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Design and Analysis of an Integrated Mems Harvester for Low Power Devices

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Abstract

This paper introduces a hybrid energy harvester generating electric power from both ambient heat and vibration. Harvesting energy from vibration was realized by piezoelectric effect Phenomena in Lead Zirconate Titanate (PZT) crystals, whereas the energy generation from heat was supplied by making use of Seebeck effect of n-type and p-type Bi2Te3 thermocouples. The industrial software Comsol Multi physics is used for the simulation. A total voltage of 17.024V was generated from the thermoelectric part and .4 V from the piezoelectric part of the device. Total power produced from the chip is predicted to be 1.91nW.

Keywords: Energy Harvesting, Micro Power Generation, Piezoelectric, Vibration, Thermoelectric

1. Introduction

Nowadays energy harvesting from single source microgenerators is not even sufficient to meet the power requirement of low-power devices. Thus, hybrid solutions utilizing multiple ambient energy sources in a single chip can be an option to overcome the low power issue.

Thermoelectric energy harvesting is a favorable option since ambient heat is always present in various environments such as mobile systems, industrial machines, and many components in a car. Several thick-film and thin-film thermo electric generators were previously introduced in literature[1-3]. High figure of merit thermoelectric materials offer the best thermoelectric efficiency in most of the cases. However, the implementation of these materials to micro devices requires complicated and high-cost fabrication steps. At this point, metals having a high thermoelectric power factor are often used as thermocouple materials[1].

Energy harvesting from vibration is a commonly used technique due to its high energy density and abundance of vibration in nature. Piezoelectric, electrostatic, and electromagnetic energy conversion mechanisms are the methods used for energy harvesting from vibration[4]. Among these piezoelectric energy harvesters have high electromechanical coupling effect, require no external voltage sources, are compatible with MEMS technology, and have received much attention accordingly[4-7]. In order to extract the maximum power from the environment, the resonant frequency of such device has to match the dominant frequency in the surroundings, whereas the frequencies of ambient available vibration sources are relatively low (normally less than 200 Hz)[8].

2. Concept and Design

The template is used to hybrid harvester consists of two systems monolithically integrated on a single base.

- Thermoelectric system.
- Piezoelectric system.

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Micros TEG consist of two different materials with relatively high seebeck coefficient value. Primarily it consists of:

- N-type Bismuth Telluride.
- P-type Bismuth Telluride.
- Junction material (here Copper).

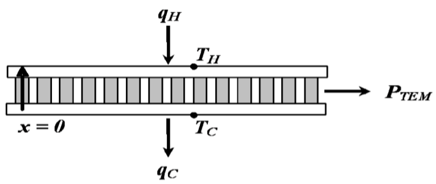


Figure 1. Structure of the thermoelectric module.

The output voltage of the energy harvesting thermoelectric generator can be expressed as

$$Vout = n\ (\alpha_1 - \alpha_2)\ (T_h - T_c)$$

Where n = No of thermocouples in the TEG,
α_1 = Seebeck coefficients of p-type Bi2Te3 V/ C,
α_2 = Seebeck coefficients of n-type Bi2Te3 V/ C,
T_h = Temperature of the hot junction, /C (or) / K,
T_c = Temperature of the cold junction. /C (or)/ K.

Piezoelectric harvester consists of two layers:

- Lead Zirconate Titanate (PZT-5A).
- Structured steel.

Figure 2. Structure of the piezoelectric module.

Power output of the system at resonance is

$$P\max = \frac{m\omega^3 Y^2}{4\zeta}$$

Where m = seismic mass at the beam end, Kg.
ω = Natural frequency of the system, Hz.
Y = Amplitude of vibration, μm.
ζ = Damping ratio.

3. Structure and Dimensions

The harvester consists of n and p-type Bismuth Telluride material sandwiched between the copper junctions. The PZT harvester is located at the right side. When temperature is applied at the base and vibrational load at the tip of the Cantilever beam. Both the structures begin to generate electric potential based on the harvesting technique[8-10].

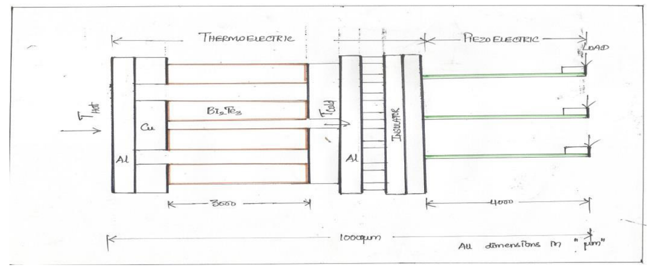


Figure 3. Schematic view of a Hybrid micro power generator.

The initial dimensions of the hybrid energy harvester are given in the Table 1.

Table 1. Dimensions

Geometric Dimensions	Values (μm)	Material Selection
Thermoelectric materials	3000	n-type and p-type Bi2Te3
Heat source	500	Aluminium
Thermal contact pads	700	Copper
Ceramic contacts	500	Silicon carbide
Heat sink layer	500	SiO_2 coating
Electrical insulation	500	Parylene-C
Piezo electric materials	4000	Lead Zirconate titanate (PZT5A)
Proof mass	300	Silicon

4. FEM Simulation

Simulation of the device has been done using the COMSOL Multiphysics tool. The heat transfer in solids, electric currents and piezoelectric devices physics has been used to model the design.

This is done mainly in 3 steps..

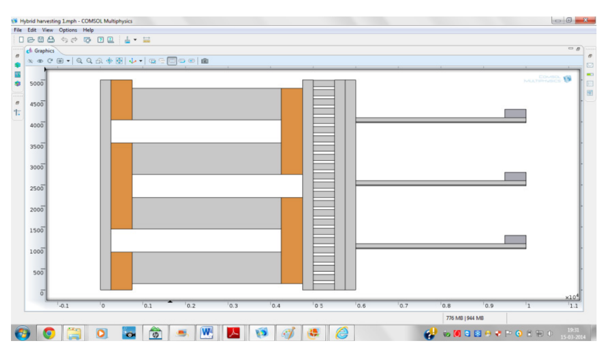


Figure 4. Defining geometry and materials.

For thermoelectric, Specify the temperature gradients.

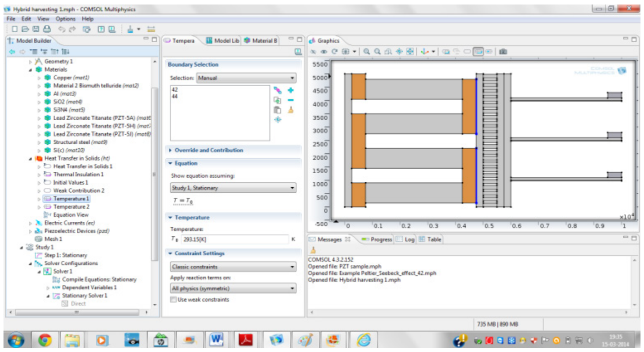
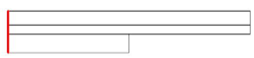
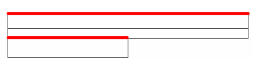
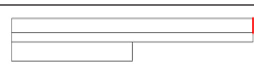


Figure 5. Setting up the physics.

For piezoelectric, apply load and specify boundary conditions as given in Table 2.

Table 2. Boundary conditions

Boundary Condition	Value	Location
1. Displacement	Fixed	
2. Electrical charge	Ground	
3. Electrical charge	Zero charge or Symmetry	
4. Load	Pressure	

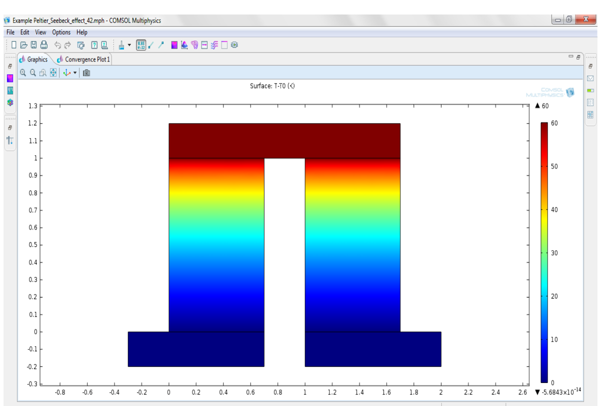


Figure 6. Thermoelectric results (temperature distribution).

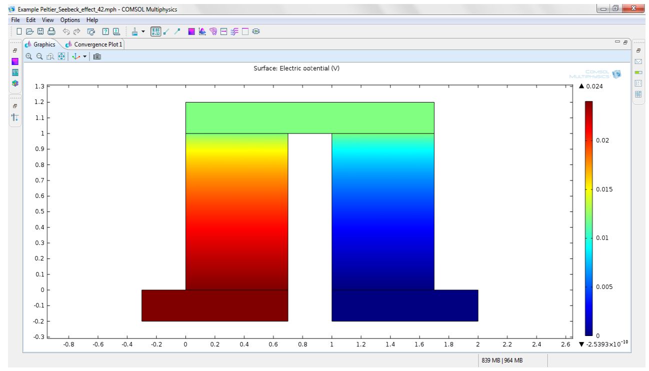


Figure 7. Thermoelectric results (electric potential).

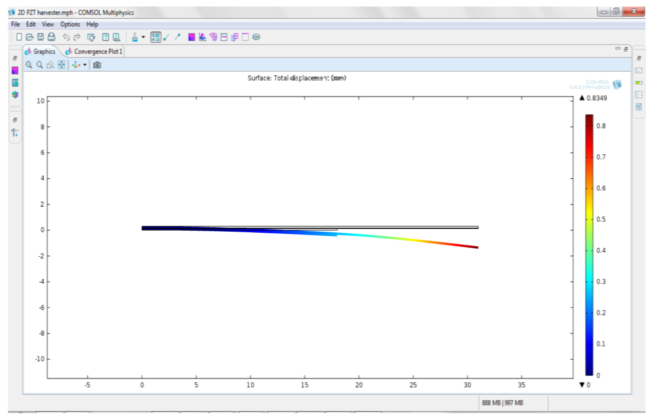


Figure 8. Piezoelectric results (displacement).

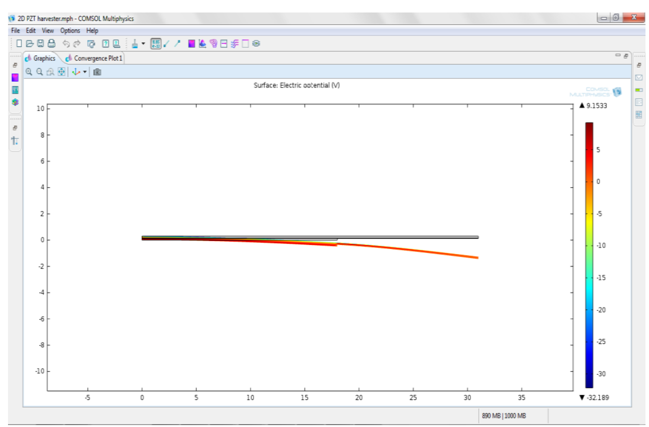


Figure 9. Piezoelectric results (electric potential).

5. Results summary and Conclusion

Table 3. Simulation and Analysis

	Maximum
Displacement(mm)	0.8
Strain(unit less)	3.825e-4
Stress (MPa)	28
Electric potential(V)	18
Electric field norm(V/m)	3.27e5

- Piezoelectric (Static analysis).
- Thermoelectric (Static analysis).

5.1 Electric Potential

Maximum = 0.024 V
Minimum = 1.57e-4 V

A multisource energy harvester, using multiple energy sources (heat and vibration) to produce electrical energy was introduced. The simulation and initial test results were obtained for the device. A total voltage of 18.024 V was generated from the device. Although energy developed is very low, power level for this particular device can be increased significantly increased by increasing the PZT cantilever number, or by using high Seebeck coefficient materials and/or by optimizing the layer thickness for better thermal and vibration based harvesting.

6. References

1. Glatz W, Muntwyler S, Hierold C. Optimization and fabrication of thick flexible polymer based micro thermoelectric generator. Sensors and Actuators A: Physical. 2006; 132; 337–45.
2. Ramaswamy S, Sengottuvelu S, Sherief Haja SH, Jaikumar S, Saravanan R, Prasadkumar C, Sivakumar T. Gastroprotective activity of ethanolic extract of *Trachyspermum ammi* fruit. International Journal of Pharma and Bio Sciences. 2010; 1(1):1. ISSN: 0975-6299.
3. Available from: www.memsnet.org
4. Saravanan T, Srinivasan V, Udayakumar R. An approach for visualization of atherosclerosis in coronary artery. Middle-East Journal of Scientific Research. 2013; 18(12):1713–7. ISSN: 1990-9233.
5. Tai-Ran Hsu .A textbook of Micro electro mechanical systems. 1st ed. Tata Mc-graw Hill Publications. New Delhi.2002 Nov.
6. Sankari Leena S, Masthan KMK, Babu NA, Bhattacharjee T, Elumalai M. Apoptosis in cancer-an update. Asian Pacific Journal of Cancer Prevention. 2012; 13(10):4873–8. ISSN: 1513-7368.
7. Huesgen T, Woias P, Kockmann N. Design and fabrication of MEMS thermoelectric generators with high temperature efficiency. Sensors and Actuators A. 2008; 145:423–9.
8. Ramaswamy S, Sengottuvelu S, Sherief Haja SH, Jaikumar S, Saravanan R, Prasadkumar C, Sivakumar T, Gastroprotective activity of ethanolic extract of *Trachyspermum ammi* fruit. International Journal of Pharma and Bio Sciences. 2010; 1(1):1. ISSN: 0975-6299.
9. Lee C, Xie J. Development of a vacuum packaged CMOS thermoelectric energy harvester. Nano /Micro Engineered and Molecular Systems. 4th IEEE International Conference; NEMS; Shenzhen. 2009. p. 803–7.
10. Kumar SS, Karrunakaran CM, Rao MRK, Balasubramanian MP. Inhibitory effects of indigofera aspalathoides on 20-methylcholanthrene induced chemical carcinogenesis in rats. Journal of Carcinogenesis. 2011; 10:1. ISSN: 1477-3163.
11. Available from: www.mems-exchange.org
12. Saravanan T, Srinivasan V, Sandiya VP. A two stage DC-DC converter with isolation for renewable energy applications. Indian Journal of Science and Technology. 2013; 6(S6):4824–30. ISSN: 0974-6846.