCTION

MEMS based force Sensor Systems plays a crucial role in various fields, and these sensors are designed for actuators and Sensors having mechanical output, and this system are used to ensure the proper working of actuator systems and load with standing stability. In this article, the force sensor system is proposed to present a load stability analyses for a conventional Cantilever beam which is used for a bio medical Analyses. Force Sensor systems are conventionally used to analyses the Mechanical actuators like grippers, and devices undergoing higher order of resonance, where the output potential is used as a measure value which when exceeding the threshold value, then the device's resonance will be reduced to maintain the stability. The MEMS based Sensor device's proposed are usually devised with Silicon and Silicon Derivative materials. To construct the MEMS devices, the silicon materials are mostly used in the form of crystalline and polycrystalline nature. The silicon derivative materials are also used to devise the MEMS device which is obtained by mixing the silicon with oxide and nitride materials. Based on the target applications the materials selections also diversified into polymer, alloys, composites (Liu, 2007), diamond (Xiangwei, 2004), and ceramics (Fonseca, 2002) for device fabrication but the cost of material is still relatively high when compared to piezoelectric material. The system undergoing mechanical stress and strain factors will be expected to undergo a deformation state, and so a Yield point analyses is presented in this article for a Bio medical sensor system which is used to analyze the stability concern of the system. The yield point criteria graphical plot is used to analyses the entire mechanicals response for the system irrespective of the input forms like thermal, electrical pulse or a direct mechanical reflex. The Yield Point analyses presented clearly displays the actuation point of the system, a linear response region of the system; region of collapse and a region of catastrophe. Apart from the Conventional Silicon and Pyrex Substrate, a LTCC and HTCC also used in the substrate definitions. The LTCC and HTCC materials are used where the Thermo pneumatic actuations or radiations impact is observed. The sensor system proposed in this article is a mobile one which can be equipped in the target systems whenever it is necessary.

2. EXPERIMENTAL SETUP

The proposed experimental setup is also a cantilever setup which is implanted in the testing system when required. The testing system consists of an array of cantilever beam devised with a Piezo-electric material is shown in Figure.1.

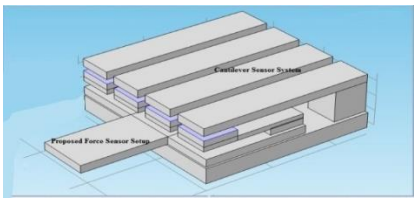


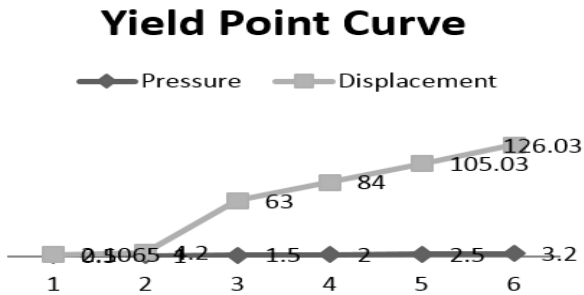
Figure.1. Setup of Target Cantilever Setup and Proposed Force Sensor Setup

The entire device setup of the system along with target bio medical cantilever setup also proposed here. The proposed cantilever force sensing system is devised with a piezoelectric material of Lead Titanium Zircon ate of grade 2.

Intellifab Analyses: The entire sensor setup fabrication is virtually carried out with Intellisuite fab solver, the silicon substrate is used, with silicon nitride anchors are used for the beam suspension. The PZT material of 2 Grade is used for the Beam fabrication, the Virtual fabrication flow of the cantilever is as follows, the device modeling follows with basic process of substrate definition, Deposition of materials, patterning process followed by etching and Boding technique to ensure a proper packaging, the virtual fabrication process carried out in the Intellifab is as follows, the Silicon material of orientation 100 is used as a substrate, followed by substrate definition silicon nitride is deposited as a anchor material where Low Pressure Chemical Vapor Deposition (LPCVD) method is used where Dichloro Silane material is used as Liquid state Precursor. The Photoresist material AZ5214 is used which has got a wall sloping profile of approximately 70 – 80%, which is deposited with Spin Coat mechanism.

Stress Strain Modeling: The Stress originated in the end point of beam propagates in Uniaxial direction pattern and the maximum strain observed in the point of suspension, from where the entire beam is suspended freely and maximum stress is observed when the beam experience the continual Resonance of vibration. The each cantilever beam subjected to vibrations will undergo modes of Resonance Cycle. The load applied in the tip of the cantilever beam where the load distribution will be in the negative Z axial point, stress propagation due to applied load will be propagating in the X, Y and even in its counter axial directions. The stress observed in the Hinge of the beam is given by $\sigma = \rho l/h$.

The stress strain curve is a direct response of the beam extracted for various load conditions. The curve of stress and strain in the system as follows.



Plot.1. Stress Strain Graph Analyses

a. The true Elastic limit for any mechanical system is the point where it begins to respond due to applied load\Pressure, where for the proposed system with this aspect ratio the system begins to respond for a applied pressure of about 0.25pa.

b. The Proportionality limit for the system is the point till then the stress strain response is a linear one and the proportionality point for the system is exhibited at 1pa.

c. The Elastic limit is the point in the stress strain graph where the system undergoes a recoverable stress due to applied load, and the in this region the device response need not be a linear one and the maximum Point of Elasticity is for a applied pressure of 1pa to 1.5pa.

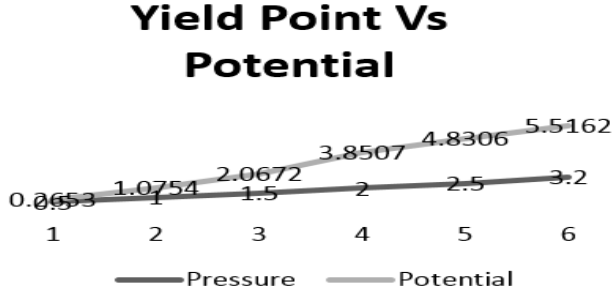
d. Elastic point to Yield point region, where the phenomenon of plasticity is observed end in structural mechanics the beam undergoes a non-recoverable displacement and the region of plasticity is between 1.5pa to 2, 2.25pa.

e. The region above the Yield point is defined to be a region of Catastrophe region where the system or beam in structural mechanics once attained this region the system will undergo complete structural Deformation, i.e. above the point of 2.5pa.

Stress Distribution: The stress exhibited in the cantilever beam is given by the integral form of $ds = \int_0^{Z0} wl$.

Where integral limit ranging from 0 to Z_0, which Z_0 be the maximum displacement achieved by the cantilever beam during resonance and Lower limit function cannot be less than 0 since distance and displacement factors cannot be in Negative form. Area of stress propagation is given by the General Area formulae for applied limit.

Potential Analyses: The yield point analyses with respect to potential response are shown in the plot 2. Where the entire device stability is analyzed with the potential output which acts as a sensor system.



Plot.2. Pressure Vs Potential Analyses

3. RESULTS

Simulation Analyses: The Simulation of the Force sensor setup of Potential estimation generated out of beam during vibrations and stress profile analyses and strain, displacement analyses are carried out in COMSOL Multi-physics Simulation Software, the Stress analyses of the beams due to the applied pressure of 1 Pascal's is simulated and analyzed as shown, the maximum displacement of about 2.609µmis experienced by the sensor setup due to the structural impact. The maximum stress withstander by the beam is directly proportional to the load exhibited by the target system which includes self-added tip mass, Material Density and the stress which is formulated by the,

$$\sigma h = \frac{(Load+Mt)*Material\ Density\ \rho}{Aspect\ Ratio}.$$

Where σh represents the Stress exhibited on Hinges, Load be applied load and self-added weight because of tip mass (m_t),

Potential Analyses for PZT 2grade material is simulated, and a range of potential has be generated for the applied Pressure of 1pa under different Eigen frequency a range of values have been extracted as shown.

Table.1 Potential Output in Eigen Frequency condition

Frequency	Potential	Frequency	Potential	Frequency	Potential
12.639	5.5162 V	12.657	3.8507 V	14.18	1.0756 V
12.657	4.8307 V	12.659	2.6071 V	14.26	0.2615

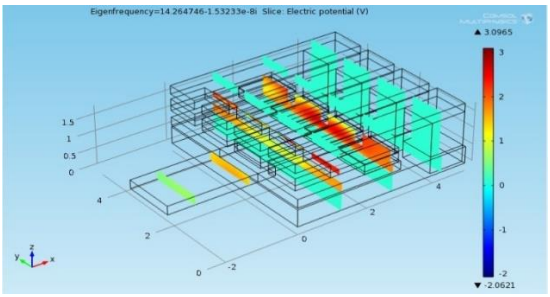


Figure.2. Potential Distribution Profile, Maximum potential of 5.516v generated for 3.2pa pressure

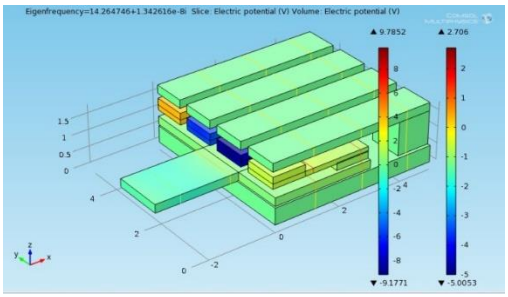
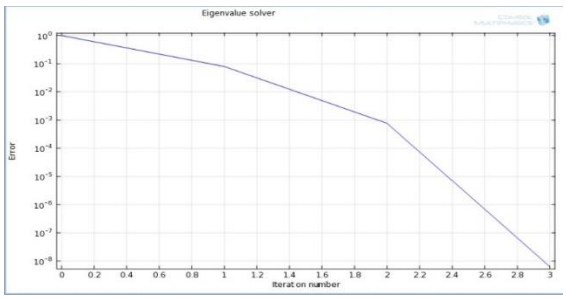


Figure.3. Potential Distribution Profile, Maximum potential of 5.516v generated for 3.2pa pressure

Graphical Analyses: Graphical analyses of the force sensor system extracted out are as shown, where the graph shows the applied pressure Vs system response over a period of time. The time as it progresses the applied pressure increases the device begin to attain the threshold level starting to lose its stability ad begin to attain structural Deformation.



Plot.3. Implanted Pressure VS System Response

4. CONCLUSION

A potential is generated out of the individual beams made of PZT material of Grade 2. The Degree of freedom is observed more in the structure, which results in the maximum displacement, and vibrations which contribute maximum power generated out of the individual beams. The Yield point graph analysis is carried out where the device's True E Limit and Catastrophic points are analyzed. The beam designed can with stand up to a pressure of about 0.9Mpa pressure, and system attains the region of catastrophe above the pressure of about 3.2 pa since it undergoes structural deformations.

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