Experimental study on thermal energy harvesting using ferroelectric materials

A Thesis

Submitted
By

MANISH VAISH (ERPS1301)

For the award of degree of

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SCHOOL OF ENGINEERING

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Mandi, Himachal Pradesh -175005

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Dedicated to

my teachers

and

Family

Declaration by the Research Scholar

This is to certify that the thesis titled "**Experimental study on thermal energy harvesting using ferroelectric materials"** submitted by me, to the Indian Institute of Technology Mandi for the award of the degree of **Master of Science (by research)**, is a bona fide record of the research work carried out by me in the School of Engineering, Indian Institute of Technology Mandi, under the supervision of Dr. Rahul Vaish and Dr. Vishal Singh Chauhan. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

In keeping with the general practice of reporting scientific observation, due acknowledgements have been made wherever the work described is based on the findings of other investigators.

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Thesis Certificate

This is to certify that the thesis titled "**Experimental study on thermal energy harvesting using ferroelectric materials**" submitted by **Manish Vaish**, to the Indian Institute of Technology Mandi for the award of the degree of **Master of Science (by research)**, is a bona fide record of the research work carried out by him under our supervision in the School of Engineering, Indian Institute of Technology Mandi. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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Preamble

Ferroelectrics form an important class of materials and are employed for a variety of applications. These materials have ability to convert thermal energy into electrical signals which is known as pyroelectric effect. Pyroelectric materials are the one of the most important class of electronic materials after semiconductors and are slowly gaining momentum in various novel applications. This has allowed them to break free of the traditional applications of sensors to novel technologies like thermal energy harvesting. It is an established fact the pyroelectric behaviour is a function of the domain response/switching behaviour when subjected to thermal gradient. The present study is based on waste heat energy harvesting using pyroelectrics ($PbZr_xTi_{(1-x)}O_3$ (PZT-5H)) and other lead-free ceramics. In order to harvest optimum energy from pyroelectric materials, different electrical circuits (parallel and series SSHI (synchronized switch harvesting on inductor)) have been used. They provide nonlinear processing of pyroelectric voltage which leads to synchronization between temperature gradient and charge extraction.

The results obtained in the present investigations have been compiled in the four chapters as follows:

Chapter 1 summarizes the introduction of thermal energy harvesting and method which has already explored in the field of thermal energy harvesting. Pyroelectric effect and ferroelectric materials are also described the later part of chapter.

Chapter 2 discussed the objectives of the thesis and argued some of the important litrature on pyroelectric energy harvesting.

Chapter 3 includes the experimental results of energy harvesting using hot/cold oil bath and radiation heating. PZT was used in this work to harvest thermal energy from radiation as well as from hot oil. The extracted charges were stored into different values of capacitors and power output was calculated across the load resistance

In Chapter 4, the results obtained from energy harvesting from PZT-5H, $Ca_{0.15}(Sr_{0.5}Ba_{0.5})_{0.85}Nb_2O_5$, and $(Ba_{0.85}Ca_{0.15})(Zr0_{.1}Ti_{0.89}Fe_{0.01})O_3$ ceramics have been explained and harvested electrical energy was stored in the capacitors. The voltage is also calculated at different values of frequency and the effects of these frequencies have been discussed in this chapter. A comparative study has been done on exploring thermal energy harvesting potential in various class of materials like $Ba_{0.9}Ca_{0.1}TiO_3$ (BCT), $Sr_{0.5}Ba_{0.5}Nb_2O_6$ (SBN), $[Bi_{0.48}Na_{0.4032}K_{0.0768}]Sr_{0.04}(Ti_{1-x}Nb_{o-x})O_3$ (BNT-Nb), $Ba_{0.85}Ca_{0.15}Zr_{0.1}Ti_{0.9}O_3$ (BCT-BZT) and $Ba_{0.85}Sr_{0.15}Zr_{0.1}Ti_{0.9}O_3$ (BST-BZT) pyroelectric ceramics. BCT ceramic has been explored at different frequency through SSHI circuits and compared to a standard circuit.
The thesis concluded by summarizing the key findings of the investigation and high lighting the results. This research is expected to greatly benefit the field of integrated Micro-Electro-Mechanical-Systems (MEMS) and low power electronics devices. The following publications are largely based on the studies conducted as a part of the research work reported over here.

- **Vaish.M,** Sharma.M**,** Vaish, R,& Chauhan.S.Vishal "Experimental study on waste heat energy harvesting using pyroelectric ceramics"**Energy Technology Vol.3(2015) 768-773**
- **Vaish. M,**Sharma.M, Vaish, R & Chauhan. S. Vishal. (2015).**"**Electrical energy generation from hot/cold air using pyroelectric ceramics"**Integrated Ferroelectrics Vol. 167,(2015) 90-97**
- **Vaish.M**, Ahamad Madhar.N , Ilahi.B Chauhan. S. Vishal & Vaish.R.(2015) "An Experimental Study on Thermal Energy Harvesting using$Ca_{0.15}(Sr_{0.5}Ba_{0.5})_{0.85}Nb_2O_5$ Pyroelectric Ceramics" **Ferroelectrics Vol. 43(2016) 52-58**
- Sharma.M,**Vaish. M,** Vaish, R & Chauhan. S. Vishal. (2015) **"**Capacitor and battery charging from hot/cold air using pyroelectric ceramics (PZT-5H)" **Integrated Ferroelectrics Vol. 176(2016) 160-170**
- **Vaish.M,** Sharma.M, Vaish, R & Chauhan. S. Vishal. (2016)."Harvesting thermal energy (via radiation) using pyroelectric material (PZT-5H): An experimental study" **Ferroelectrics letters Vol.44 (2017) 1-3**
- Kumar. A, Srikanth K.S, Kumar Sidhant, V.P. Singh, **Vaish.M**, Chauhan. S. Vishal and Vaish, R. "Lead-free pyroelectric materials for thermal energy harvesting: A comparative study**" Energy Technology, DOI: 10.1002/ente.201700819**

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Thank you all. MANISHVAISH

Table of contents