Hall Effect in Rare Earth Intermetallic Compounds TbAg_<1-x>In_x

Hall Effect in Rare Earth Intermetallic Compounds $TbAg_{1-x}In_x$

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Synopsis

The Hall effect has been observed on the polycrystals of rare earth intermetallic compounds $TbAg_{1-x}In_x$ in the paramagnetic temperature range.

The ordinary Hall coefficients R_0 are positive for all compounds and these values cannot be interpreted satisfactorily by the free electron model. The spontaneous Hall coefficients R_S are larger by about three orders of magnitude than the values of R_0. It is shown that R_S depends strongly on the residual reristivity for the compounds which has x larger than 0.1.

Rare earth intermetallic compounds $TbAg_{1-x}In_x$ exhibit the cubic CsCl structure between $x=0$ and $x=0.5$. The magnetic structure of this system is antiferromagnetic with $(\pi\pi 0)$ mode between $x=0$ and $x\fallingdotseq 0.3$, and (00π) mode between $x\fallingdotseq 0.3$ and $x=0.5$.[1] The Néel temperature has a minimum in the vicinity of $x=0.3$ at which the mode of magnetic structure changes. For all the compounds, the paramagnetic susceptibility obeys the Curie Weiss law. The paramagnetic Curie temperature is negative in silver rich side, increases monotonically with increasing x, and changes its sign to positive at $x=0.15$.

The magnetic ordering in rare earth metals and compounds is believed to take place by the indirect exchange interaction of the RKKY-type between the 4-f electrons via polarization of the conduction electrons.

This preliminary report is concerned with the measurements of the Hall effect of these compounds. The measurements were made to obtain informations on the relation between the conduction electoron and the magnetic properties, and on the relation between R_S on one hand, and R_0 and the resistivity on the other.

The polycrystalline specimens used in this experiment were prepared by a plasma-jet melting of stoichiometric mixture of rare earth metal, silver and indium metal in argon atmosphere. The purities of the elements were 99.9,

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99.999 and 99.999% for Tb, Ag and In, respectively. After anealing at 700℃ for one day in high vacuum, all the specimens were examined by x-ray diffraction to have a single phase. Each specimen was shaped into a thin plate of 0.3 mm x 3 mm x 15 mm in size. The thickness of the specimen was measured with an accuracy of ± 1/1000 mm, using a dial comparater.

The d-c Hall voltage was determined by standard two－probe technique. The sensitivity of the d-c voltmeter used in this measurement was 10^{-8}V, which was TR-6555 type manufactured by Takeda Riken Co., Ltd.. Copper wires of 0.2 mm in diameter were spot-welded onto the specimen as the probes. Measurements were made in the fields up to 15 kOe and in the paramagnetic temperature range from 77 K to room temperature. The magnetoresistance effect and the thermomagnetic effect were cancelled out by taking the arithmetical average of the observed four values in the reversal of the field direction and the current direction.

The probable error in the determination of the Hall coefficient was ± 2 %.

The Hall resistivity ρ_H is satisfactorily represented by the empirical formula

$$\rho_H = R_0 H + R_1 M$$

$$R_1 = (4\pi - N)R_0 + R_S \qquad (1)$$

where R_0 and R_S are the ordinary and spontaneous Hall coefficients, respectively. N is the demagnetizing facter, which is nearly equal to 4π in our specimens. In the paramagnetic region

$$M = \chi H = \frac{C}{T-\theta} H, \qquad \text{and eq(1) becomes}$$

$$\rho_H = R_0 H + R_S C(T-\theta)^{-1} H$$

$$\frac{\rho H}{H} = R_0 + R_S C(T-\theta)^{-1} \qquad (2)$$

where C is the Curie constant and θ is the paramagnetic Curie temperature.

As a result of measurement on each specimen, the Hall resistivity was found to be proportional to the applied field. In Fig. 1, ρ_H/H are plotted against $(T-\theta)^{-1}$ for this system. The linear dependence of ρ_H/H on $(T-\theta)^{-1}$ implies that the Hall resistivity is well expressed by eq (2). The value of R_0 can be obtained as the intersection of the extrapolation of the line to the ordinate, and R_S as the gradient divided by C.

In Fig. 2, R_0 and R_S are plotted against x. R_0 is positive for all the

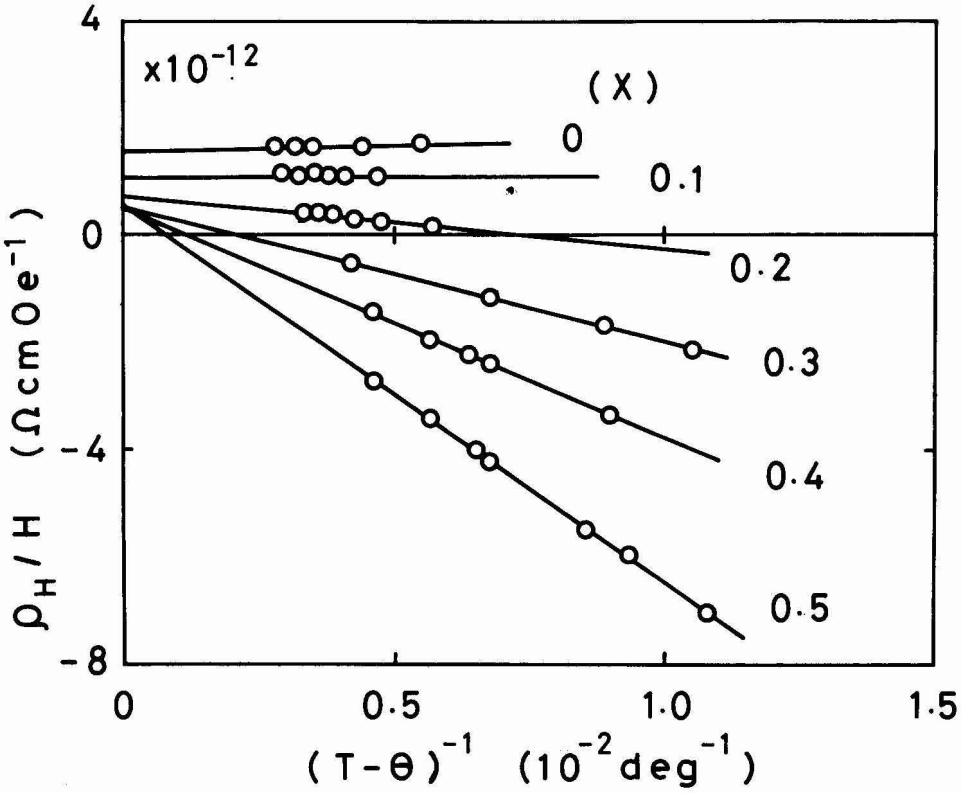

Fig. 1 The plots of ρ_H/H against $(T-\theta)^{-1}$ for $Tb Ag_{1-x} In_x$ compounds.

compounds. This suggests that charge carriers are dominantly hole like. These values of R_0 differ from the value of $R_0=(nec)^{-1}$ based on the one band model, in which all the valence electrons are assumed to become the conduction electrons. These results suggest that the Fermi surfaces are not like free electoron. But as all R_0 have the same sign, and the values do not change so much, all the compounds might have the similar electron configuration in spite of the difference in the carrier concentration. R_0 has a minimum in the vicinity of the In concentration at which the Néel temperature has a minimum. This suggests that the magnetic property is closely related to the carrier concentration. In order to get more detailed information about electron configuration of these compounds, measurements of the magnetoresistance effect were carried out. Those results and discussion will appear elsewhere in the near future.

The values of R_S are greater by about three orders of magnitude than those of R_0. R_S is positive in the compound $x=0$ and decreases with increasing x and changes its sign to negative around $x=0.1$.

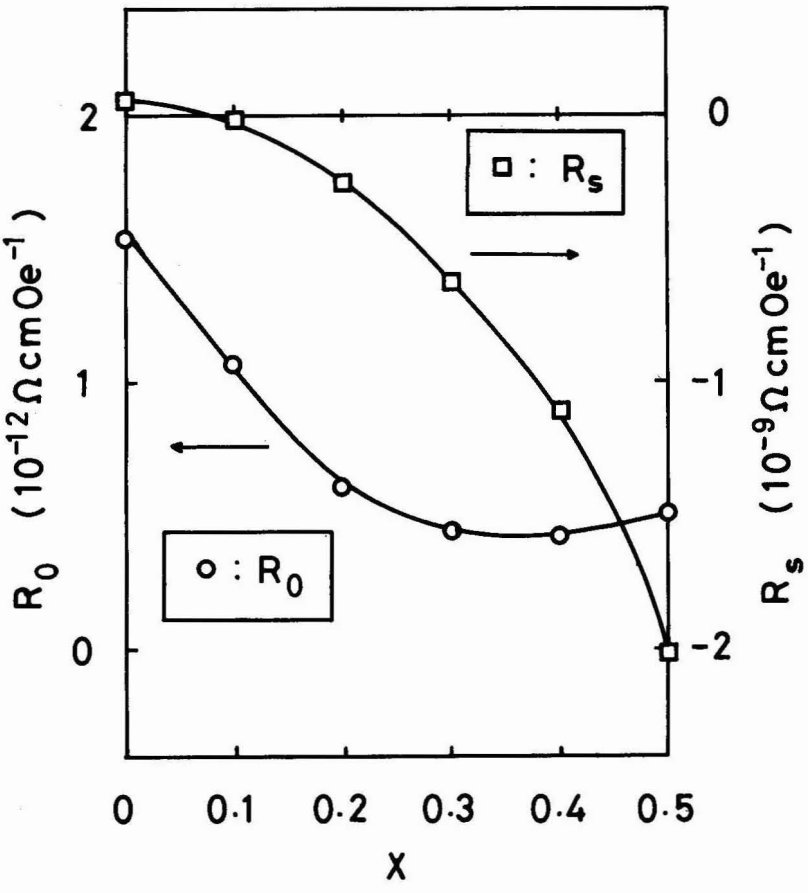

Fig. 2 The plots of ordinary Hall coefficient R_0 and spontaneous Hall coefficient R_s agaist In content x.

Generally, R_S is considered to be due to phonon[2], magnetic spin[3),4),5)] and impurity[6),7)]. In this experiment, the contribution from the phonon can be neglected because R_S is obtained as a constant of no temperature dependence.

In many of the theories treating the magnetic contribution to R_S, it is proposed that R_S has the same sign as R_0[8),9)]. It was shown experimentally that R_S has the same sign as R_0 in typical magnetic metals, such as iron, nickel[10)], heavy rare earth metals[11)]. But the relation does not hold in general for alloys and compounds, where it can be considered that other contributions are superimposed on the magnetic effect. One of these contributions may come from impurities.

In this system, the only compound in which R_S has the same sign as R_0 is

TbAg or $x=0$. The residual resistivity of $x=0$ is smaller by one or two orders of magnitude than those of $x \geqq 0.1$, and its value is comparable to that of Tb metal [12]. Then it could be said that, in $x=0$, the magnetic effect is dominant as in heavy rare earth metals [11], but in $x \geqq 0.1$, the impurity effect is not small.

In Fig. 3, the value of R_S subtracted that of $x=0$ is plotted against the

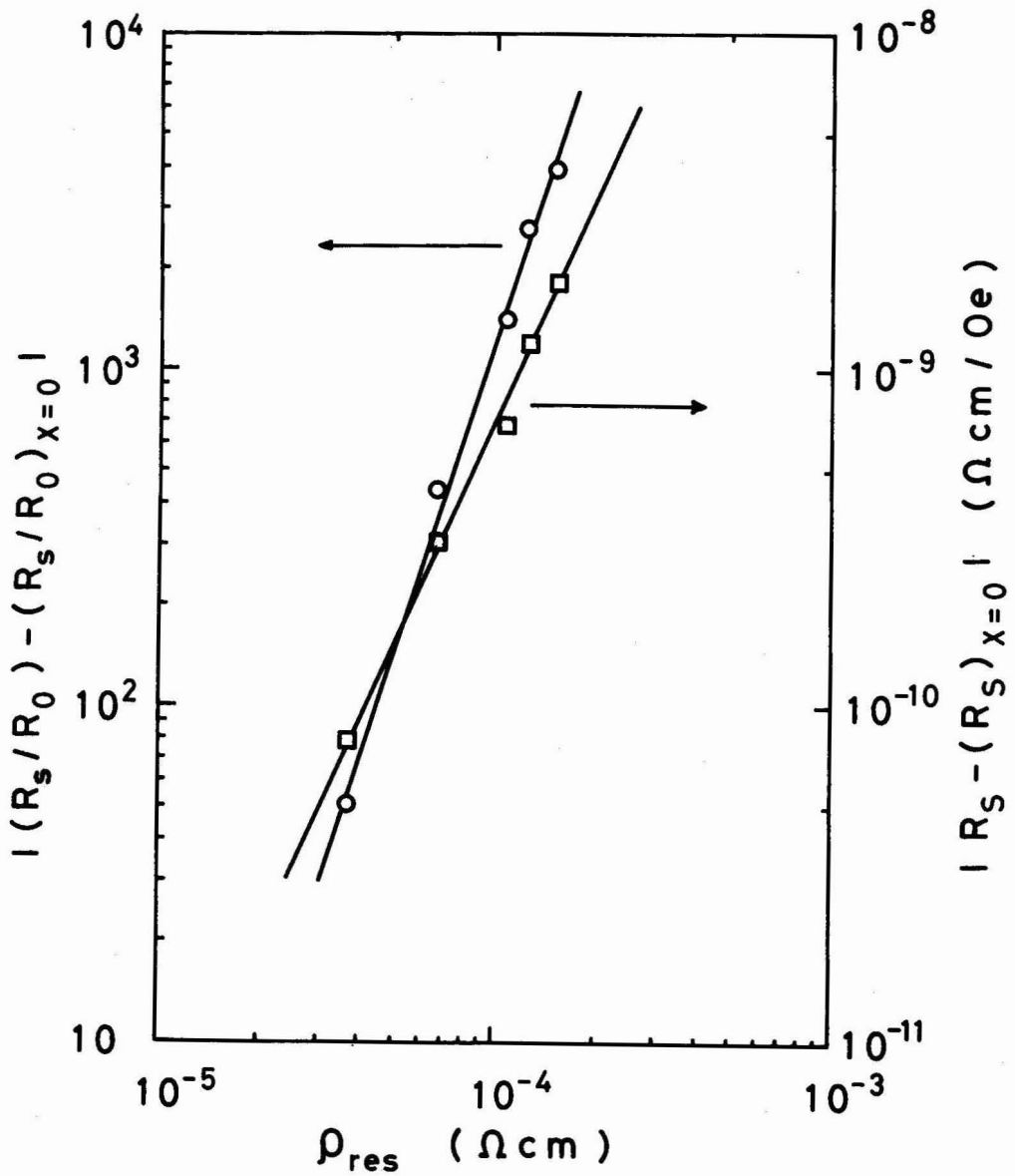

Fig. 3 The plots of R_S/R_0 and R_S subtracted those of $x=0$ against ρ_{res} in logarithmic scale.

residual resistivity ρ_{res} in logarithmic scale.

Further, according to Maranzana[5] who treated the magnetic effect on the basis of localized-spin model, R_S of the magnetic semiconductor, in which the carrier concentration depends on temperature, is proportional to R_0. Svirina et al. showed experimentally that the temperature dependence of R_S of the ferrites is proportional to R_0[13]. These suggest that the difference in the carrier concentration might be necessary to be considered in comparing R_S of compounds in this system. Thus, the ratio of R_S to R_0 subtracted that of $x=0$ is plotted against ρ_{res} at the same time in Fig. 3.

Both logarithmic values of R_S and R_S/R_0 depend almost linearly on log ρ_{res}. R_S and R_S/R_0 are proportional to 2.2 powers and 3.0 powers of ρ_{res}, respectively.

It should be noted that R_S and R_S/R_0 are also dependent on 2.5 and 4.0 powers of $(\rho_{res}+\rho_{mag})$, respectively, where ρ_{mag} is the magnetic resistivity in paramagnetic temperature range.

From the results described above, it is concluded that the impurity effect may be very large. But it cannot be drawn any conclusion pertaining to the relation between R_S and R_0, and between magnetic and impurity effects, because the number of experimental data is not sufficient.

To get more detailed information, the measurements on the similar compounds are in progress.

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