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PRESSURE EFFECT OF CURIE TEMPERATURE ON ReAl\textsubscript{2} COMPOUNDS

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Abstract. – The Curie temperature of Gd (Al\textsubscript{1-x}Co\textsubscript{x})\textsubscript{2} with C\textsubscript{15} type structure increased linearly with increasing pressure and the ratios $dT_c/ dp$ were obtained as 0.5, 0.38, 0.25 and 0, for the samples of $x = 0, 0.05, 0.1$ and 0.2, respectively. The simple RKKY model was applied to describing the pressure effect of the Curie temperature of Gd (Al\textsubscript{1-x}Co\textsubscript{x})\textsubscript{2}.

1. Introduction

The investigation of electrical and magnetic properties of the ReAl\textsubscript{2} compounds with Re = rare earth, having C\textsubscript{15} (cubic Laves) structure, has revealed that many of them are amongst the simple ferromagnets [1]. In contrast, the principal attraction of GdAl\textsubscript{2} lies in the absence of any significant effect of crystal fields on the S-state Gd\textsuperscript{3+} ion. The moment of the ion is therefore precisely known and the magnetic behaviour can be used to probe the details of the exchange interaction without any ambiguity being imposed by crystal field effects. The variation of the Curie temperatures of the compounds with the heavy rare earth elements lies reasonably close to the prediction of the RKKY theory in the absence of any significant effect of crystal fields. The variation of the Curie temperatures of the compounds with the heavy rare earth elements lies reasonably close to the prediction of the RKKY theory and it is usually assumed that the magnetic exchange interaction proceeds on the conduction electrons.

On the other hand, in the ReCo\textsubscript{2} compounds, cobalt atoms have magnetic moment about 1 $\mu_B$ if the alloyed rare earth element is magnetic [2]. For example, the YCo\textsubscript{2} and LuCo\textsubscript{2} exhibit very strong enhanced Pauli paramagnetism, being apparently on the verge of ferromagnetism [3, 4]. In the pseudobinary compound Gd (Al\textsubscript{1-x}Co\textsubscript{x})\textsubscript{2}, it was reported that the crystal structure is C\textsubscript{15} type for concentration $0 \leq x < 0.2$ and 0.63 $\leq x \leq 1$, and other is C\textsubscript{14} type [5]. The magnetic properties on both phases C\textsubscript{14} and C\textsubscript{15} are ferromagnetic. Such as, the investigation of pressure effect of Curie temperature on ReAl\textsubscript{2} is a subject of great interest from the point of view of magnetism in rare earth compounds.

In this paper, the pressure effect of the ferromagnetic Curie temperature in GdAl\textsubscript{2} and in pseudobinary compounds Gd (Al\textsubscript{1-x}Co\textsubscript{x})\textsubscript{2}, $x \leq 0.2$ was measured by induction method under hydrostatic pressure up to 10.9 kbar and temperature range 100-300 K.

2. Results and discussion

The specimens of the Gd (Al\textsubscript{1-x}Co\textsubscript{x})\textsubscript{2} compounds were prepared by arc-melting the mixtures of elements of formula proportion under a purified argon gas atmosphere. The purity of used elements is 99.9 % for Gd and 99.99 % for Co and Al. The weight of loss of the products during melting was less than 0.5 %. Powder X-ray diffraction studies using a CuK\alpha radiation show that all of the prepared specimens except for $x = 0.2$ have the crystal structure of a cubic Laves type and that there is no evidence for the presence of any impurity phases. For sample with $x = 0.2$, the diffraction pattern shows the broad lines corresponding to existence of two phases C\textsubscript{14} and C\textsubscript{15}. Figure 1 shows a concentration dependence of lattice constant in Gd (Al\textsubscript{1-x}Co\textsubscript{x})\textsubscript{2}. As seen in the figure, the lattice constant decreases linearly with increasing concentration $x$. Such a tendency was also observed by Oesterrieicher and Wallace [5]. The Curie temperature as a function of concentration $x$ decreased monotonically with increasing $x$. For the pseudobinary compound Gd (Al\textsubscript{1-x}Co\textsubscript{x})\textsubscript{2}, it is considered that the spins of the cobalt ions, which lie at sites equivalent to the aluminium ions in GdAl\textsubscript{2}, will be aligned antiparallel to the gadolinium spins.

In the pressure effects, for C\textsubscript{15} type samples, the Curie temperature increases linearly with increasing...
pressure, but the ratio $dT_c / dp$ decreases with increasing concentration $x$, as shown in figure 2.

![Graph showing $dT_c / dp$ vs. $x$ for Gd(Al$_{1-x}$Co$_x$)$_2$]

Fig. 2. - Pressure effect of Curie temperature of Gd(Al$_{1-x}$Co$_x$)$_2$ as a function of cobalt concentration.

For the sample with $x = 0.2$, two anomalies are observed in temperature dependence of the permeability. The lower one corresponds to the Curie temperature of C$_{15}$ type substance and the higher to that of C$_{14}$ type one. For C$_{15}$ type, the Curie temperature increases linearly with increasing pressure. In contrast, for C$_{14}$ type the pressure effect in the Curie temperature is negative as shown in figure 3.

Recently, Jarlborg et al. [7] have calculated the energy bands for YAl$_2$, LaAl$_2$ and CeAl$_2$ with C$_{15}$ type structure. According to them, the Fermi energies for these compounds are about 0.46 Ry. If we assume that the energy band structure of GdAl$_2$ is almost the same as that of LaAl$_2$ [7] and $m^*/m = 1.2$ [6], positive sign interaction of RKKY type can be expected, as shown in figure 4. This situation may give a positive pressure effect in GdAl$_2$.

![Graph showing $F(2kF)$ vs. $2kF$ for GdAl$_2$]

Fig. 4. - Simple RKKY interaction for GdAl$_2$. $R$ is a distance between gadolinium ions.