LETTERS TO THE EDITOR

Electrical Resistivity of In-Heusler Cu$_{2.0}$Mn$_{0.94}$In$_{1.0}$ Single Crystal

The intermetallic compound Cu$_2$MnIn is one of the Heusler alloys well known$^{(1)-(3)}$ as ferromagnetic alloys composed exclusively of non magnetic elements. However, the electrical properties of the alloys have not been studied in details. The purpose of the present report is to present our data on the electrical resistivity of an In-Heusler Cu$_{2.0}$Mn$_{0.94}$In$_{1.0}$ single crystal.

The purities of the elements used were 99.9% for electrolytic manganese, 99.9% for oxygen free copper plate and 99.9% for indium. Stoichiometric amounts of these elements corresponding to the composition Cu$_2$MnIn were sealed in an evacuated silica tube and melted 1200°C for 30 min and annealed at 600°C for 4 d. X-ray analysis of the product thus prepared revealed that it has a Heusler alloy type structure consistent with the results of other workers$^{(1)(2)}$.

The single crystal of the present experiment was grown by the Bridgman method. The product was resealed in an evacuated silica tube and moved down in a siliconit furnace at a speed of 5 mm/h. A single crystal about 25 mm in length and 15 mm in diameter was obtained. The composition of this compound was determined as Cu$_{2.0}$Mn$_{0.94}$In$_{1.0}$ by chemical analysis. The size of the samples was about 1.0 x 1.0 x 5.0 mm$^3$ for the magnetic measurement and 0.9 x 0.9 x 8.0 mm$^3$ for the electrical measurement. The magnetization was measured with a Foner type magnetometer in the temperature range from 293 to 600 K. Figure 1(b) shows the result for $H/\parallel[100]$. The same curves within the error were also observed for the [110] and [111] directions. The Curie temperature was estimated to be 530 K which is in agreement with other reports.

The electrical resistivity for prepared samples was measured by a four-terminal method in the temperature range from 4.2 to 750 K. The result in the case of current parallel to the [100] axis is shown in Fig. 1(a). The Anisotropy of electrical resistivity could not be observed. In the figure, the change in the slope of the electrical resistivity vs temperature is seen near 530 K corresponding to the ferromagnetic Curie point. On the assumption that the total resistivity $\rho_T$ is given by the sum of the residual part $\rho_0$, the phonon part $\rho_G$ and the spin disorder part $\rho_{mag}$, we obtain the following expression:

$$\rho_T = \rho_0 + \rho_G + \rho_{mag}.$$

We can separate them from each other, as shown by the dotted line in the figure and thus we obtained $4 \times 10^{-8}$ $\Omega$-m for $\rho_0$, $4.5 \times 10^{-10}$ $\Omega$-m/deg for $d\rho_G/dT$ and $59 \times 10^{-8}$ $\Omega$-m for $\rho_{mag}$. Small residual resistivity suggests that the crystal may be a single phase of the well ordered Heusler structure. The values of

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\[ \frac{d\rho_G}{dT} \text{ and } \rho_{\text{mag}} \text{ may be reasonably compared with those of Cu}_{0.15}\text{Mn}_{0.85} \text{ alloy}^{(4)}. \]

Assuming a simple model for spin disorder resistivity, the relation between the electrical resistivity of magnetic scattering term \( \rho_{\text{mag}} \) and the effective exchange coupling constant of magnetic spins \( J_{\text{eff}} \) can be represented by

\[ \rho_{\text{mag}} = 4.3 \times 10^{-4} \times \left( \frac{10^{23}}{N} \right) S(S + 1) \times J_{\text{eff}}/\varepsilon_0, \]

where \( N \) is the number of magnetic atoms per unit volume, \( S \) the magnetic spin and \( \varepsilon_0 \) the Fermi energy. From our results, the effective exchange coupling constant \( J_{\text{eff}} \) was estimated to be \( 0.2 \text{ eV} \), where the values of \( N = 1.69 \times 10^{28}/\ell \), \( S = 4.04/2 \) and \( \varepsilon_0 = 8 \text{ eV} \) were used. This value seems to be reasonable compared with the other ferromagnetic substances\(^{(5)}\).

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REFERENCES


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