Piezoelectric Layer Length and Thickness variation effects on Displacement of Cantilever type Piezoelectric Energy Harvester

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Abstract

Piezoelectric energy harvesters find applicability in remote area of application because of simple design and operation. MEMS process technology is utilized to fabricate these cantilever based structures. Piezoelectric layer length and thickness are the key parameters for controlling the resonance frequency and optimal output. In this paper the effect of length and thickness of the piezoelectric layer has been investigated. FEM results have been obtained for varying the length of piezoelectric layer from 50 to 200 µm for two different thicknesses of 2 and 5 µm. It has been observed the variation of the length of the piezoelectric layer has an effect on the total displacement of the cantilever which affects the net potential generated. As the thickness increases, the cantilever displacement decreases.

Keywords: MEMS devices, piezoelectric energy harvesters, Thin film, Cantilevers.

1. Introduction

MEMS based energy harvesters have wide range of applications such as harvesting energy from vibrations due to wind energy, machines, foot motion and many others [1-3]. Three types of mechanism are used to harvest energy from vibrations electro-magnetic effect, capacitive effect and piezoelectric effect [4,5]. Length and thickness are the key parameters for controlling the resonance frequency and optimal output of the cantilever [6-9]. FEM analysis on length effects and thickness effects of the piezoelectric layer has been investigated. FEM results have been obtained for varying the length of piezoelectric layer from 50 to 200 µm for two different thicknesses of 2 and 5 µm. It has been observed the variation of the length of the piezoelectric layer has an effect on the total displacement of the cantilever which affects the net potential generated. As the PZT layer thickness increases, the displacement of the cantilever decreases. FEM simulator COMSOL Multiphysics has been used in the FEM analysis and Structural Mechanics and Piezoelectric device study has been done for obtaining the displacement at different length and thickness. Section 2 gives detail design and FEM analysis for the cantilever structure. Section 3 gives the result and conclusion of the paper.
2. Design and FEM Analysis

Structural Mechanic analysis has been selected and piezoelectric device study [10] has been done in COMSOL Multiphysics. The base of the cantilever is Silicon; PZT piezoelectric material has been selected for the analysis. The length of the silicon cantilever has been fixed to 200 µm. The parameters for simulation are set as: Variation of Length of piezoelectric layer $l_{\text{piezo}} = 50, 75, 100, 125, 150, 175, \text{ and } 200 \, \mu m$. Thickness of piezoelectric layer $t_{\text{piezo}} = 2$ and 5 µm. Thickness of beam $T_{\text{canti}} = 10$ micron. Length of beam $L_{\text{canti}} = 200$ micron.

2.1 Effect of Length Variation on Cantilever Displacement ($T_{\text{piezo}} = 2\mu m$)

In this section, length of piezoelectric material is varied and the effect on cantilever displacement is investigated. PZT material has been selected and the thickness of the piezoelectric material is fixed at 2µm. The FEM simulations have been done and the results are shown below.

![Figure 1](image1.png)

Figure 1. (a) Displacement when $l_{\text{piezo}} = 50 \, \mu m$. (b) Displacement when $l_{\text{piezo}} = 75 \, \mu m$.

![Figure 2](image2.png)

Figure 2. (a) Displacement when $l_{\text{piezo}} = 100 \, \mu m$. (b) Displacement when $l_{\text{piezo}} = 125 \, \mu m$. 
Figure 4. Displacement when $l_{\text{piezo}} = 200\ \mu\text{m}$

FEM analysis has been done for different piezoelectric layer length at a thickness of 2 µm. Figure 1 to 4 shows the snapshots of the FEM results obtained for the piezoelectric layer length variation from 50 to 200 µm. The displacement of the cantilever increases from 0.0207 to 1.0462 µm when the length increases is varied from 50 to 200 µm. The cantilever is fixed-free type of structure, displacement is minimum near fixed end and maximum near the free end. The analysis shown in the color lines of different length versus displacement which clearly shows that there is an effect of length of PZT layer on the total displacement of the cantilever.

2.2 Effect of Length Variation on Cantilever Displacement ($T_{\text{piezo}} = 5\mu\text{m}$)

In this section, thickness of the piezoelectric material is changed to 5 µm and the effect on variation of length of piezoelectric layer on cantilever displacement is investigated. PZT material has been selected and the thickness of the piezoelectric material is fixed at 5µm. The FEM simulations have been done and the results are shown below.
FEM analysis has been done for different piezoelectric layer length at a thickness of 5 µm. Figure 5 to 7 shows the snapshots of the FEM results obtained for the piezoelectric layer length variation from 50 to 200 µm. The displacement of the cantilever increases from 0.0147 µm to 0.6615 µm when the length increases is varied from 50 to 200 µm. The cantilever is fixed-free type of structure, displacement is minimum near the fixed end and maximum near the free end. The analysis shown color lines of different length versus displacement which clearly shows that there is an effect of length of piezoelectric layer on the total displacement of the cantilever.
3. Results and Conclusion

The above investigation validates the fact that there is an effect of the length and thickness of the piezoelectric layer. Variation of length of the piezoelectric layer changes the displacement from 0.0207 to 1.0462 µm. Therefore, it can be seen that there is an effect of length of piezoelectric layer on the displacement of the cantilever structure. At a length of 200 µm, increasing the thickness from 2 to 5 µm results in the reduction of the displacement from 1.0462 to 0.6615 µm. Increasing the thickness of the layer results in reduction of the displacement. Therefore, we have investigated the length and thickness effects of the piezoelectric material. These parameters should be typically selected for optimum device performance.

References


