

Electric resistivity for molten Sb-Te and Sb₂Te₃-GeTe systems

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ABSTRACT

The aims of this study are to measure electric resistivity of the molten Sb₂Te₃-GeTe pseudo binary system and to investigate the compositional dependence of electric resistivity. The samples used were Sb₂Te₃, GeSb₄Te₇, GeSb₂Te₄, Ge₂Sb₂Te₅ and GeTe. The measurements were conducted using the four-terminal method over temperature ranges between the respective melting temperatures of the samples and 1150 K during both cooling and heating cycles. Electric resistivity for all the samples decreased with increasing temperature, suggesting that the samples are liquid semiconductors. In the Sb-Te system, Sb₂Te₃ had the largest electric resistivity at a certain temperature; on the other hand, significant compositional dependence was not found in the Sb₂Te₃-GeTe system. The compositional dependence of electric resistivity is explained from the viewpoints of enthalpy of mixing.

Keywords Sb-Te alloy, Phase Change Memory, Electric resistivity, liquid

1. INTRODUCTION

The chalcogenides in the Sb-Te and Sb₂Te₃-GeTe binary systems are used as phase change materials (PCM) in phase-change random access memory (PRAM). PRAM devices require electric resistivity of PCMs in both solid and liquid states for optimal operation. The electric resistivity for molten Sb-Te binary system was reported in the previous work[1]. Therefore, the aims of this study are to measure electric resistivity of the molten Sb₂Te₃-GeTe pseudo binary system and to investigate the compositional dependence of the electric resistivity.

2. EXPERIMENTAL

Samples used in this study were Sb₂Te₃, GeSb₄Te₇, GeSb₂Te₄, Ge₂Sb₂Te₅ and GeTe: all of these compositions are in Sb₂Te₃-GeTe pseudo binary system. Reagent grade Sb₂Te₃ and GeTe powders were weighed to the desired compositions and mixed in an alumina mortar. Electric resistivities were measured using the four-terminal method[2] over temperature ranges between the respective melting temperatures of the samples and 1150 K during both cooling and heating cycles.

3. RESULTS AND DISCUSSION

Figure 1 shows the electric resistivity of solid and liquid GeSb_2Te_4 : the values for liquid are measured in this study and those for solid are reported by Konstantinov et al[3]. The electric resistivity increases with increasing temperature up to about 750 K, which temperature dependence is same as that for metal. However, above 750 K, the electric resistivity decreases with increasing temperature in both solid and liquid states, which temperature dependence is same as that for semiconducting Si. Furthermore, the electric resistivity decreases drastically associated with melting. This temperature dependence of electric resistivity was also observed for other samples. Figure 2 shows Te concentration dependence of electric resistivity for Sb-Te system at 935 K. Sb_2Te_3 has the largest electric resistivity. Figure 3 shows GeTe concentration dependence of electric resistivity for Sb_2Te_3 -GeTe system at 1070 K. GeSb_2Te_4 shows the largest electric resistivity; however, the compositional dependence is not significant compared with that for Sb-Te system. To investigate the compositional dependence for electric resistivity for both systems, firstly, the activation energy for electric conduction was calculated for all the samples in liquid states on the basis of the following equation:

$$\sigma = \sigma_0 \exp\left(-\frac{E_a}{kT}\right)$$

where σ , σ_0 , k and T represent electric conductivity, *i.e.* the reciprocal of electric resistivity, a constant, Boltzmann's constant, and temperature. The calculated value of E_a showed correlation with electric resistivity: sample which has larger electric resistivity showed greater activation energy. The activation energy would relate to bonding energy between atoms, which can be evaluated from enthalpy of mixing. Figures 4 and 5 show enthalpy of mixing for Sb-Te and Sb_2Te_3 -GeTe systems[5], respectively. Sb_2Te_3 , *i.e.* Sb-60%Te, shows the smallest enthalpy of mixing in figure 4. This suggests that covalent bondings are formed in the mixture of Sb-Te, and the intermediate compound has the largest number of such bonding. In Sb_2Te_3 -GeTe system, the enthalpy of mixing shows no significant compositional dependence, which suggests that covalent bondings are not formed by mixing Sb_2Te_3 and GeTe. These finding suggests that the formation of covalent bonds decreases the number of carriers resulting in increase of electric resistivity.

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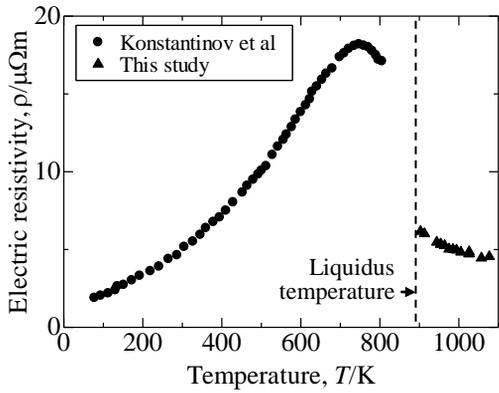


Fig. 1 Electric resistivity of GeSb_2Te_4 as a function of temperature with reported values by Konstantinov et al[3]

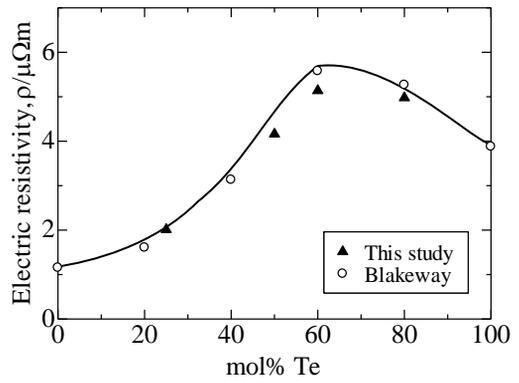


Fig. 2 Te concentration dependence of electric resistivity of Sb-Te system at 935 K with reported value by Blakeway[4]

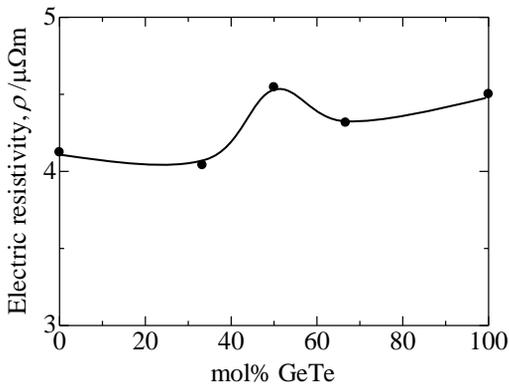


Fig. 3 Electric resistivity of Sb_2Te_3 -GeTe system at 1070 K as function of GeTe concentration

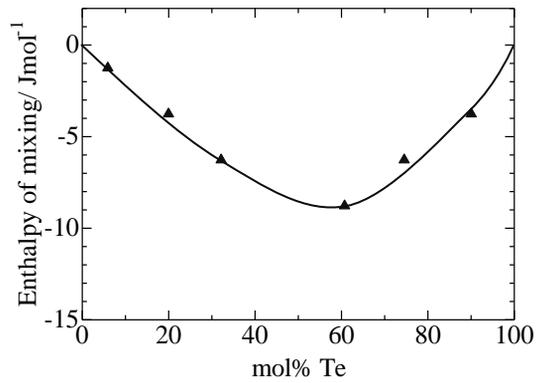


Fig. 4 Enthalpy of mixing for Sb-Te system as a function of Te concentration [5]

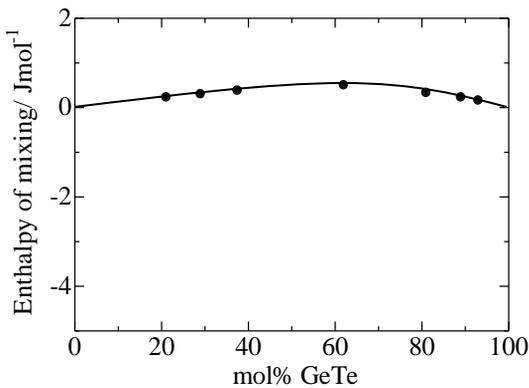


Fig. 5 Enthalpy of mixing for Sb_2Te_3 -GeTe system as a function of GeTe concentration [5]