

TABLE OF CONTENTS

CHAPTER	Page
1 INTRODUCTION	1
Motivation	1
Research Objectives	3
Scope and Limitation of the Thesis	4
Anticipated Outcomes of the Thesis	4
Thesis structure	4
References	5
2 THEORY AND LITERATURE REVIEWS	6
Thermoelectrics	6
Seebeck Effect	6
Peltier Effect	7
Thomson Effect	8
The Kelvin Relationships	8
Figure of Merit	9
Thermoelectric Materials	12
Germanium Antimony Telluride	13
Thermoelectric cell and module	16
Thermoelectric applicatons	18
Low power generation	19
High power generation	21
References	24

TABLE OF CONTENTS (continued)

CHAPTER	Page
3 METHODOLOGY	27
Sample preparation	27
Phase formation	27
Chemical composition analysis	27
Sample identification	29
Surface microstructure	31
Vicker hardness	33
Electrical resistivity.....	34
Seebeck coefficient.....	34
Thermal conductivity	35
Density.....	36
Archimedes's principle.....	37
Dimensionless figure of merit.....	37
Calculation thermoelectric properties of GeTe and Sb_2Te_3	38
Thermoelectric cell and module.....	39
Fabricaton of the thermoelectric unileg cell	40
Fabrication of the thermoelectric module.....	41
Power generation measurement of thermogenerator	42
The maximum theoretical efficiency for conversion of heat transferred...	44
Conversion efficiency of thermoelectric cell and module.....	45
Thermoelectric applications	46
Summary of investigating topics	47
Referrences.....	49

TABLE OF CONTENTS (continued)

CHAPTER	Page
4 RESULTS AND DISCUSSION	51
Sample preparation	51
Phase formation	52
Energy dispersive X-ray spectroscopy	53
Crystal structure and chemical composition of GST	57
Crystal structure and grain orientation	57
Microstructure of GST-hotpress sample	63
Vicker hardness	63
Thermoelectric properties of GST-hotpress sample	64
Electrical conductivity	64
Thermal conductivity	66
Dimensionless figure of merit	67
Electronic structure of GeTe and Sb ₂ Te ₃	69
Thermoelectric cell and module test	73
Thermoelectric applications	74
Summary	74
References	75
5 CONCLUSION	77
Phase formation	77
Chemical composition	78
Crystal structure	78
Microstructure	78
Thermoelectric properties	79
Calculation thermoelectric properties of GeTe and Sb ₂ Te ₃	79

TABLE OF CONTENTS (continued)

CHAPTER	Page
Fabrication of thermogenerator prototype	80
Application of thermogenerator install in stove fuel	80
APPENDICE A:PAPER	83
APPENDICE B: EXPERIENCE TO EXCHANGE STUDENT AT OSAKA PREFECTURE UNIVERSITY	89
APPENDICE C: INTERNATIONAL CONFERENCE	92
APPENDICE D: PUBLICATIONS	94
APPENDICE E: A BRIEF HISTORY OF RESEARCHER	98

บัณฑิตวิทยาลัย มหาวิทยาลัยราชภัฏสุรินทร์

LIST OF TABLES

Table	Page
1 Shows elemental compositions (%) of GST-hotpress company, GST-anneal, and GST-melt from literature	56
2 Room-temperature lattice parameters (a and c), lattice volume (V), and R factors (Rp and Rwp) of GST prepared by hotpressing method from company. The lattice parameter a and c were determined by Le Bail analysis.	61

บัณฑิตวิทยาลัย มหาวิทยาลัยราชภัฏสุราษฎร์ธานี

LIST OF FIGURES

Figure	Page
1 Schematic basic thermocouple	6
2 Thermoelectric generator (left); Thermoelectric refrigerator (right)	9
3 Generating efficiency as a function of temperature and thermocouple material figure-of-merit	11
4 Schematic dependence of electrical conductivity, Seebeck coefficient, power factor, and thermal conductivity on concentration of free carriers	12
5 The GeSbTe system with composition $\text{GeTe-Sb}_2\text{Te}_3$	15
6 Schematic of thermoelectric cell. The power generation from thermal of thermoelectric cell.....	17
7 Schematic of thermoelectric module, many unicouples (n/p pairs) are connected electrically in series to form a module. Heat exchangers are used on either side of the module to enhance heat transfer into/out of the TE module.vector	18
8 Conventional arrangement for thermoelectric power generation. Q1 is the heat supplied by the heat source. P is the electrical power generated. Q2 is the heat dissipated to the heat sink, which is the thermal energy wasted.	19
9 Schematic diagram of the TG-DTA system	28
10 Show TG-DTA measurement at Osaka Prefecture University.....	28

LIST OF FIGURES (Continued)

Figure	Page
11 Diffraction (i.e. constructive interference of the scattered X-rays) will occur if the Bragg condition (eq. 3.1) is fulfilled and of the scattering vector K is parallel to the normal of the hkl -planes. (Myers, 2002).....	30
12 The X-ray diffraction (XRD) measurements was performed on (left) Rigaku Smart Lab at Osaka Prefecture University and (right) Center of Excellence on Alternative Energy at Sakon Nakhon Rajabhat University.....	31
13 Schematic diagram of the FE-SEM equipment	32
14 The FE-SEM observations were performed on a Hitachi Ultra-high Resolution Scanning Electron Microscope SU8000 at Osaka Prefecture University	32
15 Vickers hardness tester Model at CEAE, Sakon Nakhon Rajabhat University....	33
16 Show ZEM-3; ULVAC Technologies apparatus.....	35
17 Show thermal conductivity was measured by using FlashTE; PicoTherm at Osaka University	36
18 Show density Kit at CEAE Sakon Nakhon Rajabhat University	37
19 Crystal structure and the Brillouin zone of (a) GeTe face centered cubic lattice (Setyawan & Curtarolo, 2010) and (b) Sb ₂ Te ₃ rhombohedral lattice structure (Yavorsky, Hinsche, Mertig, & Zahn, 2011).....	39
20 c construct of uni-legs thermoelectric module (Nemoto et al., 2012).....	40

21	Show process of fabrication the GST unileg cell.....	41
22	Shows diagram of fabrication TE-GST module	42
23	Shows schematic diagram how to measure power generation of thermoelectric module	43
24	Shows schematic diagram how to measure power generation of thermoelectric modules commercial	44
25	Shows (a) the stove fuel at rice mill industry, (b) thermoscan of area on machine and (c) schematic diagram of thermogenerator system	46
26	Show schematic diagram of thesis process	48
27	Shows a Germanium antimony telluride ingot from rare-metal material company, China and dimensions of cylindrical ingot.....	51
28	The TG and DTA vs temperature of GST-hotpress company sample (a) evaporation of Te showing at 673 K (b) the melting temperature of GST-Hotpress company showing at 873 K.....	53
29	Shows elemental mapping of GST-hotpress company, indicating apparent Ge-deviation.....	54
30	Shows EDX mapping by yellow circle we found grained were detected in GST-hotpress company sample.....	55

LIST OF FIGURES (Continued)

Figure	Page
<p>31 (a) XRD patterns of GST-hotpress company, GST-melt (Kosuga et al., 2014), and GST-anneal (Matsunaga et al., 2010). (b) Enlarged images in the range $2\theta=16-20^\circ$. The left peak corresponds to the Bragg peak of the 0 0 6 tetradymite structure (denoted T1) and the right peak is that of the 0 0 21 homologous structure (denoted H1). (c) Enlarged images of the range $2\theta=37-40^\circ$. The left peak corresponds to the Bragg peak of the 1010 tetradymite structure (denoted T2) and the right peak is that of the 1034 homologous structure (denoted H2).)</p>	58
<p>32 XRD patterns and Rietveld refinement of GST of GST-hotpress company. The dotted and solid lines represent the observed data and pattern fit, respectively. The vertical marks show the Bragg peaks of GeSb6Te10 with a homologous structure. The bottom curve was obtained the difference between the observed and calculated patterns (Namhongsa et al., 2017)</p>	60
<p>33 SEM images for GST particles prepared by a hot-pressing method (bar = 1 μm) material</p>	63
<p>34 Shows pressing of GST-hotpress company sample from the micro hardness tester.</p>	64
<p>35 Show comparison the temperature dependence of the electrical conductivity of the GST-hotpress company sample with literature data [Kosuga et al., 2015] (Namhongsa et al., 2017)</p>	65

36	Show comparison the temperature dependence of the Seebeck coefficient of GST-hotpress company sample with literature data [Kosuga et al., 2015] (Namhongsa et al., 2017)	66
37	Temperature dependence of the thermal conductivity of GST-hotpress company sample compared with literature data [Kosuga et al., 2015]...	67
38	Show temperature dependence of the dimensionless figure of merit of GST-hotpress company sample compared with literature data [Kosuga et al., 2015]	68
39	Show the structure of compound GeSb ₆ Te ₁₀ is assumed to have the stacking (Shelimova et al., 2000).....	69
40	Shows orbital projected of density of states of GeTe, GeSb ₆ Te ₁₀ , and Sb ₂ Te ₃	71
41	Show crystal structure of GeSb ₆ Te ₁₀ with homologous structure consist Ge ₁ Sb ₂ Te ₄ -type slabs and Sb ₂ Te ₃ -types slabs, respectively.....	72
42	Show crystal structure of Ge ₁ Sb ₂ Te ₄ TiO ₂	72
43	Show crystal structure of Sb ₂ Te	72
44	Show measured p-p junction 1 pair of GST thermoelectric cell.	73
45	Show measured p-p junction 15 pairs of GST thermoelectric cell	73
46	Show thermoelectric module from TEC Thermoelectric gencell technology and process of analyzed performance of 6-8 module by setting system on laboratory	74
47	Shows system and how to measured electrical power of thermoelectric module for generate lighting system.....	74
48	Show thermogenerator machine for install on stove fuel of rice dryer Machine.....	75

49 Show measured electrical power of 6–8 thermoelectric module

from commercial for generating electricity for lighting system..... 76

บัณฑิตวิทยาลัย มหาวิทยาลัยราชภัฏสุราษฎร์ธานี