ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 3, March 2016

Design of Bimorph Cantilever Structure with IDE for Effective Energy harvesting

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ABSTRACT: This paper describes the design and structural analysis of bimorph cantilever structure along with interdigitated electrode which plays a vital role in the effective energy harvesting. The optimization is done on number of PZT strips, spacing between IDE fingers and on length, width, thickness of PZT strips to obtain the novel structure. The novel bimorph structure with dimension (7000 X 1655 X 15)µm generates 13.4Volt at 23.94Hz.

KEYWORDS: Bimorph cantilever, IDE, Effective energy harvester, PZT strips, Pt strips, Al strips, Displacement, Potential, Frequency, Optimization.

I. INTRODUCTION

Energy harvesters play a vital role in power generation. It is the better alternative for all other energy sources such as solar, wind, thermal etc. They make use of vibrations to harvest energy. Vibration is chosen as source for energy harvesting because it is available in abundance in the earth by means of vehicle motion, human movements and seismic vibrations that vary in frequency and amplitude. These vibrational sources can be harvested by three different methods to generate energy. They are electrostatic, electromagnetic and piezoelectric methods of energy harvesting. Among this, the electrostatic method requires some external sources, electromagnetic method is at macro scale and its fabrication is difficult whereas piezoelectric methods of energy harvesting is at MEMS scale and make use of low frequency vibration to generate energy and also it is compact and have high power density. So piezoelectric means of energy harvesting is considered efficient than other methods. To find out how piezoelectric method is effective the literature survey has been done by analyzing the three types of energy harvesting techniques used in several areas of applications [1]-[10].

The cantilever structure consists of a beam with one end fixed and other end is said to be free. According to piezoelectric effect, when we apply mechanical energy at one end we are able to obtain electrical energy at the opposite end by making use of this principle we can design a cantilever with piezoelectric material as beam [2]. In this type of cantilever we can apply stress at free end by means of force or mass or acceleration so as to obtain a corresponding strain developed at the fixed end. Interdigitated electrode structure is used to achieve high potential. IDE structures exhibit longitudinal piezoelectric effect due to which they provide twice the potential of PPE which exhibit transverse piezoelectric effect [11].

The use of PZT-5H ie.lead zirconate titanate as piezoelectric material is to have a high piezoelectric coupling. The piezoelectric materials have high dielectric constant so the use of IDE with these materials will generate high voltages because of the decoupling between electrode and PZT. The d33 mode provides higher power with the IDE structure then d31 mode [12]. The power output also varies depending upon the IDE finger width and spacing between two fingers [13] [14]. The frequency get reduces when we increase the length of the structure. The potential increases when the number of PZT fiber increases and also varies with the IDE dimensions. We can obtain a maximum potential and minimum displacement at the resonant frequency when it matches with the natural frequency. The range of natural frequency is from 5Hz to 500Hz.

The stress is given in the form of acceleration and the strain developed is in the form of voltage. The structure is designed based on PiezoMUMPs design rules and considerations. The novel structure is designed by analyzing the previous work proposed in [14]-[18].

The bimorph cantilever structure can be described as a sandwich-type cantilever in which two layers of a piezoelectric material are laminated onto one surface of a supporting beam or plate. The two piezoelectric layers are

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ISSN (Print) : 2320-9798

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generally poled in the same direction, typically in the direction normal to the supporting beam/plate. When opposing electric fields are applied to the two piezoelectric layers, their corresponding dimensional changes are of the opposite character, which gives rise to bending of the beam. Thus due to this phenomenon the bimorph structure generates potential more than the unimorph structure.

In this paper sec 2 describes the optimization on number of PZT strips, spacing between IDE fingers and optimization on length, width, thickness of PZT strips. sec 3 describes the geometry of novel bimorph structure, sec 4 concludes the results obtained and sec 5 list the references.

II. OPTIMIZATION

The structural optimization is done in order to find best length, width, thickness and number of PZT strips in single silicon base, which produce high potential. The optimization for number of PZT strips is shown in table 1.

Table 1:Optimization-Number of PZT Strips

Number of PZT Strips	Potential	Frequency
3	8.25	26.29
4	6.51	25.03
5	7.65	25.56
6	8.73	24.86
7	11.3	24.05
8	13.4	23.99

From table1 we infer that the increase in number of PZT strips decreases the frequency, decrease and increase in the potential so the maximum usage of 8 number of PZT strips which produces high potential is taken as the final structure. .

The variation in spacing between the electrode fingers will cause considerable changes in the performance of the structure so the optimization is done and is shown in table 2.

Table 2: Optimization-Spacing between IDE fingers

Spacing between IDE Fingers	Potential	Frequency
100	9.87	23.1
200	10.3	23.7
300	11.1	23.8
400	13.4	23.9

From table 2 the spacing between electrodes is more means the area occupied by electrode will be large so that more amount of surface charges are developed which will increase the potential then further optimization on length, width and thickness have been done as shown in table 3.

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Table 3:Optimization Table on Length, Width, Thickness

Thickness (µm)	Width (µm)	Length 1 (3000µm)		Length 2 (4000µm)		Length 3 (5000µm)		Length 4 (6000µm)		Length 5 (7000µm)	
		F(Hz)	P(V)	F(Hz)	P(V)	F(Hz)	P(V)	F(Hz)	P(V)	F(Hz)	P(V)
2.5	25	139.7	7.8	79.33	8.95	45.77	12.1	30.65	12.3	23.99	13.4
	50	139.8	6.96	75.21	10.8	48.25	11.3	34.06	6.56	24.40	9.96
	80	140.5	11	78.57	8.84	50.43	12	33.62	9.25	25.75	11
	95	141.5	10.4	78.62	11	50.06	10	35.03	9.36	26.99	10
5	25	278.5	11	155.6	12.3	98.53	11.1	68.52	11	49.19	10.3
	50	278.4	9.8	156.5	8.51	101.5	9.55	69.31	10.6	50.35	9.16
	80	279.3	6.42	156.8	7.6	100.6	9.36	69.53	10.7	50.33	10.4
	95	287.3	10.4	157.7	10.7	100.7	9.26	70.15	9.99	50.18	9.14
7.5	25	416.4	7.67	235.2	8.34	150.8	10.3	66.5	9.98	85.91	9.99
	50	416.2	10.6	235	10	152.6	8.89	95.3	10	87.34	9.67
	80	418.3	6.81	234	8.96	154.6	6.53	98.6	9.26	86.12	9.08
	95	423.6	8.02	238.7	10.3	153.1	7.56	100.1	8.98	89.3	8.98
10	25	490.8	8.53	312.5	10.1	212.6	6.52	120.8	6.66	91.90	10
	50	498.5	6.54	315.4	9.15	213.9	9.62	138.6	6.37	92.67	9.08
	80	515.6	7.58	311.5	8.95	217.0	8.59	140.5	8.02	91.85	8.96
	95	507.9	8.52	313.7	10.3	220.6	9.49	149.2	9.92	90.01	9.59

The set of length , width and thickness has been taken and the structure is simulated for all those combination of dimensions. Among them for which combination of length, width and thickness the structure generates higher potential at lower frequency is observed and made as novel structure. The graph has been plotted from the analysis results to show how the novel structure is obtained from the above optimization table.

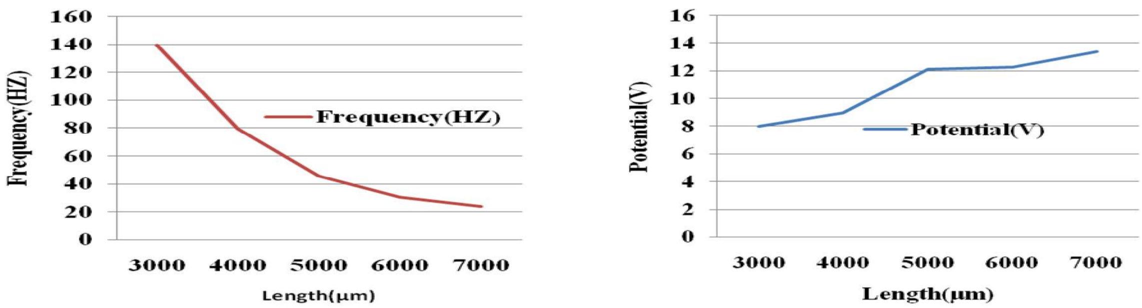

Figure 1: Frequency and Potential plot for varying length at constant width and thickness.

The graph has been plotted for both frequency and potential versus length while keeping the width and thickness constant. From this graph it is shown that at the length of 7000µm high potential of 13.4V is obtained at low frequency of 23.9HZ.

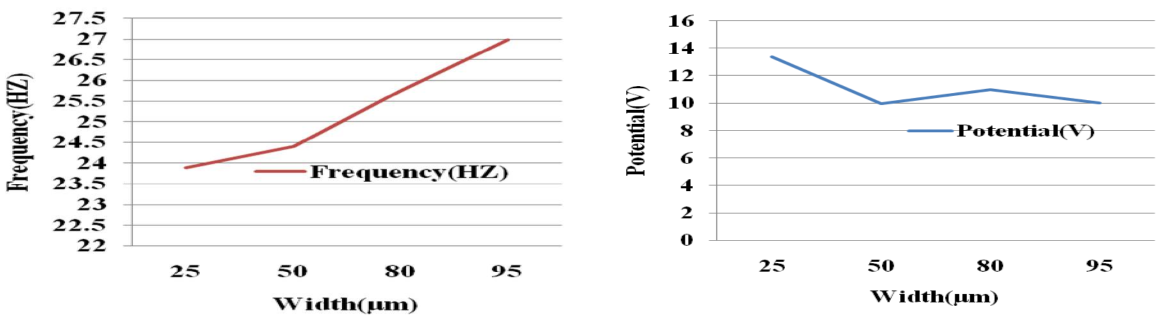

Figure 2: Frequency and Potential plot for varying width at constant length and thickness.

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International Journal of Innovative Research in Computer and Communication Engineering

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Here frequency and potential versus width graph is plotted with constant length and thickness. From this graph it is noticed that at the width of 25µm high potential of 13.4V is obtained at low frequency of 23.9HZ.

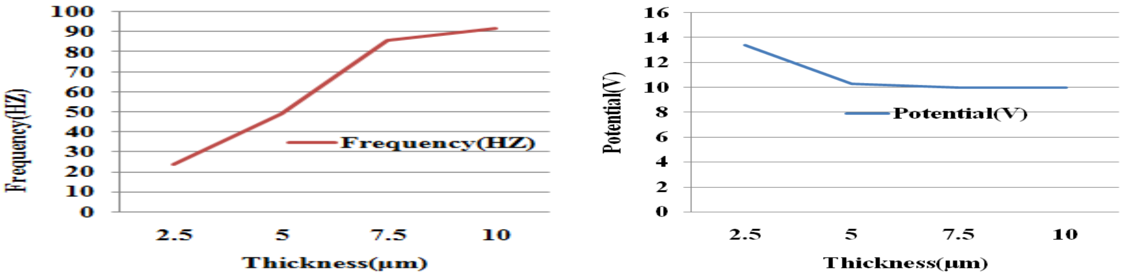

Figure 3: Frequency and Potential plot for varying thickness at constant length and width

Similarly the graph has been plotted for frequency and potential versus thickness at constant width and length. So from this graph the structure with the thickness of 2.5µm generates high potential of 13.4V at low frequency of 23.9HZ

III. NOVEL STRUCTURE

The geometry consists of silicon base with dimension (7000X1655X2.5)µm and bimorph structure over the base consist of Al layer with dimension (7000X25X5)µm is sandwiched between the PZT layers of dimension (7000X25X2.5)µm and the platinum strips of dimension (7000X20X2.5)µm is placed at the first and last PZT strips then the electrode fingers made of platinum of dimension (10X1300X2.5)µm is placed over PZT and between platinum strips to form interdigitated electrode structure. The geometry is shown in figure 4.

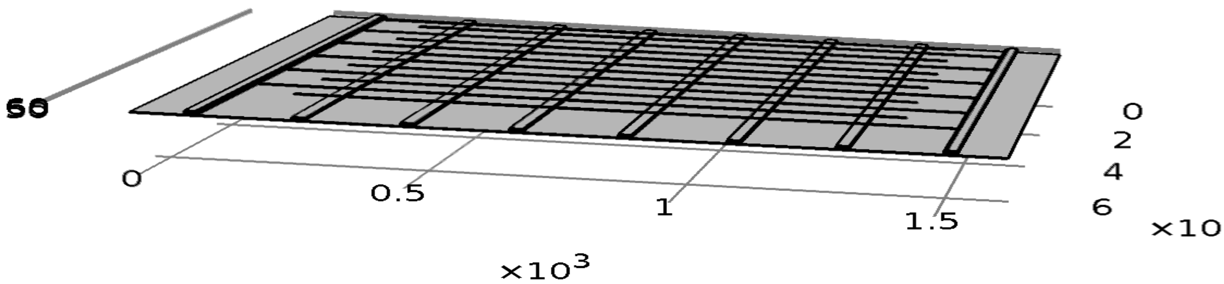

Figure 4 Geometry of Bimorph Structure

The displacement, potential and mode shape are shown in figure 5, 6 &7.

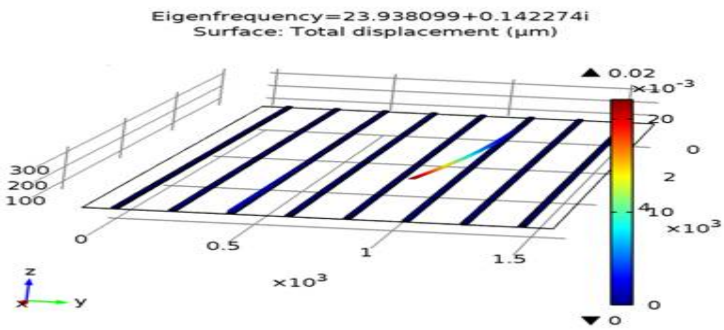

Figure 5: Displacement Plot

DOI: 10.15680/IJIRCCE.2016. 0403116

ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

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Vol. 4, Issue 3, March 2016

The cantilever displaces upto 0.02µm at 23.94Hz which is called as resonant frequency. The displacement place a vital role in the energy harvester module.

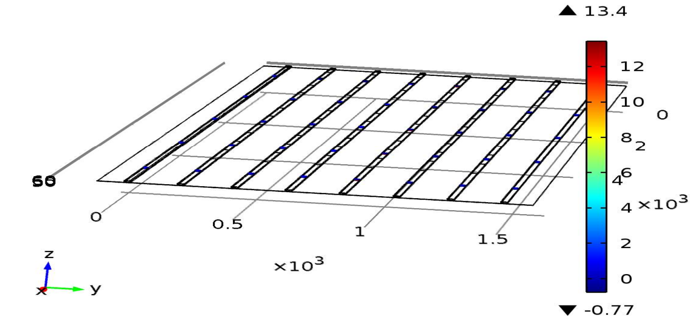

Figure 6: Potential Plot

The cantilever generates a voltage of 13.4V at 23.94Hz. The generated voltage is used to power up the load.

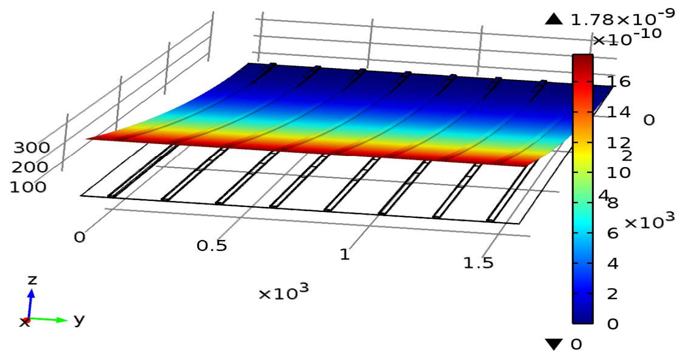

Figure 7: Mode Shape of the structure

The mode shape represents the displacement of entire structure at resonant frequency. The structure displaces upto 1.78 µm at 23.98Hz.

IV. CONCLUSION

The bimorph cantilever structure is designed for effective energy harvesting. The optimization on number of PZT, length-width-thickness of PZT strips are done for fixing the PZT strips dimensions and number of PZT to be used to generate higher potential at lower frequency. The optimization on spacing between IDE fingers are done to fix the space between each IDE finger. Thus the novel structure designed generates 13.4V at 23.94Hz. The generated potential is used in various applications to power up the loads.

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