

**DESIGN AND FABRICATION OF FULLY
AUTOMATED EXPERIMENTAL SETUPS
FOR CHARACTERIZATION OF
THERMOELECTRIC MATERIALS**

A THESIS

submitted by

ASHUTOSH PATEL

(Enrollment no.: S14006)

for the award of the degree

of

MASTER OF SCIENCE

(by Research)



**SCHOOL OF ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY MANDI.**

JUNE 2017

DECLARATION BY RESEARCH ADVISOR

This is to certify that the thesis entitled "**DESIGN AND FABRICATION OF FULLY AUTOMATED EXPERIMENTAL SETUPS FOR CHARACTERIZATION OF THERMOELECTRIC MATERIALS**", submitted by **Ashutosh Patel**, to the Indian Institute of Technology Mandi, for the award of the degree of **Master of Science**, is a bonafide record of the research work done by him under my supervision. 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.

Place: Mandi
Date: 3rd June 2017

Dr. Sudhir K. Pandey
Research Guide
Assistant Professor
School of Engineering
IIT-Mandi, 175 005

DECLARATION BY RESEARCH SCHOLAR

This is to certify that the thesis entitled "**DESIGN AND FABRICATION OF FULLY AUTOMATED EXPERIMENTAL SETUPS FOR CHARACTERIZATION OF THERMOELECTRIC MATERIALS**", submitted by me, to the Indian Institute of Technology Mandi, for the award of the degree of **Master of Science**, is a bonafide record of the research work done by me under the supervision of Dr. Sudhir K. Pandey. 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.

Place: Mandi
Date: 3rd June 2017

Ashutosh Patel
(En. no.: S14006)

ACKNOWLEDGEMENTS

It is my duty to acknowledge people who have helped me directly or indirectly in my work. First of all, I want to thank my thesis supervisor Dr. Sudhir K. Pandey for his constant guidance, motivation, and support. I owe my gratitude to my supervisor and lab members, whose constant support, encouragement, and healthy discussions are never forgotten. This helped me to develop self-learning skills.

I also sincerely acknowledge our workshop staffs for their help in the fabrication of the measurement setups. I am thankful to MHRD for providing fellowship to pursue the course at IIT Mandi. I acknowledge Dr. Viswanath Balakrishnan for using his lab facilities and valuable discussions with him. I also thank Dr. Bindu Radhamany for her guidance and giving me an opportunity to work in her research group which helped me to explore the different area of research. I am thankful to my APC committee members Dr. Rajeev Kumar, Dr. Md. Talha, Dr. Arpan Gupta, and Dr. Kaustav Mukherjee for their timely assessment, suggestion, and guidance which were helpful to improve myself. My sincere thanks to all my friends my parents and family members for their constant moral support and love.

ABSTRACT

In this thesis, We discuss the fabrication of the experimental setups for Seebeck coefficient (α) and thermal conductivity (κ) measurement at high temperature. We also discuss the fabrication of high temperature figure of merit ($Z\bar{T}$) measurement setup, which can measure α , κ , and electrical resistivity (ρ), simultaneously to find out $Z\bar{T}$ value. Simple design and use of minimal components make these setups compact, lightweight, and more user-friendly. A dedicated thin heater is built to heat the sample. It's small cross section ($8\text{mm}\times 8\text{mm}$) and very low thickness ($\sim 1\text{mm}$) minimizes the heat loss and further simplified the sample holder design. Heat loss value required for thermal conductivity measurement has been found out by developing a simple measurement methodology based on the parallel thermal conductance technique. Low heat loss is achieved by using gypsum insulator block and by optimizing its dimension. The requirement of more number of sensors and wires in the simultaneous measurement of α , κ , and ρ have been resolved by performing temperature as well as voltage measurements using same thermocouples. Use of commonly available low-cost materials and in-house fabrication of components including thin heater reduces the cost of the setup. It also provides low cost and easy replacement of any parts in case of damage. Low cost, lightweight, compact design, and use of minimal components are the key features of these measurement setups.

KEYWORDS: Figure of merit; Z meter; Seebeck coefficient; thermopower, Thermal conductivity; Heat loss; High temperature setup; LabVIEW; Thin heater.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	i
ABSTRACT	ii
LIST OF TABLES	v
LIST OF FIGURES	vii
1 Introduction	1
1.1 Background	1
1.1.1 Low temperature thermoelectric generator	2
1.1.2 Intermediate temperature thermoelectric generator	3
1.1.3 High temperature thermoelectric generator	3
1.2 Performance of thermoelectric devices	4
1.3 Instrumentation	5
1.3.1 Setups for high temperature Seebeck coefficient (α) measurement	9
1.3.2 Setups for high temperature thermal conductivity (κ) measurement	10
1.3.3 Setups for high temperature figure of merit ($Z\bar{T}$) measurement	11
1.4 Objective of the current thesis	13
1.5 Contribution to this thesis	14
1.6 References	15
2 Automated instrumentation for high-temperature Seebeck coefficient measurements	18
2.1 Measurement methodology	20
2.2 Measurement setup	22
2.3 Calibration of the setup using standard samples	25
2.4 Conclusion	34

2.5	References	35
3	Fabrication of setup for high temperature thermal conductivity measurement	36
3.1	Measurement methodology	37
3.2	Measurement setup	39
3.3	Calibration of the setup using standard samples	41
3.3.1	Heat loss, heat flow, and temperature gradient measurements	42
3.3.2	Thermal conductivity measurement	44
3.4	Conclusion	47
3.5	References	49
4	Fabrication of fully automated setup for high temperature thermoelectric figure-of-merit measurement	50
4.1	Measurement methodology	51
4.2	Measurement Setup	55
4.3	Calibration of the setup using standard samples	57
4.4	Conclusion	60
4.5	References	62
5	Summary and concluding remarks	63
5.1	References	66