Design of flexible Substrate based energy harvester for sensor nodes

Neha S Kadam¹, Prof. Suyog.S. Hirve²
1,² Department of Electrical Engineering, BVDUCOE, Pune, India
¹nehakadam1194@rediffmail.com, ²sshirve@bvucoep.edu.in

June 8, 2018

Abstract

"Energy saved is energy produced" this quote holds true in present day scenario of energy crisis. The potential is there to save the energy but it needs a dedicated approach and effective planning. Advent of Nano technology and advancement of material science one such potential area of energy saving is the wireless sensor network. Some materials exhibit the properties of piezoelectricity which is the charge that is collected in certain solid material in response to a given mechanical tension. A piezoelectric material generates visible piezoelectric energy when there uniform structure is deformed by about 0.2% of the original structure. The presented work tries to harness this property of piezoelectric material and analyzing the performance of piezoelectric energy harvester. The piezoelectric material which is used in the work is zinc oxide (ZnO), Copper (Cu) is used as electrode material which captures the charge generated & polyethylene terephthalate (PET) is used for cantilever structure. Two types of cantilever structure are studied in the work namely uni-morph & Bi-morph respectively. Eigen frequency analysis is done to get the resonance frequency for proposed energy harvester by using Comsol multi physics software. Comsol multi physics model is used to provide the readings on the Eigen frequency, resonance frequency,
tension and voltage output of all energy harvester based on piezoelectricity. The results were formulated in form of graph for clear understanding of effects of various parameters.

**Key Words:** Piezoelectric, Eigen frequency, Resonance Frequency, Cantilevers

1 INTRODUCTION

The human civilization is obsessed with the future prediction. Efforts have been implemented to predict a happening in its most accurate way. A simple example is the prediction of rainfall and its impact on agriculture. A prediction depends on the accuracy and interconnection of data. Wireless sensor networks measure environmental condition like temperature, sound, pollution level etc. Remote Sensor Network are an rising technology with lots of potential applications and opportunities. A significant amount of nodes with sensing and wireless communications capabilities, deployed in an area of interest, build a wireless sensor network. With the advent of Micro Electronics Mechanical Systems there is now possibility to realize tiny and cost effective devices, capable of wireless communication [10]. WSNs can be differentiated from other technologies because of a set of distinct requirements and unique feature, including for density, energy requirements, and computational capabilities. A renowned engineering body has classified the network technologies by characteristics. Usually the WSNs are has a data limit of 2Mbps of data rate and 1.5 km of wireless coverage. When it comes application part of wireless sensor networks 4 broad areas are covered by these networks namely area surveillance, health care, atmospheric sensing & industrial monitoring.

All wireless sensor networks primarily run on batteries. Batteries have a limited life cycle and other technological constraints. In wireless sensor networks (WSNs), demand of distinct applications and modest energy storage efficiency of sensor nodes makes it obligatory to increase sensor lifetime, circuit and protocols has to be energy efficient strategy has to be implemented. Energy harvesting from environmental vibrations provides a great solution for powering the energy to small-scale electronic devices. The presented work demonstrates the piezoelectric efficiency of some metal
substrate that can be used as source of harvesting energy for remote sensor networks. It is a process of converting environmental vibrational energy into electrical energy. The idea is to keep these metal substrate flexible so that they can be used in any environment and to adjust in extreme condition. Piezoelectricity as an electric charge that is collected in certain solid materials. For the presented work Zinc Oxide (ZnO) is used as piezoelectric material, Copper (Cu) act as a electrode which store the charge, polyethylene terephthalate is used as cantilever structure. The frequency domain analysis study is used to enumerate the reaction of a linear or liberalized model subjected to harmonic excitation for one or several frequencies. energy harvester simulation has been done in COMSOL Multiphysics tool. Analysis of frequency is conducted within the restricted condition to achieve the resonance frequency for proposed energy harvester.

Cantilever design is commonly used piezoelectric energy harvesters, in particular for vibrational forces, as greater mechanical tension can be produced, and construction of piezoelectric cantilevers is relatively easy [4]. A greater number of the piezoelectric energy devices used for harvesting uses a uni-morph or bi-imorph cantilever design. In the presented work simulation of Uni-morph and Bi-morph structure is made in COMSOL Multiphysics model. The PET (polyethylene terephthalate) is used as cantilever which creates the mechanical stress due to vibration and when the mechanical stress is provided through vibration in cantilever structure, zinc oxide the piezoelectric material generates electric charge in the process which is stored in copper electrodes.

2 Comparison and Results

Unimorph Piezoelectric Energy Harvester

![Unimorph Cantilever](image)

Fig.1. Unimorph Cantilever

A lean piezoelectric structure can be constructed into a cantilever, fixing it with a non-piezoelectric layer usually a metal act-
ing as a conductor of the generated charge. Such a configuration is called a "unimorph" as only one active layer the piezoelectric layer is used in this structure.

Fig.2. Electric Potential with maximum value of 2.4 V for uni-morph structure

For a uni-morph structure electric potential of 2.4 V was observed at resonance frequency 100 Hz.

Since we are using cantilevers for our demonstration von mises stress test was conducted to check whether cantilever will withstand for given load condition.

Fig.3. Total Displacement with Frequency

As in fig.3. shows total displacement 600 m was observed at a resonance frequency 100 Hz. On the tip of cantilever we obtained maximum displacement.

Fig.4. Von Mises graph for Uni-Morph structure
For PET material yield stress value is 5 Mpa against maximum value Von Mises Stress is of 4.5 Mpa.

A cantilever can also be made by creating two lean layers of piezoelectric structure into the same metal layer to increase the power output of the unit, it is called a bimorph structure as two active layers are used. Bi-morph structure possesses the capability of increasing the output of the energy harvester in spite of any considerable rise in the device volume.

As in fig.7 shows total displacement 600 um was observed at a resonance frequency 100 Hz. On the tip of cantilever we obtained maximum displacement.
For PET material yield stress value is 1.6 Mpa against maximum value Von Mises Stress is of 1.4 Mpa.

The metal substrate are used as cantilevers in the presented work. Two types of structure was used in the presented work namely uni-morph and Bi-morph. In uni-morph structure one layer of substrate was piezoelectric layer and the other one was a non-piezoelectric layer while in case of Bi-Morph structure the metallic layer is sandwiched between two piezoelectric layers.

Table 1. Material Property

<table>
<thead>
<tr>
<th>Property</th>
<th>ZnO</th>
<th>Ca</th>
<th>PET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (g/cm³)</td>
<td>6.2</td>
<td>5.6</td>
<td>1.18</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td>6200</td>
<td>5600</td>
<td>900</td>
</tr>
<tr>
<td>Poisson’s Ratio</td>
<td>0.3</td>
<td>0.46</td>
<td>0.37</td>
</tr>
</tbody>
</table>

The piezoelectric material have defined parameters. stress $T_p$ as input, the strain coefficient $d_{ip}$ gives the relationship between the applied stress and the electric induction $D_i$ (therefore, current density is $j_p = dD/dt$), while the voltage coefficient $g_{ip}$ gives the voltage

$$V = T_p g_{ip}$$

Table 2. Number of layers per electric potential

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Uni-Morph</th>
<th>Bi-Morph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Potential</td>
<td>2.4 V</td>
<td>3.6 V</td>
</tr>
<tr>
<td>No. of layers</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

The comparison for uni-morph and bi-morph structure is presented in form of graph.

Fig 9. Frequency vs. Electric Potential comparison
3 Conclusion

Energy harvesting systems based on piezoelectric concept provides excellent solution of renewable source of power to supplement traditional batteries in sensor nodes. The great potential of remote sensor node has created a demand for harvesting energy from the surrounding environment for wireless devices. Wireless remote monitoring of mechanical structures and biomedical sensors are such energy harvesting applications where piezoelectric energy can be used. Energy harvesting through piezoelectric technique has provided a greater advantage over other techniques: Excellence power density and amenity of applications and efficiency to construct the piezoelectric material in order to capture the vibrating energy into distinct scales.

Acknowledgement The authors are thankful to Dr Gopal Gawande (hod_extc@ssgmce.ac.in) and Prof. M.I Bhaiyya (bhaiyya.manish@gmail.com) for their valuable suggestions in this presented work.

References


