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Transport and Thermal Properties of Amorphous Mn-Y Alloys

Manabu Ikebe[a], Hiroyuki Fujishiro[a], Yoshihisa Obi[b], Hiroyasu Fujimori[b] and Koshichi Noto[a]

[a] Faculty of Engineering, Iwate University, 4-3-5, Ueda, Morioka 020, Japan
[b] Institute for Materials Research, Tohoku University, Aoba-ku, Sendai 980, Japan

The thermal conductivity κ, thermal diffusivity α and electrical resistivity ρ were measured between 15K and 150K for $Mn_{100-X}Y_X$ binary amorphous alloys which were prepared by high rate dc sputtering. α was measured quasi-simultaneously with κ by an arbitrary heating method. No anomaly associated with spin glass transition was observed in transport properties. The specific heat C was estimated from the relation $C = \kappa/\alpha$, which indicated the Debye temperature $\Theta_D \approx 250K$ for $Mn_{52}Y_{48}$.

1. INTRODUCTION

Magnetic properties of Mn atoms in amorphous alloys strongly depend on their mutual distance and environment. As a result, Mn based binary amorphous alloys exhibit various interesting properties from the viewpoint of the magnetism [1-4]. Magnetic properties of amorphous $Mn_{100-X}Y_X$ alloys were previously investigated by the present authors [3]. The ac-susceptibility measurement suggested a monotonic decrease of the spin glass transition temperature T_G with increasing Y concentration X. This paper reports the results of the thermal and the electrical transport measurement on Mn-Y amorphous system. The electron and phonon contributions to the thermal conductivity κ were separated by use of the Wiedemann-Franz law. The specific heat C was estimated from the ratio of the conductivity and diffusivity. Studies on the thermal transport in metallic amorphous systems are scarce and accumulation of the data seems to be necessary.

2. EXPERIMENTAL

Amorphous Mn-Y alloys were prepared in bulk forms by a high rate dc-sputtering technique. All the samples were confirmed to have an amorphous structure by X-ray diffraction and compositions were determined by chemical analyses. Typical sample dimensions were ~ 3 x 0.3 x 12mm^3 with a total weight ~50mg. The electrical resistivity ρ was measured by a standard four-terminal method and the thermal conductivity κ was measured by a steady state heat flow method [5]. AuFe(0.07at.%)-chromel thermocouples were used as thermometers. For a typical sample ($Mn_{52}Y_{48}$) the thermal diffusivity α was also measured by an arbitrary heating method developed by the present authors [6,7]. For all the measurements, a Gifford-McMahon cycle He refrigerator was used as a cryostat.

3. RESULTS AND DISCUSSION

Fig. 1 shows ρ vs. temperature T for $Mn_{57}Y_{43}$, $Mn_{52}Y_{48}$ and $Mn_{37}Y_{63}$. The observed ρ values are about 300μΩcm at 15K and about 260μΩcm at 280K for all the samples. Relatively large values of ρ with a negative temperature coefficient are considered to come from the amorphous structure of the present Mn-Y alloys. According to our previous report, T_G values of $Mn_{57}Y_{43}$, $Mn_{52}Y_{48}$ and $Mn_{37}Y_{63}$ were estimated to be about 40K, 35K and 25K, respectively. No anomaly was observed in the ρ vs. T curves associated with the spin glass transition.

Fig. 2 shows κ vs. T curves for the corresponding samples. The κ values of Mn-Y are also very small for a metallic system, which may also be regarded as a characteristic of an amorphous structure. No anomalous behavior of κ was observed around T_G either.

In Fig. 3 we devided κ of $Mn_{52}Y_{48}$ into the electronic component κ_e and the phonon component κ_{ph}.

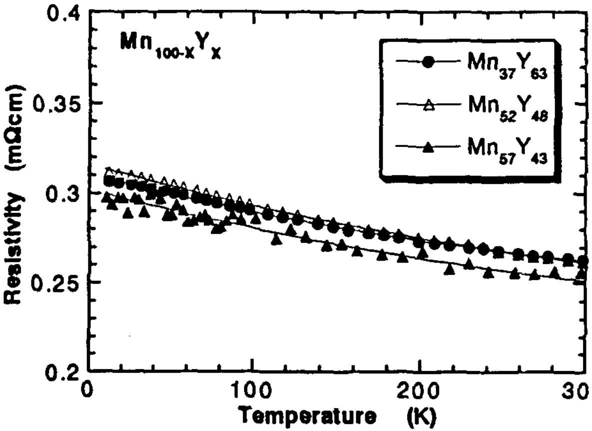

Fig. 1. Temperature dependence of the electrical resistivity of $Mn_{100-X}Y_X$.

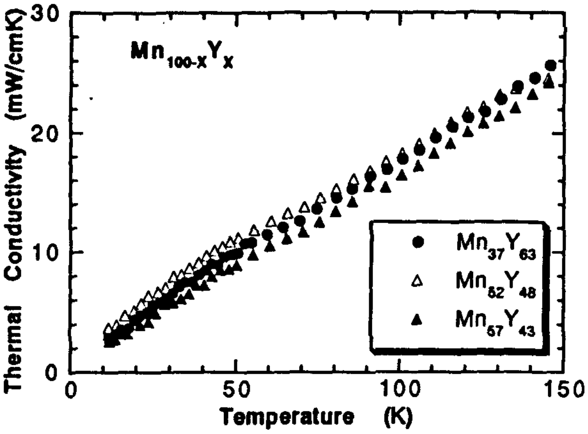

Fig. 2. Temperature dependence of the thermal conductivity.

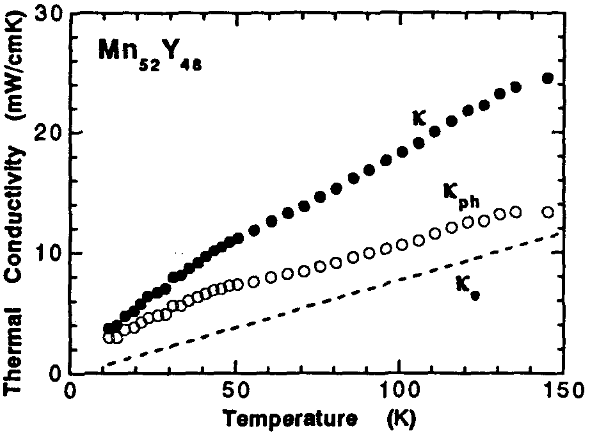

Fig. 3. Total κ, the electronic contribution κ_e and the phonon contribution κ_{ph} of $Mn_{52}Y_{48}$.

κ_e was estimated from the Wiedemann-Franz law,

$$\kappa_e(T)=L_0T/\rho(T), \qquad (1)$$

where L_0(=2.45 × 10^{-8} Watt ohm cm/deg) is the Lorentz number. The values of $\kappa_e(T)$ were almost the same for the present three MnY amorphous alloys because of almost the same ρ values in Fig. 1. κ_{ph} (=$\kappa-\kappa_e$) slightly surpassed κ_e at high temperatures above 100K. κ_{ph}, however, became overwhelmingly dominant in the low temperature region below 50K.

In Fig. 4, we show the thermal diffusivity α of $Mn_{52}Y_{48}$ which was measured quasi-simultaneously with κ under an identical experimental setup [6,7]. The specific heat C (per unit volume) can be estimated from the relation C=κ/α. The molar specific heat C_M of $Mn_{52}Y_{48}$ was determined by use of the measured density d=5.0g/cm^3. The result is plotted also in Fig. 4. The behavior of C_M corresponds to Debye temperature Θ_D~250K, though the estimation of the absolute value of C_M is not very accurate due to possible ±5% error in every κ, α and d determination.

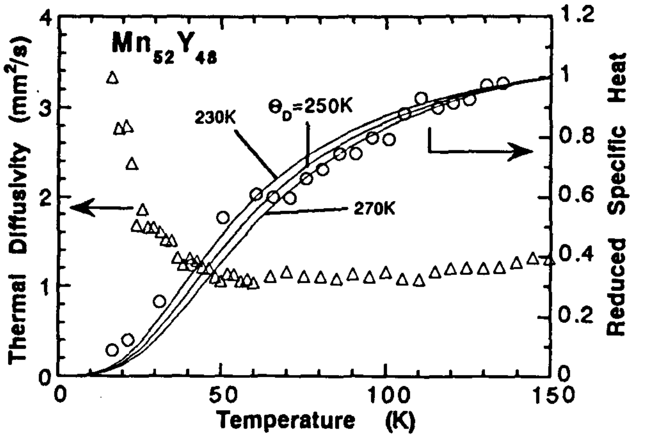

Fig. 4. The thermal diffusivity and the estimated specific heat of $Mn_{52}Y_{48}$ as a function of temperature. The value of the specific heat is normalized by the measured one at 150K (~27J/molK). Debye specific heat curves are shown for comparison.

4. SUMMARY

The transport and the thermal properties of an amorphous spin glass system $Mn_{100-X}Y_X$ were studied. No anomaly accompanied with the spin glass transition was confirmed in the transport properties. The absence of anomaly near T_G in the phonon thermal conductivity may indicate that the phonon-spin coupling is not so strong in amorphous Mn-Y system. Quasi-simultaneous measurement of κ and α enabled us to determine the specific heat of the sputtered amorphous alloy with weight of only about 50mg. The Debye temperature of $Mn_{52}Y_{48}$ is estimated to be 250K from the specific heat.

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