# Comparative Analysis Of MEMS Piezoelectric Energy Harvesters Capacitive Pressure Sensor Based On The Mechanical Vibrations Using Different Materials

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***Abstract- MEMS plays a vital role in manufacturing several electronic devices.It has a wide application in electronics manufacturing field.The fabrication of MEMS is very popular because of its miniature size,capacity power,sensitivity,etc. MEMS fabrication is possible even at high resonant frequency devices which can be operated at regular frequencies and greater bandwidths.Simulation is done using COMSOL multiphysics software.A surface capacitive pressure sensor has been simulated using different materials.The capacitance is analysed and the graphs are plotted.***

***Keywords: MEMS,Capacitive Pressure sensor,sensitivity,micromachined accelerometer,,Fabrication***

## 1. INTRODUCTION

Micro-Electro-Mechanical Systems, or MEMS, is a technology that in its most general form can be defined as miniaturized mechanical[1] and electro-mechanical elements (i.e., devices and structures) that are made using the techniques of microfabrication. The critical physical dimensions of MEMS devices can vary from well below one micron on the lower end of the dimensional spectrum, all the way to several millimeters. Likewise, the types of MEMS devices can vary from relatively simple structures having no moving elements, to extremely complex electromechanical systems with multiple moving elements under the control of integrated microelectronics[2,3]. The one 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 in different parts of the world. In the United States they are predominantly called MEMS, while in some other parts of the world they are called “Microsystems Technology” or “micromachined devices”.

Over the past several decades MEMS[4,5] researchers and developers have demonstrated an extremely large number of microsensors for almost every possible sensing modality including temperature, pressure, inertial forces, chemical species, magnetic fields, radiation, etc. Remarkably, many of these micromachined sensors have demonstrated performances exceeding those of their macroscale counterparts. That is, the micromachined version of, for example, a pressure transducer, usually outperforms a pressure[6,7] sensor made using the most precise macroscale level machining techniques. Not only is the performance of MEMS devices exceptional, but their method of production leverages the same batch fabrication techniques used in the integrated circuit industry – which can translate into low per-device production costs, as well as many other benefits. Consequently, it is possible to not only achieve stellar device[8,9,10] performance, but to do so at a relatively low cost level. Not surprisingly, silicon based discrete microsensors were quickly commercially exploited and the markets for these devices continue to grow at a rapid rate.

More recently, the MEMS research and development community has demonstrated a number of microactuators including: microvalves for control of gas and liquid flows; optical switches and mirrors to redirect or modulate light beams; independently controlled micromirror arrays for displays, microresonators[11,12] for a number of different applications, micropumps to develop positive fluid pressures, microflaps to modulate airstreams on airfoils, as well as many others. Surprisingly, even though these microactuators are extremely small, they frequently can cause effects at the macroscale level; that is, these tiny actuators can perform mechanical feats far larger[13,14] than their size would imply. For example, researchers have placed small microactuators on the leading edge of airfoils of an aircraft and have been able to steer the aircraft using only these microminiaturized devices.

Microelectromechanical sensors are micro-scale devices that enable the operation of complex systems by converting physical stimuli from the mechanical, thermal, chemical and optical domains to the electrical domain. MEMS[15,16] engineers engage technologies across a wide set of scientific disciplines including physics, chemistry, material science, integrated circuit fabrication and manufacturing. As a result of its inter disciplinary nature, MEMS technology has found use in many industries, especially automotive, medical and aerospace. Research institutions and industries have made relentless effort in the past decades in developing smaller and better microelectromechanical devices and components. MEMS and microsensor products have become increasingly dominant in every aspect of commercial[17,18]l marketplace as the technologies for microfabrication and miniaturization continue to be developed.

## 2. EXISTING SYSTEM

Microsensors are the widely used MEMS device today. MEMS is a technology that considers micro fabrication of microscale devices on semiconductor chips. MEMS devices can replace bulky actuators and sensors with microscale devices that can be produced using integrated circuit photolithography. MEMS are made up of components between 1 to 100 micrometers in size (i.e. 0.001 to 0.1 mm) and MEMS devices are available in size from 20 micrometers to a millimeter. The need for miniaturization has become more prominent than ever, as engineering systems and devices have become more and more complex and sophisticated. Miniaturization is the only way to have new and competitive engineering systems performing multifunctions with manageable size.

The miniaturized systems have better response time, faster analysis and diagnosis, good statistical results, improved automation possibilities with reduced risk and costs. The sensors are built to sense the existence and intensity of certain physical parameters and are primarily employed to observe the temporal effects of the environment. MEMS device is composed of two main groups of functional systems - active and passive systems. Active[19] components are the important functional blocks that produce a measurable response to a change in some physical properties of the environment. Passive systems are those which when interfaced with the active system contribute a full-fledged MEMS device[20].

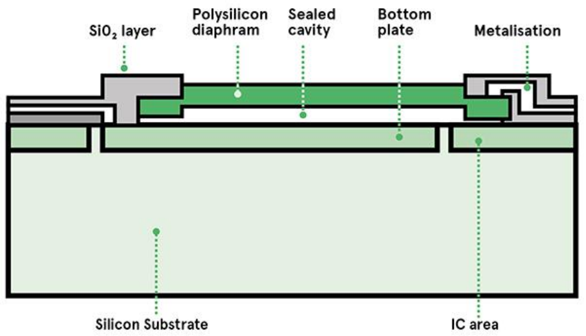


Figure 1: Capacitive Pressure sensor

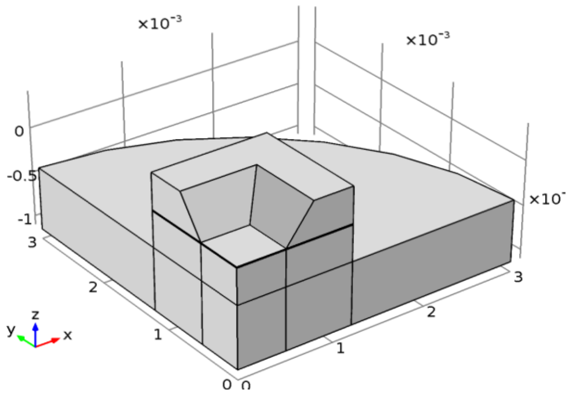

Figure: 2 LEAD ZIRCONATE TITANATE PZT-5

## 3. EXPERIMENTAL ANALYSIS

Microsensors are the widely used MEMS device today. MEMS is a technology that considers micro fabrication of microscale devices on semiconductor chips. MEMS devices can replace bulky actuators and sensors with microscale devices that can be produced using integrated circuit photolithography. MEMS are made up of components between 1 to 100 micrometers in size (i.e. 0.001 to 0.1 mm) and MEMS devices are available in size from 20 micrometers to a millimeter. The need for miniaturization has become more prominent than ever, as engineering systems and devices have become more and more complex and sophisticated. Miniaturization is the only way to have new and competitive engineering systems performing multifunctions with manageable size.

Table 1: Different materials and their properties

| S.no | Material used | Poisson's ratio(1) | Coefficient of thermal expansion(1/K) | Youngs Modulus (GPA) | Density(Kg/m$^3$) |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| 1. | Silicon | 0.06 | 2.6e-6 | 170[GPa] | 2330 |
| 2. | Steel AISI 4340 | 0.28 | 12.3e-6 | 205e9 | 7850 |
| 3 | Zno | 0.075 | 8.5 | 210 | 5680 |
| 4. | Lead Zirconate titanate(PZT-5J) | 0.62 | 1641 | 48-135 | 7400 |
| 5 | Lithium Niobate | | 43.6 | 245 | 4700 |
| 6 | Barium Titanate | 0.35 | 1976 | 67 | 6020 |
| 7 | Ammonium Dihydrogen Phosphate | 0.33 | 55.9 | 67.3 | 1803 |

The various materilas are analysed for the pressure sensor behavior.The materials used for analysis are silicon,steel ,Zno, Lead Zirconate titanate(PZT-5J), Lithium Niobate, Barium Titanate , Ammonium Dihydrogen Phosphate.The properties of these materials are taken into account and an analysis is performed for various behavior for displacement. The displacement is calculated using the formula

$$\nabla_m \cdot (\epsilon_{0,vac}(\epsilon_r - \mathbf{I})\mathbf{E}_m) = \rho_v$$
$$\nabla_s \cdot (\epsilon_{0,vac}\mathbf{E}) = 0$$
$$\mathbf{E}_m = -\nabla_m V$$
$$\mathbf{E} = -\nabla_s V$$

The electric potential is also calculated using the formiula which is given as follows:

$$\nabla_m \cdot (\epsilon_{0,vac}(\epsilon_r - \mathbf{I})\mathbf{E}_m) = \rho_v$$
$$\nabla_s \cdot (\epsilon_{0,vac}\mathbf{E}) = 0$$
$$\mathbf{E}_m = -\nabla_m V$$
$$\mathbf{E} = -\nabla_s V$$

## 4. RESULTS AND DISCUSSIONS

The relationship between diaphragm displacement and capacitance ia analysed.The pressure and capacitance has been calculated and plotted graphically.The graphs are plotted for various parameters and the capacitance is observed.

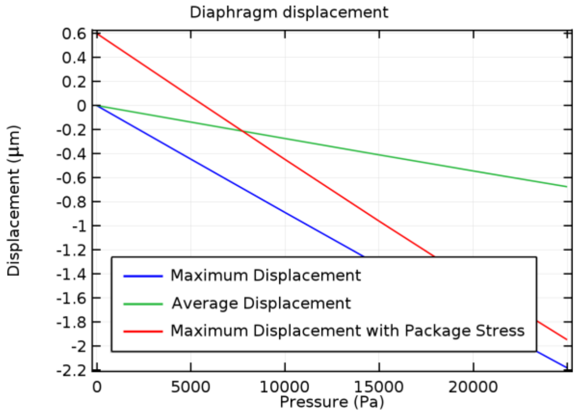


Figure 3:Pressure Vs Displacement

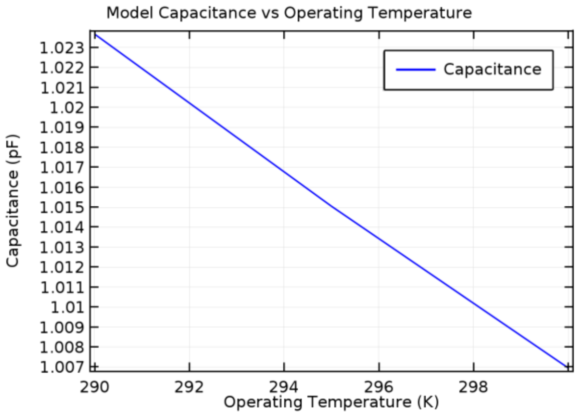


Figure 4: Temperature Vs Capacitance

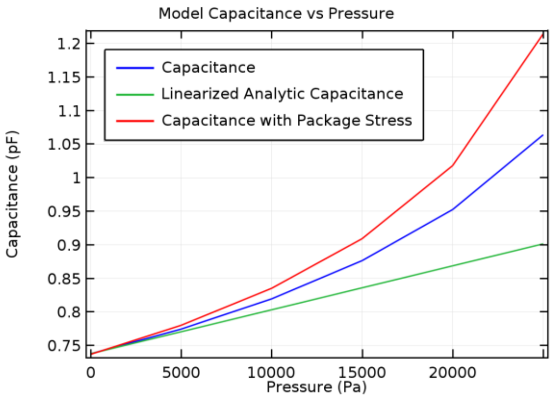


Figure 5: Pressure Vs Capacitance

## 5. CONCLUSION

This research work focuses on the simulation analysis and charac-terization of seven different piezoelectric materials embedded upon a cantilever beam energy harvester of a specified dimension. Max-imum pressure is exerted upon all materials upon any force exerted. Lithium Zirconate Titanate produces more surface potential and also it exhibits high dielectric property and due to this reason they are used as capacitors in storing the devel-oped charge. The capacitance is observed for all the materials and it has been plotted for the materials and their bejaviour is analysed..

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