CHAPTER 5

CONCLUSIONS

In this thesis, we studied generate electricity of Germanium Antimony Telluride (GST) thermoelectric material from heat source in rice mill industry. The GST material was prepared by hot pressing method from rare-metal material company. The properties of GST material have been investigated further viz physical properties, crystal structure and microstructure, and thermoelectric properties. Conclusions based on the finding of this thesis are as follows:

Research Conclusions

Phase Formation

The behavior of melting temperature of GST analyzed by using TG-DTA. The temperature of about 423-723 K in TG% line, the weight of GST-hotpress company has decreased with increasing temperature, corresponding to Tellurium has evaporation of the starting materials. In the DTA line has decreased by melting in two steps of in the weight loss at each temperature. First drop consist by Tellurium has evaporation occur, which in this part is endothermic effect of Tellurium. The second drop occurs in the temperature above 880 K consists a melting point from this part indicating relative of TG% and DTA because in this part the weight of GST-hotpress company compound have decreased to zero value with increasing temperature. The reaction described the system of GST-hotpress company absorbs energy from surrounding in measurement; usually but not always in the form of heat.

Chemical composition

From the elemental compositional analysis at each point, we found that the there is a certain tendency in the ratio of Ge, Sb, and Te. For instance, Point A (Ge: Sb: Te=6.82, 35.52, 57.67) has close value of the nominal composition of $GeSb_6Te_{10}$ (Ge: Sb :Te=5.88, 35.29, 58.82). Whereas Point B (Ge: Sb: Te=8.64, 33.78, 57.58) has higher content of Ge and lower content of Sb than that of nominal composition. Likewise, Point C (Ge: Sb: Te=0.46, 40.79, 58.75) has lower content of Ge and higher ratio of Sb, than that of nominal composition.

Crystal Structure

The performed Rietveld analysis assuming that GST-hotpress company contains the $GeSb_6Te_{10}$-type HG structure and the Sb_2Te_3-type TD structure. The obtained phase fraction ratio of the $GeSb_6Te_{10}$ structure to the Sb_2Te_3 structure is ca. 40–60wt.%. This results are indicate that GST-hotpress contains not only the $GeSb_6Te_{10}$ structure but also the Sb_2Te_3 structure. The GST has been crystal structure of is hexagonal and high intensity in (hkl) of (0017) obtained the lattice parameters of a=4.26168, b=4.26168, c=101.73 ($a=b\neq c$). It appeared that, where all the observed lines can be correspond 95%.

Microstructure

GST-hotpress company shows exhibit denser microstructure after water quenched. From this grain of samples show that a distinct layer structure with the sheet of Sb_2Te_3, consistent with the hexagonal structure. On the slab of Sb_2Te_3 consist with Ge grains. From the above, these results can be corresponding and confirm with crystal structure in literature.

Thermoelectric properties of $GeSb_6Te_{10}$ material

For GST hotpress sample was show the characteristic behavior of degenerate semiconductors. The ρ values of the GST-hotpress company sample are 0.208 $M\Omega^{-1}$ m^{-1} at 310 K to 0.0965 $M\Omega^{-1}$ m^{-1} at 664 K respectively. The GST-hotpress company shows the same tendency as GST-melt and GST-anneal, but the values are slightly different. These values are lower than that of the GST-melt and GST-anneal samples of Kosuga *et al.* 0.241 $M\Omega^{-1}$ m^{-1} and 0.551 $M\Omega^{-1}$ m^{-1} respectively, which was prepared by spark plasma sintering. The S values of these samples are positively, indicating p-type conduction. The S values of GST-hotpress was increases with increasing temperature from 17.9μV K^{-1} at 310 K to 67.8μV K^{-1} at 664 K, respectively. The κ values of the GST-hotpress company were be similar to GST-anneal from literature data. The κ values GST-hotpress company sample is 3.4 $Wm^{-1}K^{-1}$, 2.48 $Wm^{-1}K^{-1}$ at 300 K, 623 K, respectively. The GST material possess typical metallic behavior with p-type electrical conduction. The optimum amount of GST-hotpress for maximizing should be around ZT = 0.1 at 623 K.

Calculations thermoelectric properties.

The Ge-Sb-Te (GST) materials have a rhombohedral structure mixture between $(GeTe)_n(Sb_2Te_3)m$ homologous (HG) compounds. The GST materials are compound very narrow band gaps semiconductors in the energy range 0.20-2.80 eV and highly regarded as good performance TE materials. We calculated thermoelelctric properties of GeTe and Sb_2Te_3 system using the density functional theory (DFT) and Boltzmann transport theory calculations based on QUANTUM ESPRESSO and BoltzTraP package. The band structure of GeTe show direct band gap 0.47 eV at L-point, meanwhile, Sb_2Te_3 show direct band gap 0.19 eV at Γ-point. The Seebeck coefficient, electrical conductivity, thermal conductivity and power factor dependent on Fermi energy were predicted for future experimental of Ge-Sb-Te materials. Our calculated show the highest power factor of GeTe with value.

Fabrication of thermogenerator prototype from $GeSb_6Te_{10}$ thermoelectric material. Thermoelectric cell and module from GST-hotpress company shows slightly values can't generate electricity for lighting system. The electrical power of GST-hotpress company cell (one pair) unileg has voltage around 0.006 Volt, GST-hotpress company module (16 pairs) unileg has voltage around 0.010 Volt at temperature difference around 100 degree celcius, respectively.

Application of thermogenerator prototype bring to industry of Sri Sakon Pure Rice Rice Co.,Ltd. at Sakon Nakhon province, Thailand.

For thermogenerator prototype application we invented machine consist with thermoelectric module from commercial around 8 modules, four heat sinks and four ventilation fan stick on stainless steel wire. The highest value of electrical power is 9 Watt at temperature difference around 112 degree Celsius per 8 modules. The electrical power can be generate electricity for two light bulbs on these system. As these results of the findings in this research, suggestions for future studies could be the following:

1. Germanium antimony telluride (GST materials) discussed as high performance TE, because of a long crystal structure consist with two type of slab caus GST compound have a good electrical properties and low thermal conductivity.

2. The thermoelectric generator can be generate electricity from another waste heat source in industry. The innovated thermoelectric generator from GST or BiTe group can be used with low temperature and have a good thermoelectric properties. In the other hand, the generated current for turn on the light has a lowest value. In the future, the properties of GST material can be applied and developed to innovation for generated the highly electricity.