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Irreversible suppression of spin fluctuations at the metamagnetic phase transition in $Er_{0.55}Y_{0.45}Co_2$

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Abstract

In the quasi-binary intermetallic compound $Er_{0.55}Y_{0.45}Co_2$, an irreversible change of 44% in the coefficient of the linear term of the low-temperature specific heat γ is observed in zero field after application of a 5 T magnetic field in addition to the change in the electrical resistivity and unit cell volume. The decrease of γ is attributed not only to the decrease in density of the electronic states, but also to the suppression of spin fluctuations.

1. Introduction

The intermetallic compounds of the type RCo_2 with non-magnetic R ions (yttrium, lutetium, scandium) are exchange-enhanced Pauli paramagnets and their electronic properties (magnetic susceptibility, electrical resistivity, specific heat) are considerably influenced by spin fluctuations [1]. In specific-heat measurements on these compounds in magnetic fields up to 10 T, a decrease of the coefficient γ of the linear term of the low-temperature specific heat with increasing magnetic field has been reported [2]. In ref. 2, the decrease of γ in applied magnetic field (4% for YCo_2) is attributed to the suppression of the spin fluctuations.

High-field magnetization measurements on YCo_2 up to 94 T [3] have confirmed the first-order metamagnetic transition predicted earlier [4] at a critical field $B_c \approx 70$ T. A splitting of the d band at the transition leads to the appearance of a magnetic moment μ_{Co} of $0.55\mu_B$ per Co atom. According to refs. 5 and 6, such a transition should lead to a decrease of γ, because the density of states at the Fermi level $N(E_F)$ in the high-field ferromagnetic state is about 70% of that in the paramagnetic state. On the other hand, the splitting of the d band should lead to considerable suppression of the spin fluctuations.

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2. Measurements and analysis

The metamagnetic transition in the RCo_2 compounds can be produced by a considerably lower applied magnetic field if R ions with a magnetic moment are present, for example, in the compounds $Er_{1-x}Y_xCo_2$ [7] and $Ho_{1-x}Y_xCo_2$ [8]. As shown in ref. 7, near the critical concentration x_c, where the R subsystem is partly disordered and the 3d band splitting is rather weak ($\mu_{Co} \leqslant 0.3\mu_B$), the cobalt subsystem experiences an effective magnetic field

$$B_{eff} = \lambda_{R\text{–}Co}(1-x)\langle \mu_R(B)\rangle + B \qquad (1)$$

where $\lambda_{R\text{–}Co} < 0$ is the molecular field constant of the R–Co exchange interaction, $\langle \mu_R(B)\rangle$ is the field-dependent average magnetic moment per R ion, and B is the external field. For $Er_{1-x}Y_xCo_2$ at $x_c = 0.45$, and for $Ho_{1-x}Y_xCo_2$ at $x_c = 0.577$, the irreversible splitting of the d band is observed in a low external field of about 0.4 T. This field leads to an increase of $\langle \mu_R\rangle$ in the first term in eqn. (1) and, consequently, to an increase of B_{eff} (from 66 to 72 T in the case of $Er_{1-x}Y_xCo_2$). This leads to the metamagnetic transition with irreversible increase of μ_{Co} from $0.3\mu_B$ to $0.9\mu_B$ [7]. This transition, as can be seen in Fig. 1(a), is accompanied by a sharp irreversible decrease of the electrical resistivity ($\Delta\rho/\rho = -40\%$). The decrease of ρ is apparently caused by the decrease of the contribution from scattering on the spin fluctuations with 3d band splitting. It should be mentioned that the sample can be returned into its initial state only by heating up to T_c and subsequent cooling in zero field. The increase of μ_{Co} also leads to the appearance of a magnetovolume anomaly in the thermal expansion (Fig. 1(b)). The volume effect $\Delta V/V$ reaches 3.8×10^{-3}. The irreversibility in the behaviour of the magnetization and the resistivity is due to hysteresis in the $\mu_{Co}(B_{eff})$ dependence near B_c, which accompanies the phase transition in the d electron system.

We have also investigated the temperature dependence of the specific heat of $Er_{0.55}Y_{0.45}Co_2$ in magnetic fields up to 5 T by an adiabatic method. The broad peak in the c_p/T *vs.* T dependence at $B=0$ (Fig. 2) indicates the Curie temperature T_c, which correlates well with the $\rho(T)$ and $a(T)$ data. After application of a magnetic field $B=5$ T, a huge irreversible decrease

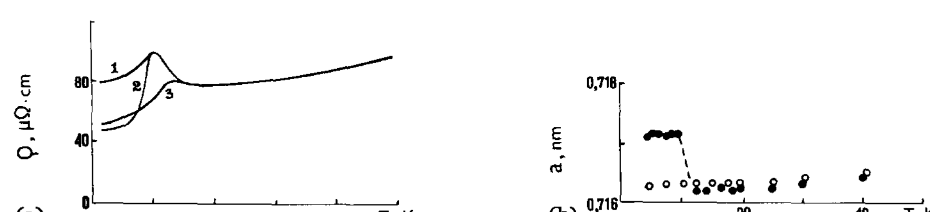
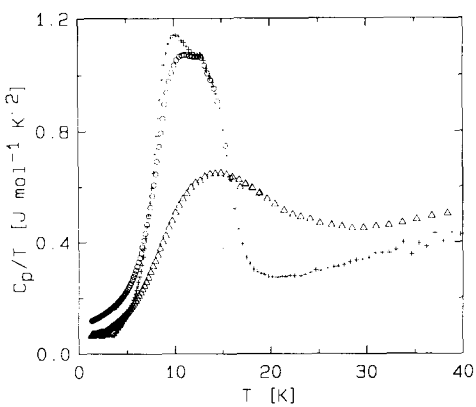


Fig. 1. (a) Temperature dependences of the resistivity of $Er_{0.55}Y_{0.45}Co_2$: curve 1 was obtained with increasing temperature in zero magnetic field; curve 2 also corresponds to zero field, but was obtained with increasing temperature after applying a 5 T field at 1.8 K; curve 3 was obtained in a field of 3 T. (b) Temperature dependences of the lattice parameter a measured in zero field (○) and in 0.4 T (●).



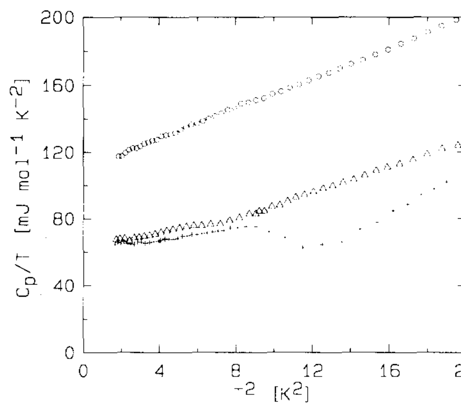


Fig. 2. Temperature dependences of the specific heat c_p/T: ○, $B=0$ T; +, $B=0$ T after application of 5 T at 1.2 K; △, $B=5$ T.

Fig. 3. Low-temperature part of specific heat plotted as c_p/T *vs.* T^2: ○, $B=0$ T; +, $B=0$ T after application of 5 T at 1.2 K; △, $B=5$ T.

of γ (from 108 to 61 mJ mol^{-1} K^{-2}, $\Delta\gamma/\gamma=-44\%$) is observed in zero magnetic field. This is shown in Fig. 3 where the dependences c_p/T *vs.* T^2 are presented.

In the paramagnon model, the low-temperature specific heat can be represented as follows [9]:

$$c_p=\gamma T+\beta^* T^3+\delta T^3 \ln T \qquad (2)$$

where $\gamma=\gamma_0(1+\lambda_{e-ph}+\lambda_{sf})$ (γ_0 is the electronic specific-heat coefficient corresponding to the bare density of states, λ_{e-ph} is the electron–phonon enhancement factor, λ_{sf} is the spin-fluctuation enhancement factor); $\beta^*=\beta-\delta \ln T_{sf}$ (β is the Debye lattice contribution, δ is a spin-fluctuation-dependent factor, T_{sf} is the spin-fluctuation temperature). The $T^3 \ln T$ term in eqn. (2) could not be observed in YCo_2 and (R, Y)Co_2 compounds [2, 10]. According to refs. 5 and 6, the irreversible splitting of the d band is followed by a decrease of about 30% in the density of states at the Fermi level and, therefore, by a decrease of the γ_0. The observed decrease of γ by 44% illustrates an additional reduction by the suppression of the spin fluctuations (decrease of λ_{sf}). The considerable contribution to γ from spin fluctuations in $R_{1-x}Y_xCo_2$ compounds is also reported in refs. 10 and 11, where the specific heat for compounds with R≡Ho, Dy, Er was studied in zero magnetic field.

The suppression of the spin fluctuations should also change the coefficient β^* in eqn. (2). However, it is not possible to draw any conclusions about the change of β^* from the present measurements because of the proximity of the magnetic ordering which influences the c_p/T *vs.* T dependence even at rather low temperatures.

The feature at about 3 K (Fig. 3) and the change in the shape of the specific-heat peak at 10 K in zero field after application of a 5 T field (Fig.

2) may be connected with a change of the 3d band splitting with increasing temperature.

3. Conclusion

In the quasi-binary intermetallic compound $Er_{0.55}Y_{0.45}Co_2$, an irreversible splitting of the cobalt 3d band occurs in a relatively low magnetic field of 0.4 T. Electrical resistivity, thermal expansion and specific heat have been investigated without magnetic field (unsplit 3d band) and in zero field after application of a field of 5 T (split 3d band). An irreversible change of 44% in the coefficient of the linear term of the low-temperature specific heat γ is observed in addition to changes in electrical resistivity and unit cell volume. The decrease of γ is attributed not only to a decrease in the density of states, but also to suppression of spin fluctuations, which can contribute considerably to the low-temperature specific heat.

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References

1 D. Gignoux, F. Givord, R. Lemaire and F. Tasset, *J. Less-Common Met.*, *94* (1983) 1.
2 K. Ikeda, K. H. Gschneidner, Jr., R. J. Stierman, T.-W. E. Tsang and O. D. McMasters, *Phys. Rev. B*, *29* (1984) 5039.
3 T. Goto, K. Fukamuchi, T. Sakibara and H. Komatsu, *Solid State Commun.*, *72* (1989) 945.
4 E. P. Wohlfarth, *J. Phys. (Paris), Lett.*, *41* (1980) L563.
5 H. Yamada, J. Inoue, K. Terao, S. Kanda and M. Shimizu, *J. Phys. F.*, *14* (1984) 1943.
6 H. Wada, T. Inoue, M. Hada, M. Shiga and Y. Nakamura, *Phys. Stat. Sol. B*, *162* (1990) 407.
7 N. V. Baranov, A. I. Kozlov, A. N. Pirogov and E. V. Sinitsyn, *Sov. Phys. — JETP*, *69* (1989) 382.
8 N. V. Baranov, A. I. Kozlov and A. N. Pirogov, *Fiz. Met. Metalloved.*, *11* (1990) 46.
9 M. T. Beal-Monod and E. Daniel, *Phys. Rev. B*, *27* (1983) 4467.
10 N. Pillmayr, C. Schmitzer, E. Gratz, G. Hilscher and V. Sechovsky, *J. Magn. Magn. Mater.*, *70* (1987) 162.
11 G. Hilscher, N. Pillmayr, C. Schmitzer and E. Gratz, *Phys. Rev. B*, *37* (1988) 3480.