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 eletro-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_{piezo} = 50, 75, 100, 125, 150, 175, and 200 µm. Thickness of piezoelectric layer t_{piezo}= 2 and 5 µm. Thickness of beam T_{canti} = 10 micron. Length of beam L_{canti} = 200 micron.

2.1 Effect of Length Variation on Cantilever Displacement (T_{piezo} = 2µm)

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.

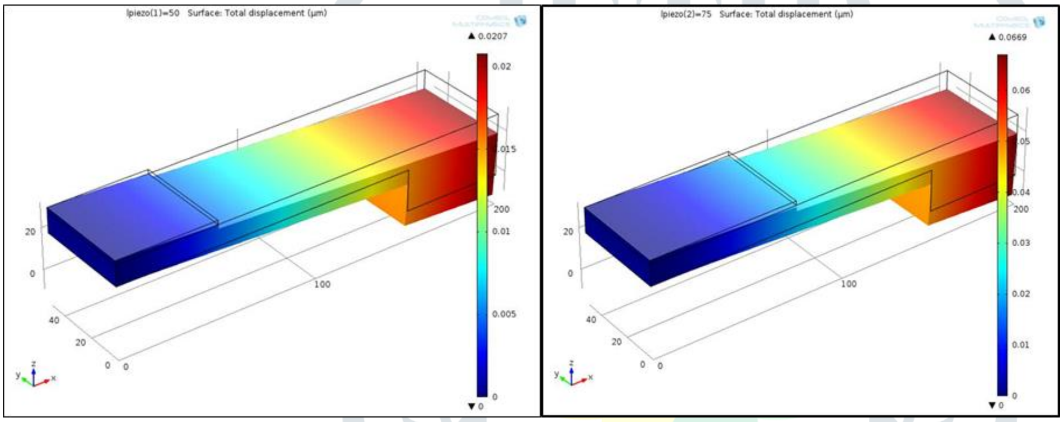

Figure 1. (a) Displacement when l_{piezo} = 50 µm. (b) Displacement when l_{piezo} = 75 µm.

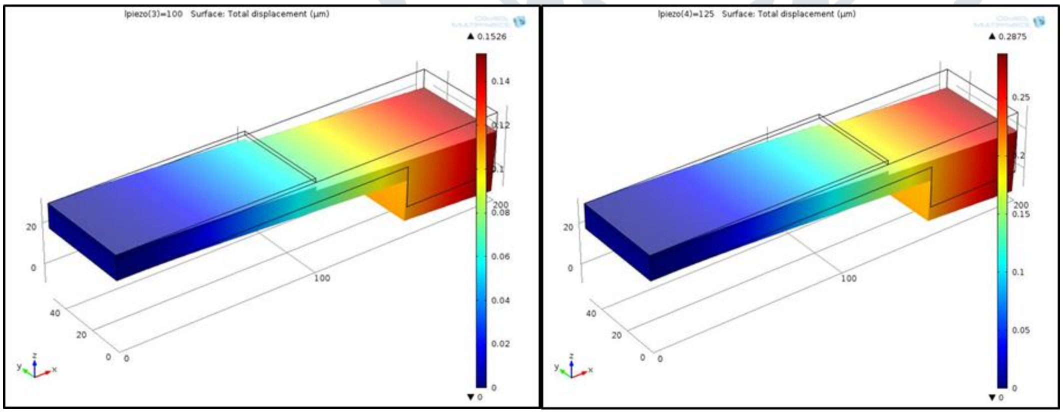

Figure 2. (a) Displacement when l_{piezo} = 100 µm. (b) Displacement when l_{piezo} = 125 µm.

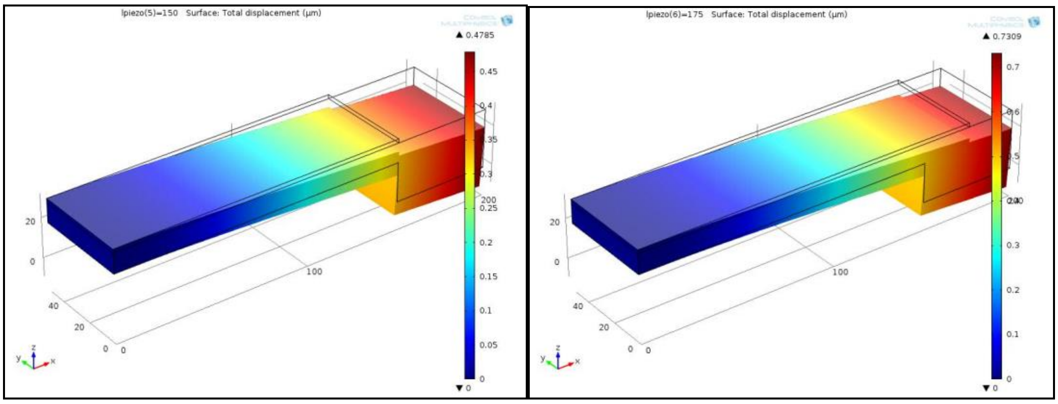

Figure 3. (a) Displacement when l_{piezo} = 150 µm. (b) Displacement when l_{piezo} = 175 µm.

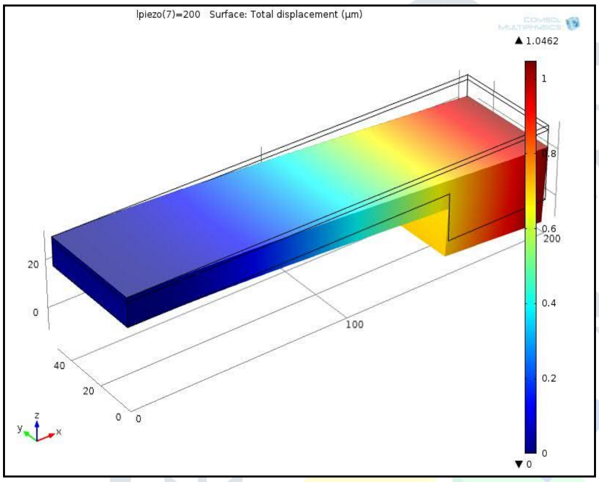

Figure 4. Displacement when l_{piezo} = 200 µm

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_{piezo} = 5µm)

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.

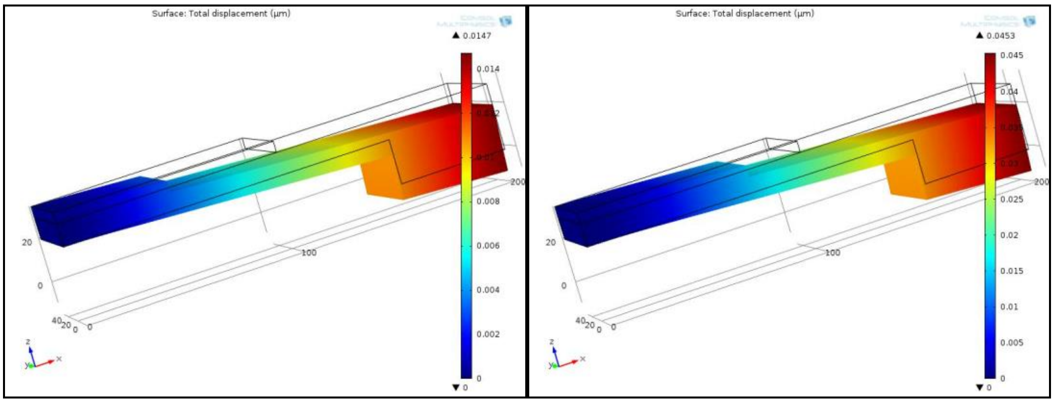

Figure. 5 (a) Displacement when l_{piezo} = 50 μm. (b) Displacement when l_{piezo} = 75 μm.

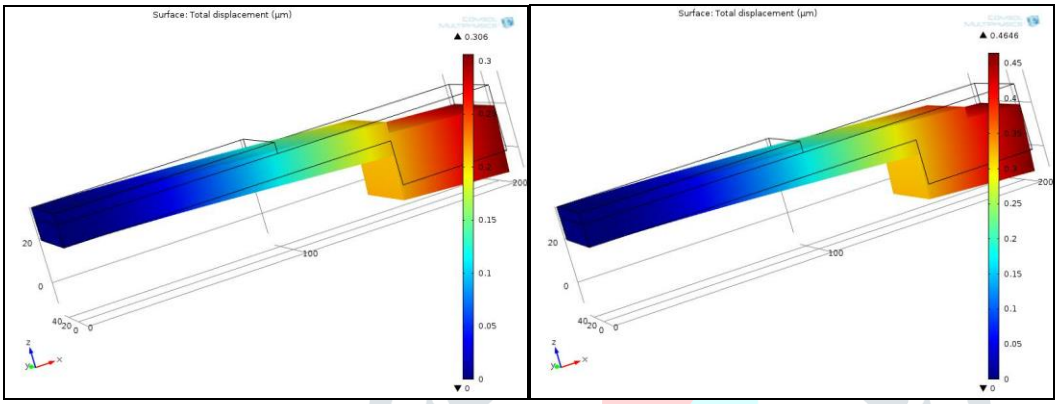

Fig. 6 (a) Displacement when l_{piezo} = 150 μm (b) Displacement when l_{piezo} = 175 μm

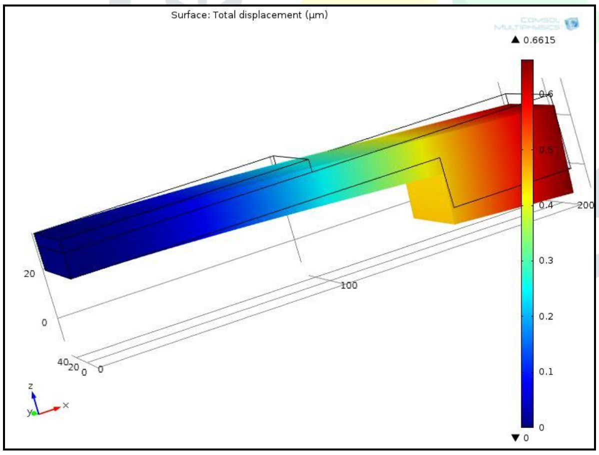

Figure 7. Displacement when l_{piezo} = 200 μm

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

[1] E. Halvorsen, "Energy harvesters driven by broadband random vibrations,"*J.Microelectromech. Syst.*, vol. 17, no. 5, pp. 1061–1071,Oct. 2008.

[2] H. Liu, C. J. Tay, C. Quan, T. Kobayashi, and C. Lee, "Piezoelectric MEMS energy harvester for low-frequency vibrations with wideband operation range and steadily increased output power," *J. Micromech.Microeng.*, vol. 20, no. 5, pp. 1131–1142, Oct. 2011.

[3] L. Mateu and F. Moll, "Optimum piezoelectric bending beam structures for energy harvesting using shoe inserts," *J. Intell. Mater. Syst. Struct.*, vol. 16, no. 10, pp. 835–845, 2005.

[4] P. Glynne-Jones, S. P. Beeby, and N. M. White, "Towards a piezoelectric vibration-powered microgenerator," *IEE Proc.-Sci., Meas.,Technol.*, vol. 148, no. 2, pp. 68–72, 2001.

[5] J. W. Yi, W. Y. Shih, and W.-H. Shih, "Effect of length, width, and mode on the mass detection sensitivity of piezoelectric unimorph cantilevers," *J. Appl. Phys.*, vol. 91, no. 3, pp. 1680–1686, 2002.

[6] S. Saadon and O. Sidek, "Shape optimization of cantilever-based MEMS piezoelectric energy harvester for low frequency applications," in *Proc. IEEE 15th Int. Conf. Comput. Modelling Simulation (UKSim)*, Apr. 2013, pp. 202–208.

[7] S. M. Shahruz, "Design of mechanical band-pass filters for energy scavenging," *J. Sound Vib.*, vol. 292, nos. 3–5, pp. 987–998, 2006.

[8] M. S. M. Soliman, E. M. Abdel-Rahman, E. F. El-Saadany, and R. R. Mansour, "A wideband vibration-based energy harvester," *J. Micromech. Microeng.*, vol. 18, no. 11, p. 115021, 2008.

[9] D. Zhu, M. J. Tudor, and S. P. Beeby, "Strategies for increasing the operating frequency range of vibration energy harvesters: A review," *Meas. Sci. Technol.*, vol. 21, no. 2, p. 022001, 2010.

[10] S. Saxena, R. Sharma, and B. D. Pant, "Dynamic characterization of fabricated guided two beam and four beam cantilever type MEMS based piezoelectric energy harvester having pyramidal shape seismic mass," *Microsyst. Technol.*, vol. 23, no. 12, pp. 5947–5958, 2017.