MAGNETIC AND ELECTRIC PROPERTIES OF INTERMETALLIC COMPOUNDS RCu4Pd (R = Gd, Tb, Dy, Ho AND Er)

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Abstract. – The magnetic and electric properties are studied for the intermetallic compounds RCu_4Pd (R = Gd, Tb, Dy, Ho and Er). All the prepared compounds are found to be ferromagnetic. The electrical resistivity shows the temperature variation characteristic of compounds which order magnetically.

The intermetallic compounds RM_5 formed between heavy rare earth metals (R) and noble metals (M) have the cubic $AuBe_5$-type crystal structure. The rare earth atoms are situated on a face centered cubic lattice of this structure. The magnetic properties of the cubic RCu_5 compounds have been investigated by Buschow *et al.* [1]. The effect of replacement of Cu by Ag or Au on the crystallographic and magnetic properties has been studied by Takeshita *et al.* [2] and Kaneko *et al.* [3]. The crystal structure of RCu_4Ag (or Au) is also cubic RCu_5 (or $MgCu_4Sn$)-type and the Ag or Au atoms are situated at the (1/4, 1/4, 1/4) positions of the unit cell. The results of magnetic measurements showed that those compounds are antiferromagnetic at the Gd compound side and ferromagnetic at the Er compound side. The Néel (Curie) temperatures are low through the compounds and the paramagnetic Curie temperatures have both positive and negative signs.

In this paper, we have studied the magnetic and electric properties of the compounds RCu_4Pd (R = Gd, Tb, Dy, Ho and Er) in order to examine the relation between the number of conduction electrons and magnetic properties.

The specimens were prepared by arc-melting the constituent elements with desired composition. The products were annealed at 600 °C for 1 week. The results of powder X-ray diffraction studies showed that all the prepared specimens are single phase with the $MgCu_4Sn$-type crystal structure.

Figure 1 shows the ac magnetic permeability (μ) *versus* temperature (T) curve for $GdCu_4Pd$. As temperature increases the permeability decreases abruptly around 110 K. The Curie temperature defined as shown in the figure is $T_C = 116$ K. The Curie temperatures thus determined are given in table I together with the paramagnetic Curie temperatures in reference [4]. The Curie temperature is in good agreement with the paramagnetic Curie temperature for all the compounds.

The electrical resistivity (ρ) was measured by a four probes method in the temperature range from 4.2 K to 300 K. Figure 2 shows the ρ *versus* T curves for the compounds RCu_4Pd (R = Gd, Tb, Dy, Ho and Er). The electrical resistivity shows a behavior characteristic of compounds which order magnetically below the temperature corresponding to T_C except for $HoCu_4Pd$. T_C defined as an anomaly point shown in the $\rho - T$ curve is also given in table I. The values of θ_P and T_C's in the table agree well each other.

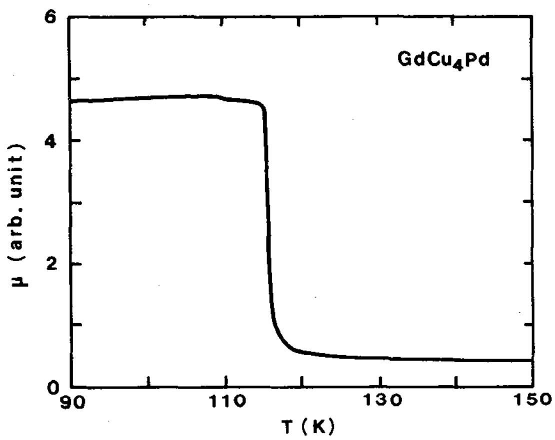

Fig. 1. – Temperature variation of ac permeability of $GdCu_4Pd$.

Table I. – *The values of* θ_p *and* T_C *for* RCu_4Pd (R = Gd, Tb, Dy, Ho *and* Er). θ_p *is from reference* [4]. T_C^{μ} *and* T_C^{ρ} *are the Curie temperatures obtained from the magnetic and electric measurements, respectively.*

R	Gd	Tb	Dy	Ho	Er
θ_p (K)	108	79	48	30	16
T_C^{μ} (K)	116	76	47	31	15
T_C^{ρ} (K)	116	76	47	–	14

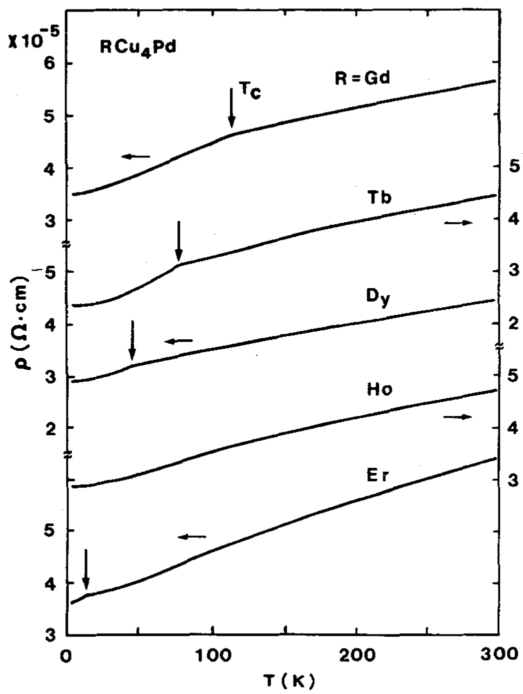

Fig. 2. – Temperature variations of electrical resistivities of RCu_4Pd (R = Gd, Tb, Dy, Ho and Er).

The dominant exchange interaction responsible for an occurence of magnetic order in the rare earth compounds is usually ascribed to the RKKY indirect exchange interaction [5]. The paramagnetic Curie temperature is given by

$$k_B\theta_p = -\left(3z^2 / 4E_f\right)(g-1)^2 \times \\ \times J(J+1)\,J(0)^2 \sum_{m \neq n} F(2k_f R_{mn}), \quad (1)$$

where the symbols in equation (1) have the same meaning as in reference [5]. The sign of θ_p depends only on the sign of the Ruderman-Kittel sum $\sum_{m\neq n} F(2k_f R_{mn})$ In a series of rare earth compounds with a cubic crystal structure, if the number of electrons in the conduction band is assumed to be constant, the values of θ_p for the compounds are expected to have the same sign. Since Cu, Ag and Au are assumed to contribute the same number of electrons to the conduction band, the values of $\sum_{m\neq n} F(2k_f R_{mn})$ are identical for RCu_5, RCu_4Ag and RCu_4Au. Accordingly, θ_p is expected to have the same sign for a series of the above compounds. However, the values of θ_p for them are both positive and negative as mentioned above. Buschow *et al.* [1] and Takeshita *et al.* [2] have examined the values of $\sum_{m\neq n} F(2k_f R_{mn})$ as a function of k_f / k_f^0 for the compounds RCu_5 and RCu_4Ag. Here, k_f^0 is the free electron Fermi wave number if both Cu and Ag contribute one electron and an R element contributes three electrons to the conduction band of the compounds. According to their examinations, as k_f / k_f^0 increases the sum changes its sign from negative to positive at $k_f / k_f^0 = 0.78$ and then from positive to negative at 1.05. They have pointed out that the values of k_f / k_f^0 in the vicinity of 0.78 are appropriate to RCu_5 and RCu_4Ag on the basis of the experimental results on the Knight shift and θ_p for RCu_5, $DyZnCu_4$ and RCu_4Ag. The appearance of positive and negative values of θ_p described above is derived by allowing k_f to vary slightly from compound to compound, which means that the number of conduction electrons per atom in each of these compounds is slithtly different in a sense of free electron model [2]. The above discussion suggests that the reduction in number of conduction electrons will make the compound ferromagnetic. Since Pd has one less valence electron than Cu, Ag and Au, the compounds RCu_4Pd contain less conduction electrons than RCu_4M (M = Cu, Ag and Au). The appearance of ferromagnetism in RCu_4Pd is consistent with the above suggestion. Lastly, it should be noted that the conduction electrons in real compounds are not free electrons and the exchange interaction depends on the conduction band structure. Thus, the knowledge of the conduction band is needed for detailed understanding of the magnetic properties of these compounds.

[1] Buschow, K. H. J., Van der Goot, A. S. and Birkhan, J., *J. Less-Common Met.* **19** (1969) 433; Buschow, K. H. J., Van Diepen, A. M. and De Wijn, H. W., *J. Appl. Phys.* **41** (1970) 4609.

[2] Takeshita, T., Malik, S. K., El Attar, A. A. and Wallace, W. E., *AIP Conf. Proc.* **34** (1976) 230.

[3] Kaneko, T., Arai, S., Abe, S. and Kamigaki, K., *J. Phys. Soc. Jpn* **55** (1986) 4441.

[4] Abe, S., Nakazawa, H., Kaneko, T., Yoshida, H. and Kamigaki, K., to be published in *J. Phys. Soc. Jpn.*

[5] Ruderman, M. A. and Kittel, C., *Phys. Rev.* **96** (1954) 99;
Kasuya, T., *Prog. Theor. Phys.* **16** (1956) 45;
Yoshida, K., *Phys. Rev.* **106** (1957) 893.