Thermal conductivity measurements of Sb-Te alloys by hot strip method

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Abstract

The thermal conductivities of Sb-*x* at%Te alloys (x = 14, 25, 44, 60, 70 and 90) have been measured by the hot strip method from room temperature up to temperature just below the respective melting points. For the intermetallic compound Sb_2Te_3 (x = 60), the thermal conductivity decreases up to approximately 600 K and then increases. For other Sb-*x* at%Te alloys where $x > 60$, the thermal conductivities of the alloys decrease with increasing temperature. In contrast, for $x < 60$, the thermal conductivities of the alloys keep roughly constant up to approximately 600 K and then increase with increasing temperature. It is proposed that free electron dominates the heat transport below 600 K and ambipolar diffusion also contributes to the increase in the thermal conductivity at higher temperatures.

Key words : Thermal conductivity, Sb-*x* at%Te alloys, hot strip method, Phase change materials

1. INTRODUCTION

Phase change random access memory (PCRAM) is a promising nonvolatile data storage technology for next generation memory[1)]. Sb-Te binary alloys have been suggested to be suitable candidates for PCM devices because of a dramatic change in electric resistivities associated with transformation between amorphous and crystalline phases, which forms the basis for data storage[2, 3)]. The phase transformation is controlled by Joule-heating and cooling processes and, thus, accurate data for thermal conductivity of Sb-Te binary alloys are indispensable to optimal designing for PCM devices. The present work aims to determine thermal conductivities of Sb-Te binary alloys as functions of temperature and composition.

2. EXPERIMENTAL

Samples used were Sb-*x* at% Te (x = 14, 25, 44, 60, 70, and 90). Thermal conductivity was measured by the hot strip method[4)], a schematic diagram of the apparatus is in Fig. 1. Cylindrical samples of Sb-Te (20 mm diameter and 40-50 mm length) were prepared from Sb (99.9 mass%) and Te (99.9 mass%) powders except for Sb_2Te_3, which was produced by Kojundo Chemical Laboratory. Thermal conductivity measurements were conducted in argon atmosphere from 298 K up to temperatures just below the respective melting points.

3. RESULTS & DISCUSSION

According to the phase diagram, the alloys fall into three groups: Sb_2Te_3, alloys having $x < 60$ and alloys having $x > 60$. The second and last groups are named Sb-rich and Te-rich alloys for convenience, respectively. Fig. 2 shows the temperature dependence of Sb-rich alloys together with the data for Sb obtained by Konno et al.[5)]. It can be seen that the thermal conductivities of all Sb-rich alloys keep roughly constant below approximately 600 K and, above 600 K, increase with increasing temperature. The thermal conductivities of the Sb-rich alloys decrease with increasing Te concentration. Fig. 3 shows the temperature dependence of thermal conductivities for the Te-rich alloys together with the data for Sb_2Te_3. It can be seen that the thermal conductivity of Sb_2Te_3 has interesting temperature dependence: it decreases with increasing temperature up to approximately 600 K and then decreases. The thermal conductivities of the Te-rich alloys decrease with temperature increase until their melting points are attained, and this behavior is similar to that of Sb_2Te_3 below 600 K. The temperature dependencies of the Te-rich alloys are quite close to each other although the magnitude of thermal conductivity decreases with the Te concentration increase. It can be seen in Figs. 2 and 3 that the thermal conductivities have quite different temperature dependences below and above 600 K. Below 600 K, free electrons are supposed to dominate the heat conduction and thus the W-F law[6, 7] would be applied. The ambipolar diffusion[8] is more effective at higher temperature and contributes to the increase of thermal conductivity.

4. CONCLUSIONS

The thermal conductivities of Sb-x mol%Te alloys (x = 14, 25, 44, 60, 70 and 90) have been measured by the hot strip method. The heat conduction mechanisms have been discussed based on the thermal conductivity data. It is proposed that free electrons dominate the heat transport below 600 K and ambipolar diffusion contributes to the increase in the thermal conductivity at higher temperatures.

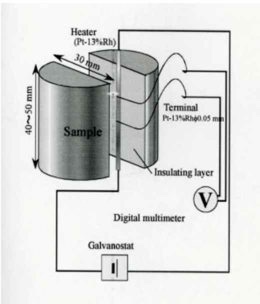

Fig. 1 Schematic diagram for hot strip method

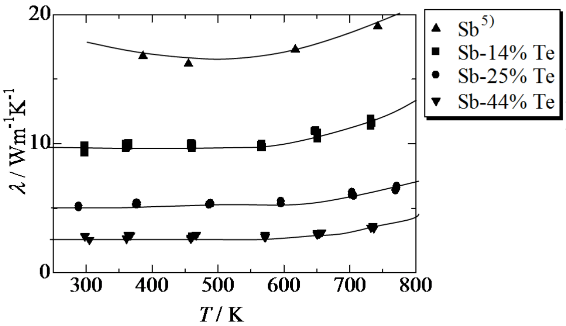

Fig. 2 Thermal conductivities of Sb-rich samples as function of temperature

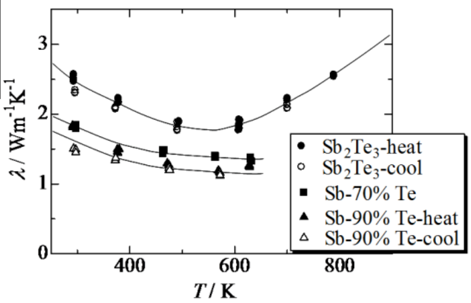

Fig. 3 Thermal conductivities of Te-rich alloys as function of temperature

REFERENCES

1) S. Lai, IEDM Tech. Dig. 2003, p. 10.1.1. 2) H. J. Borg, M. van Schijindel, and J. C. N. Rijpers, Jpn. J. Appl. Phys. 40, 1592 (2001). 3) N. Oomachi, S. Ashida, and N. Nakamura, Jpn. J. Appl. Phys. 41, 1695 (2002). 4) R. Lan, R. Endo, M. Kuwahara, Y. Kobayashi, and M. Susa, Jpn. J. Appl. Phys. 49, 078003 (2010). 5) S. Konno, Sci. Repts. Tohoku Imp. Univ. 8, 169 (1919). 6) G. Wiedemann and R. Franz, Annalen der Physik und Chemie, 89, 497 (1853). 7) L. Lorenz, Annalen der Physik und Chemie, 13, 422 (1881). 8) J. M. Ziman, Electrons and Phonons, (Clarendon Press, Oxford, 1960), pp.427.

Biography

Rui Lan graduated from Dalian University of Technology with a bachelor's degree in China in 2005. In 2007 she achieved the Japanese government scholarship and entered Tokyo Institute of Technology in Japan. She obtained the degree of master of engineering in Tokyo Institute of Technology in 2009. Since then, she has been investigating the thermophysical properties of phase change materials Sb-Te and Ge-Sb-Te alloys as the content of her doctor thesis. She will expect a PhD from Tokyo Institute of Technology in March, 2012.