Simulation and Optimization of MEMS Piezoelectric Energy Harvester with a Non-traditional Geometry

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Abstract

Piezoelectric energy harvester converts mechanical vibrations into electrical energy via piezoelectric effect. The geometry of the piezoelectric cantilever beam greatly affects its vibration energy harvesting ability [1]. In this paper a MEMS based energy harvester with a non-traditional geometry is designed. The design of the energy harvester consists of a rectangular cantilever structure with triangular shape at the tip (Figure 1). The simulation results demonstrated that the new cantilever structure can improve the strain distribution and generate more voltage than the triangular and rectangular structures. The proposed structure is simulated using the software COMSOL Multiphysics. This structure can be used to power wireless micro-sensors. Piezoelectric application mode is used to model the rectangular cantilever with triangular shape at the tip of the energy harvesting device. It is also used for analyzing the electrical and mechanical behavior of the Energy Harvester. The vertical acceleration is applied using body load Fz equal to aρ in each subdomain where a = 0.1*g where a represents the acceleration magnitude, g acceleration due to gravity and ρ is the density of the material. The thickness of the structure is varied manually. The next stage is to use moving mesh application mode to optimize the thickness of piezoelectric layer and to use Arbitrary Lagrangian Eulerian (ALE) technique to compute the mesh deformation [2,3]. The simulation results of a rectangular cantilever with triangular shape at the tip consisting of Lead Zirconate Titanate(PZT) as piezoelectric material and stainless steel as the substrate has been obtained . Vertical acceleration is applied using body load Fz and the resulting beam deflection profile and output voltage is measured for various thickness values. The thickness of PZT is varied to get maximum voltage and displacement (Figure 2). The Length, width and thickness of cantilever is obtained as 27000µm x 3000µm x 200µm. The results are compared with rectangular and triangular geometries(Figure 3). The simulation results demonstrated that under same conditions the new cantilever structure can improve the strain distribution and generate more voltage than the triangular and rectangular structures (Figure 4). An output voltage of 6.4mV and a deflection of 100nm is obtained for a thickness of 200µm . The next stage is to use moving mesh application mode to optimize the thickness of piezoelectric layer and to use Arbitrary Lagrangian Eulerian (ALE) technique to compute the mesh deformation.

Reference

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[2] M. Guizzetti, V. Ferrari, D. Marioli and T.Zawada, “Thickness optimization of a piezoelectric converter for energy harvesting,” Proceedings of the COMSOL Conference, 2009.
[3] Suyog N Jagtap and Roy Paily, “Geometry Optimization of a MEMS-based Energy Harvesting Device” Proceeding of the 2011 IEEE Students' Technology Symposium 14-16 January, 2011, IIT Kharagpur

Figures used in the abstract

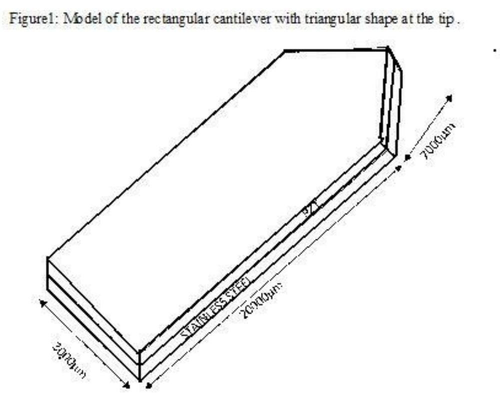

Figure 1: Model of the rectangular cantilever with triangular shape at the tip.

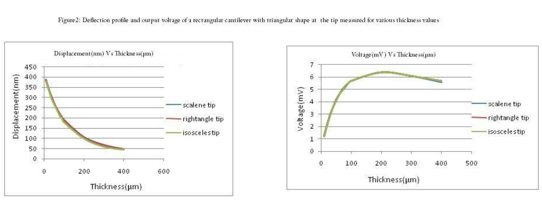

Figure 2: Deflection profile and output voltage of a rectangular cantilever with triangular shape at the tip measured for various thickness values.

Figure 3: Variation of Voltage Vs Thickness and Displacement Vs Thickness

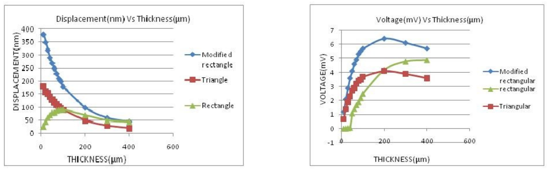

Figure 3: Variation of Voltage Vs Thickness and Displacement Vs Thickness.

Figure 4: Performance Comparison table for different geometries of dimension Length, width and thickness 27000µm x 3000µm x 200µm

Sl.No	Cantilevers of different geometry	Output voltage(mV)	Beam Deflection(nm
1.	Rectangular cantilever with triangular shape at the tip	6.4	100
2.	Rectangular cantilever	4.9	45
3.	Triangular cantilever	4.1	50

Figure 4: Performance Comparison table for different geometries of dimension Length, width and thickness 27000µm x 3000µm x 200µm.