A study on solar energy harvesting using pyroelectric materials

A Thesis

Submitted
By

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For the award of degree of

Master of Science (by research)

SCHOOL OF ENGINEERING

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Dedicated to

my teachers

and

Family

Declaration by the Research Scholar

This is to certify that the thesis titled "**A study of solar energy harvesting using pyroelectric 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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<u>Thesis Certificate</u>

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Preamble

Pyroelectric energy harvesting is the process of converting wasted thermal energy to other useful form of energy. This energy harvesting technique is based on the pyroelectric effect of ferroelectric materials. Generated current due to pyroelectric effect is a function the pyroelectric coefficient, surface of material and the time varying temperature gradient. In the current study, a simple model is developed to predict the possibilities of solar energy harvesting using pyroelectric effect. The proposed method uses solar radiation for heating and natural/force air for cooling at different cycle frequencies to maintain higher temperature gradient and to achieve higher power/energy density. Complete work has been explained in five chapters.

Chapter 1 covers a basic understanding of energy harvesting, ferroelectric, pyroelectric materials and provides literature survey of pyroelectric energy harvesting devices.

Chapter 2 includes the investigations on possible power output from solar energy using direct pyroelectric method or employing Ericsson cycle. Polyvinylidene difluoride copolymer Trifluoroethylene-Chlorofluoroethylene P(VDF-TrFE-CFE) thin films were used in conjunction with pyroelectric effect and forced cooling to simultaneously increase energy and power density.

Chapter 3 demonstrates comparison between different pyroelectric materials for harvesting solar energy. Seven different pyroelectric materials including $(NH_2CH_2COOH)_3 \cdot H_2SO_4$(TGS), $Sr_{0.5}Ba_{0.5}Nb_2O_6$, $Ca_{0.2}(Sr_{0.5}Ba_{0.5})_{0.8}Nb_2O_6$, $Pb(Zr_{0.5}Ti_{0.5})O_3$, PVDF, $BaTiO_3$ and $LiTaO_3$ have been studied. Best found material was again investigated for different heating and cooling cycle frequencies for finding optimum cycle frequency for better power generation. Additionally, these cycle frequencies were studied across different load resistance and load capacitance for optimum power transfer.

Chapter 4 illustrates energy and exergy analyses of pyroelectric tryglycine sulfate (TGS)-based solar energy harvesting system. Exergy was studied at different cycle frequencies.

Chapter 5 demonstrates an investigation on design based figure of merits for pyroelectric radiation heat energy harvesting. Influence of different material and design variables on pyroelectric-based solar energy harvesting system was studied and clubbed into the form of figure of merits.

The thesis ends with conclusions and future directions. The following publications are largely based on the studies conducted as a part of the research work reported over here.

Articles published

- **Manish Sharma**, Aditya Chauhan, Rahul Vaish, and Vishal Singh Chauhan. "Finite element analysis on solar energy harvesting using ferroelectric polymer." **Solar Energy** 115 (2015): 722-732.
- **Manish Sharma**, Aditya Chauhan, Rahul Vaish and Vishal Singh Chauhan, "Pyroelectric materials for solar energy harvesting: a comparative study," **Journal of Smart Material and Structure** 24 (2015): 105013**.**
- **Manish Sharma,** Rahul Vaish and Vishal Singh Chauhan. "Energy and exergy analysis of pyroelectric-based solar energy harvesting system," **Energy Technology** 3 (2015):1271-1278.
- Manish Vaish, **Manish Sharma**, Rahul Vaish and Vishal Singh Chauhan. "Experimental study on waste heat energy harvesting using pyroelectric ceramics," **Energy Technology** 3 (2015): 768-773.
- Gaurav Vats, **Manish Sharma**, Rahul Vaish and Vishal Singh Chauhan, "Application oriented selection of optimal sintering temperature from user perspective: a study on $K_{0.5}Na_{0.5}NbO_3$ Ceramics," **Ferroelectric** 481(2015): 64-76.

- Manish Vaish, **M. Sharma**, R. Vaish, V.S.Chauhan, "Electrical energy generation from hot/cold air using pyroelectric ceramics" **Integrated Ferroelectrics** 167.1 (2015): 60-67.
- **Manish Sharma,** Rahul Vaish and Vishal Singh Chauhan. Energy and exergy analyses of pyroelectric Tryglycine sulfate (TGS)-based solar energy harvesting system, **"Material Research Express"** (Accepted 2016).

Other articles

- **Manish Sharma,** Manish Vaish, Rahul Vaish and Vishal Singh Chauhan, "Capacitor and battery charging from hot/cold air using pyroelectric ceramics (PZT-5H)" **Integrated ferroelectrics** (Communicated 2015).
- **Manish Sharma,** Rahul Vaish and Vishal Singh Chauhan. Formulation of figure of merits for pyroelectric energy harvesting devices**, "Energy Technology"** (Communicated 2015).

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