Design & Simulation of Various Shapes of Cantilever Beam for Piezoelectric Power Generator

P. Graak [1], A. Gupta[1] S. Kaur [1], P. Chhabra[1], Dinesh Kumar[1], Arjun Shetty[2]

[1]Department of Electronics science, Kurukshetra University, Kurukshetra 136119
[2]Electrical Communication Engineering, Indian Institute of Science, Bangalore 560012
Email: priya.chhabra@kuk.ac.in

Abstract

Micro-electromechanical systems (MEMS) piezoelectric harvester provides alternative power sources. Energy harvesting is utilized in power generator with characteristics length of less then 1 mm and more then 1 micron. The cantilever geometries have been made using Structure mechanics module for generated power. The piezoelectric material (PZT-5H) with thickness of 0.5 µm and silicon as base material with thickness 1.5 µm is added to cantilever using piezoelectric devices module. Among various shapes like (E,pi,T) though which E shaped cantilever shows the greatest deflection of 0.6078 µm and the power as 49.05 µW, whereas the T and pi shaped cantilever gives less piezoelectric voltage.

Introduction

Energy harvesting utilizes ambient vibrations for micro and nano scale device which can be converted into electrical energy by piezoelectric energy transducer. Generated power can be used for various applications like sensors and storage devices. Energy harvester does not require an external energy source and compatible with MEMS technology. All piezoelectric materials shows piezoelectric effect which means that if material is strained then change in electric voltage will appear. Piezoelectric material shows high potential and high piezoelectric coefficient as compare to the other materials. It can be used as a power generator because these material have large power and ease of application. We proposed the various piezoelectric cantilever beams (E,pi,T) using the structural mechanics module in COMSOL Multiphysics to convert mechanical energy into electrical energy. The produced electrical energy can be used as a great power source for portable electronics. By changing the properties of various materials , the one with well defined outcomes at lower commercial values and easy availability is chosen [1].

Geometry

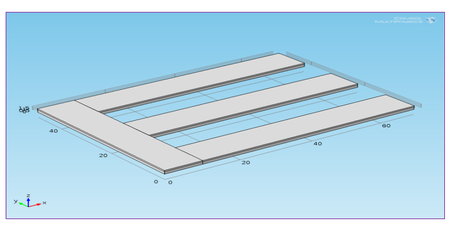
E shaped cantilever is a beam anchored at only one end having greater length as compare to its width and thickness. Very sensitive optical and capacitive methods have been used to measure static deflection in the cantilever beam. The movement of cantilever is effected by its length ,width, thickness and various properties used to make the structure. The cantilever end deflection can be calculated as:

$$\partial = \frac{3\sigma(1-v)L^2}{Et^2} \quad (1)$$

Where ‘ν’ is Poisson's ratio, ‘E’ is Young's modulus, ‘L’ is the beam length and ‘t’ is the cantilever thickness. The Cantilever spring Constant ‘k’ relates to the cantilever dimensions and material constants is given by [2]:

$$k = \frac{F}{\delta} = \frac{Ewt^3}{4L^3\,k} \quad (2)$$

The calculated power for power generator is given by eq. 3 where ‘P_{avg}’ is the average power generated and ‘v’ is the electric potential found via the simulation of the cantilever beams and ‘R_{load}’ is the resistive load or impedance[3].



$$P_{avg} = \frac{V^2}{R_{load}} \quad (3)$$

Fig 1. Geometry of E shaped cantilever

Model of Energy Harvesting System

Cantilever beam consists of two layers, base layer as silicon and upper layer is made up of PZT-5H material. The one end of the beam is fixed and another end is suspended freely. Interfacing circuit includes a transducer to convert produced vibrations into electrical energy. At the end a storage battery or a load circuit has been used in order to store the harvested energy [4].

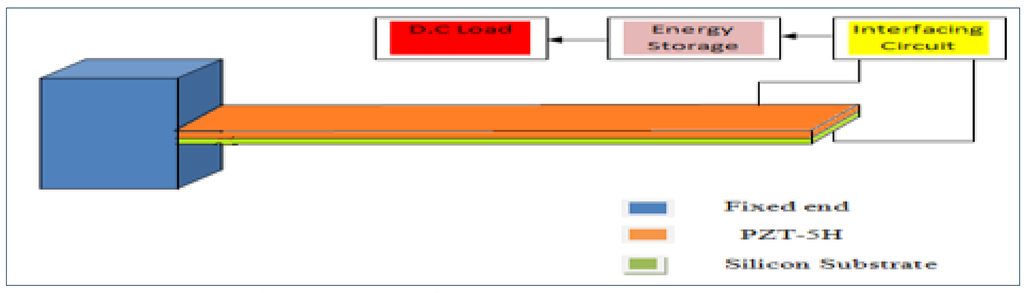


Fig 2. Model of Energy Harvesting system

Material properties

Table 1. Properties of materials used

Material Properties	PZT-5H	Silicon
Young’s modulus(GPa)	63	165
Density(kg/m$^{3)}$	7500	2330
Poisson Ratio	0.31	0.3

Table 2: Device Specifications

Layer	PZT-5H	Silicon
Length (um)	60	60
Width (um)	10	10
Thickness(um)	0.5	1.5

Design procedure

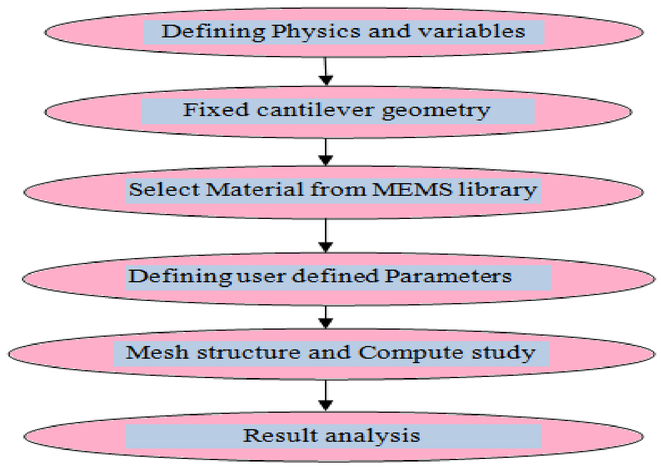


Fig 3. Flow Chart Process for designing the cantilever

Results & Conclusion

It has been observed that increase in deflection with a decrease in electric potential which leads to the increase in generated power. The E shape from the all other traditional geometries will have maximum displacement. The displacement and generated piezoelectric voltage and generated power of different geometries has been compared in Table 3. on the basis of simulated geometries in the Comsol Multiphysics.

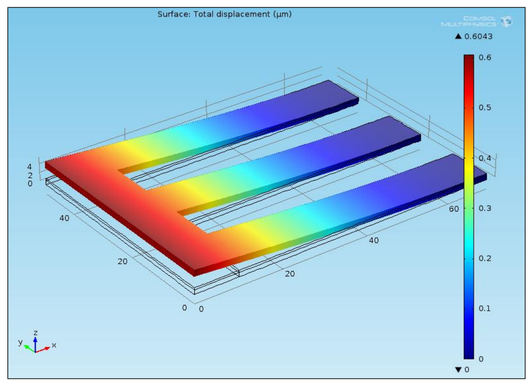


Fig 4. Displacement of E Shaped Cantilever

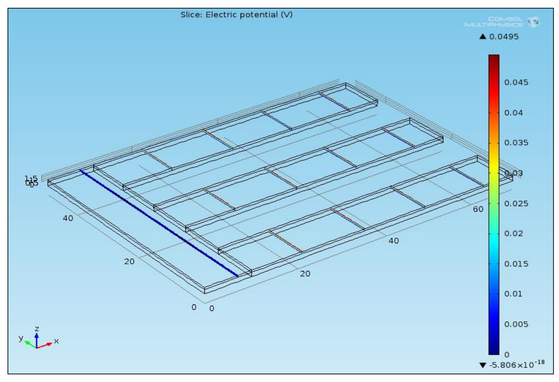


Fig 5. Generated piezoelectric voltage in E shaped Cantilever

Table 3. Comparison of deflection, generated piezoelectric voltages for various cantilevers

Geometry	Displacement (µm)	Piezoelectric Voltage (V)	Power generated (µW)
Π shaped	0.3517	0.0426	36.29
T shaped	0.5288	0.0386	29.2
E shaped	0.6078	0.0495	49.05

A huge amount of waste heat from industrial processes and many other sources with the help of vibrations sense by the various designed cantilever beams can be converted into electricity. The various shaped of cantilever can be the best source of energy harvesting. It can be of great promise for the future of the upcoming generations by developing such MEMS based smart devices. The durability and efficiency will seems well after fabrication of designs mentioned in paper.

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