Design Of Cantilever MEMS Switch

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***Abstract*-This paper deals with the Piezo-electric MEMS (Micro-Electro-Mechanical-System) sensor model which acts as an energy harvester based on vibrations. Vibration energy harvesting has been employed for converting ample amount of kinetic energy into electric energy by several different transduction methods. Among many harvesting transducers, the piezoelectric energy harvester (PEH) is compatible with MEMS technology and has high electromechanical coupling effects and requires no external voltage source and has been accordingly in most of the recent research. It provides a green and practically infinite alternative power source to conventional energy sources, this harvester will significantly explore the applications of wireless sensor networks, biomedical implants etc., which may generate mW or µW level of power. The simplicity associated with piezoelectric micro-sensors make them very attractive for MEMS applications in which ambient vibrations are harvested and converted into electric energy. These micro shaped-generators can become an alternative to the battery-based solutions in the future.**

***Keywords*- Piezoelectric material, MEMS, Piezoelectric energy harvester.**

I. INTRODUCTION

Micro-Electro-Mechanical-System (MEMS) is a technology in its most general form can be called as miniaturized as mechanical and electro-mechanical system. It can be made using a technique of micro fabrication. The physical dimension of MEMS device can vary well below from one micron on the lower end of the dimensional spectrum. Likewise the types of MEMS device can vary from relatively simple structures having no moving elements to extremely complex electromechanical system with multiple moving elements under the control of integrated microelectronics. The main criterion of MEMS is that there are at least some elements having some sort of mechanical functionality whether or not these elements can move. The term used to define MEMS varies worldwide. In the United States it is predominantly called as MEMS. While in some other parts of the world it is called as “Microsystems Technology” or “Micro machined devices”.

A. *The functional unit of MEMS are*

1. Miniaturized Structure
2. Sensors
3. Actuators
4. Microelectronics

B. *Sensors and Actuators:*

Micro sensors and micro actuators are appropriately categorized as “Transducers”, which is defined as device that converts one form of energy into other. In the case of micro sensors, the device typically converts a measured mechanical signal into an electrical signal.

Over the past several decades MEMS researchers and developers have demonstrated an extremely large number of micro sensors for almost every possible sensing modality including temperature, pressure, inertial forces, chemical spices, and magnetic fields, radiation, etc. Remarkably, many of these micro machined sensors have demonstrated performances exceeding those of their micro scale counterparts.

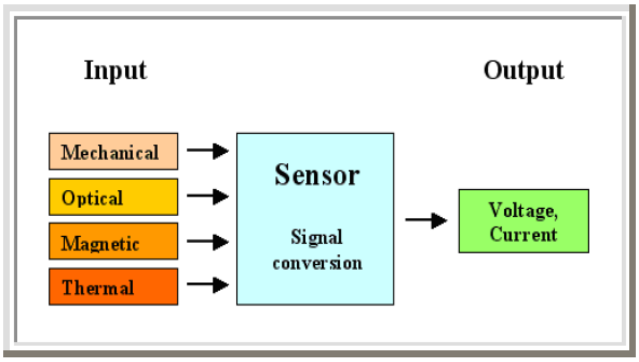

Fig. 1.1 Block diagram of MEMS

C. Piezo-MEMS:

The world piezoelectricity means electricity resulting from pressure. The flexibility associated with piezoelectric material makes them very attractive for power harvesting. Piezoelectric materials posses a large amount of mechanical energy that can be converted into electric energy, and they can withstand large strain magnitude. Piezo MEMS are Micro Electro Mechanical Systems with piezo as active component. When these miniaturized devices are coupled with IC (integrated circuit) components they are able to interact with the environment or other on-chip parts. The piezo MEMS sensor or actuators are widely used in industry in electro mechanic, optoelectronic or micro-fluidic systems.

D. Cantilever Beam:

Basically MEMS cantilever sensor relies on mechanical deformation of the structure or in other words the deflection of membrane or beam structure. When the cantilever is loaded its stress element deforms. The MEMS Cantilever will bend. As this deformation occurs, the structure changes shape and points on the structure displace. The concept is that deflection occurs when a disturbance or loading is applied to the cantilever in free end or along the MEMS cantilever surface. Normally the disturbance or loading is a force or mass that is attached to the MEMS cantilever in which it will make the MEMS cantilever bending. As the MEMS cantilever deflects, the resulted deformation is termed bending. External applied loads which cause bending will result in reactions at the free end, consisting of displacement or deflection ∂max

$$\partial \text{max} \;=\frac{Fl^3}{3EI}$$

Where ∂max is the maximum deflection, F is force applied, l is the cantilever length, E is the Young's Modulus for the cantilever material which in this research is silicon and I is the moment inertia for the cantilever.

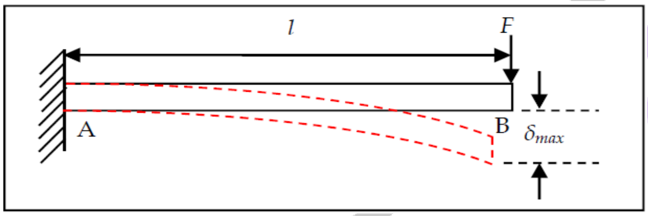

Figure 1.2 Schematic of MEMS cantilever deflection.

In the meanwhile, the cantilever will also sense stress that occurred during deflection. There are two type of stress occurred: tensile and compressive stress where tensile occurs at the top of cantilever and compression acts at the bottom of cantilever. Since the piezo-resistors are located at the top surface, research will be focuses at top surface of the cantilever.

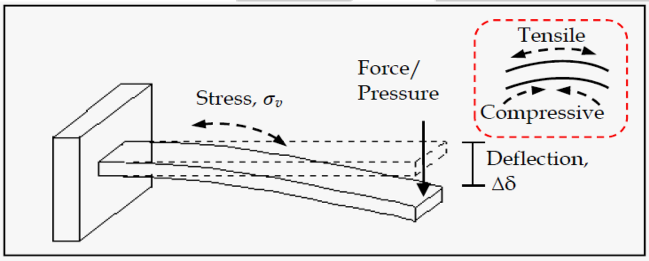

Fig. 1.3 Stress occurred during force applied

Maximum stress can be calculated using equation for a constant cross section beam.

$$\sigma\text{max}=\frac{6\text{Fl}}{\text{bh}^2}$$

Where F is force applied on cantilever, l is cantilever length, σmax is the maximum stress, h is the height from the centre axis to the top surface of the cantilever, b is width of cantilever and I is moment of inertia.

E. Piezo-MEMS sensor structure:

In general a sensor structure contains a base layer on which a device is mounted. The dielectric layer is imposed on the base and over which the anchor is placed. This anchor supports the cantilever beam which is mounted over it. Below the cantilever ground layer is deposited. At the top of the beam the terminal is taken out, from which the output is drawn. The device configuration is decided from different papers and predefined structure in Comsol.

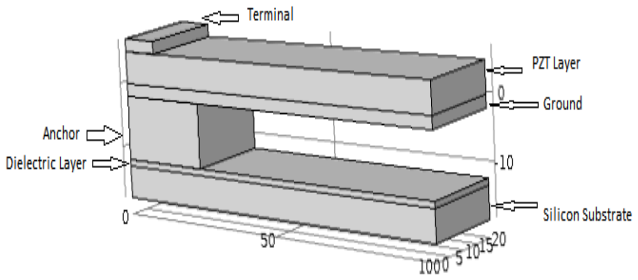

Fig.1.4 Diagram of MEMS Structure

F. Sensitivity of cantilever:

Sensitivity of cantilever is nothing but how fast it reacts and how much deformation is occurring after application of load. The sensitivity of micro cantilever piezo sensor decreases as the concentration of analysts decreases. So in order to produce measurable result of cantilever (displacement) analysts require will be more.

G. Energy Harvesting:

Mechanical compression or tension on a poled piezoelectric ceramic element changes the dipole movement, creating a voltage. Compression along the direction of polarization or tension perpendicular to the direction of polarization generates voltage.

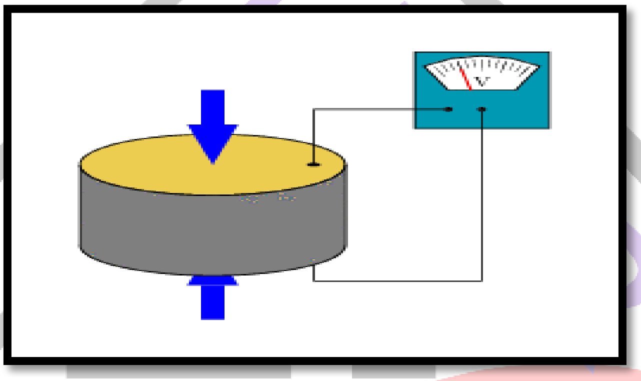

Fig. 1.5

There are two ways to Harvest Energy with Piezoelectric material, piezoelectric material generates energy when it is stressed and strained. This primary mechanical stress generates a voltage and current pulse, the product of which is power (Watts). There are two technologies reviewed in this report that harvest energy in two different ways, but both rely on stressing a piezoelectric element. In the first case, a stack of piezoelectric materials is compressed to generate energy and a pulse of power is registered with each compression cycle (such as the passage of a vehicle tire over the stack). The second case is based on what can be simplified and inferred from product. The energy harvesting mechanism appears to be an array of cantilever or bent beam piezoelectric energy harvesters. The power profile continues to generate power for a longer duration as the vibrations decay. An array of many devices within a small volume leads to higher energy or power density.

II. LITURATURE SURVEY

Highest power can be generated using this configuration under lower excitation frequencies and load resistance.Energy harvesting from mechanical vibrations using piezoelectric cantilever beam, smart structures and materials. [1]

Literature [2] proposed that combination of bimorph structures is possible, series and parallel types. Series and parallel triple layer bimorph structures were presented by Ng and Liao.

The series triple layer bimorph is made up of metallic layer sandwich between two piezoelectric materials and piezoelectric patches are electrically connected in series.

The parallel triple layer bimorph is also sandwich between two piezoelectric materials. The piezoelectric material is connected in parallel. The parallel triple-layer bimorph generates the highest power under medium excited frequencies and load resistance under this topic.

“Feasibility study of a self powered piezoelectric sensor”.

Literature [3] proposed that bimorph cantilever with a proof mask attached to its tip. Their result shows that reducing the bimorph thickness and increasing the attached proof mass decreases the harvester’s frequency and produced maximum harvested power, under this topic.
“Performance of piezoelectric bimorph for scavenging vibration energy”.

Literature [4] proposed that by varying length and width of proof mass affects the output of harvested power, under this topic.
“A vibration energy harvesting sensor platform for increased industrial efficiency”.

Literature [5] proposed that the geometric structure of cantilever also plays a vital role in improving harvester’s efficiency. Rectangular shaped cantilever structure are most commonly used in MEMS based piezoelectric harvesters. They are easy to implement and effective in harvesting energy from ambient vibrations, under this topic.
“A review of vibration based MEMS piezoelectric energy harvesters”.

III. CONCLUSION

The maximum power is produced at the loads below the open circuit limits. The base acceleration amplitude will affect the power limitations of the harvesters. The analyzer prediction is 0.25 mW across the load of 5KΩ. Thus by increasing the cantilever branches will increase the frequency band of the harvesters, but causes more difficulties in MEMS fabrication process. Hence by achieving impedance matching in between the structure, control can be very simple and requires low power with low frequency with more output as specified above.

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