Band metamagnetism of the compound $Er_{0.55}Y_{0.45}Co_2$ in a weak magnetic field

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It is concluded from measurements of the electrical resistivity, the thermal expansion, and neutron diffraction that the *d* band of the compound $Er_{0.55}Y_{0.45}Co_2$ undergoes an irreversible splitting when a weak external magnetic field ($\sim$4 kOe) is applied at 4.2 K.

In rare-earth intermetallic compounds $R_{1-x}Y_xCo_2$ the *d* band formed by the hybridization of the 3*d* electrons of cobalt with the 5*d* (or 4*d*, in the case of yttrium) electrons of the R metal exhibits the properties of a band metamagnet.[1,2] The effective field acting on the *d* subsystem in the compounds $R_{1-x}Y_xCo_2$ can be described by

$$H_{\text{eff}} = \lambda_{R-Co}(1-x)\langle\vec{\mu}_R(\mathbf{H})\rangle + \mathbf{H}, \quad (1)$$

where λ_{R-Co} is a coefficient characterizing the exchange interaction between the R and Co ions, $\langle\mu_R\rangle$ is the average magnetic moment of the R ion, and H is the external field. The concentration of the magnetically active R ions can be chosen in such a way that the vlaue of H_{eff} at $H=0$ is slightly below the critical field $H_{\text{eff}}^{\text{cr}}$ (700–1000 kOe) for the metamagnetic transition in the system of collectivized *d* electrons. In this case we would expect that the imposition of an external field weak in comparison with $H_{\text{eff}}^{\text{cr}}$ would cause substantial changes in the state of the *d* subsystem. The R subsystem, partially disordered because of dilution with yttrium,[3] would serve as a sort of amplifier of the effect of the external field by virtue of R–Co exchange.

In this letter we are reporting an attempt to realize a metamagnetic transition in the *d* subsystem of the compound $Er_{0.55}Y_{0.45}Co_2$ at 4.2 K. It is in this compound, according to our preliminary measurements, that the effect of an external field on the magnetic state at 4.2 K is most apparent. Data on the change in the magnetic state of the samples were obtained by measuring the electrical resistivity ρ, the thermal expansion, and neutron diffraction.

The methods for synthesizing the samples and for determining their resistivity are described in Ref. 4. The thermal-expansion measurements were carried out on an x-ray diffractometer. The neutron diffraction was carried out on a sample pressed from a powder of the compound. The neutron wavelength was 2.416 Å.

It can be seen from Fig. 1 that the imposition of an external field at $T=4.2$ K on a sample of the compound $Er_{0.55}Y_{0.45}Co_2$, for which the relation $H_{\text{eff}} < H_{\text{eff}}^{\text{cr}}$ holds in the initial state and in which the splitting of the *d* band is slight in the initial state, causes an irreversible decrease in ρ by a factor of nearly two at $H \geqslant 4$ kOe. It also causes a qualitative change in the temperature dependence of the resistivity. After the field is applied, this temperature dependence becomes similar to $\rho(T)$ for erbium-rich

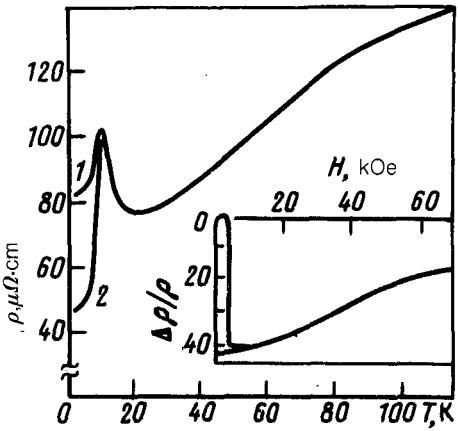

FIG. 1. Temperature dependence of the electrical resistivity of $Er_{0.55}Y_{0.45}Co_2$. 1—Measured before the imposition of a field; 2—measured after the imposition of a field $H \geqslant 4$ kOe. The inset shows the field dependence of the resistivity change in $Er_{0.55}Y_{0.45}Co_2$ at $T = 4.2$ K.

compounds[3] $Er_{1-x}Y_xCo_2$ ($x \leqslant 0.3$), in which the d band is split even at $H = 0$. In an external field at $T = 4.2$ K, the splitting of the d band thus increases in the compound $Er_{0.55}Y_{0.45}Co_2$.

The same conclusion is implied by the results on the thermal expansion (Fig. 2). At 4.2 K the imposition of a field $H = 4$ kOe is seen to be accompanied by an increase in the lattice constant. The corresponding increase in the size of the unit cell, $\Delta V/V$, is 3.8×10^{-3}, in good agreement (see the inset in Fig. 2) with the values found for $\Delta V/V$ at the magnetic-ordering temperature in compounds with a high erbium concentration.[5]

Figure 3 shows the results of neutron-diffraction measurements of the compound $Er_{0.55}Y_{0.45}Co_2$ at 4.2 K. We see that the imposition of an external field causes a change in the intensities of the reflection on the neutron diffraction pattern; these changes indicate a change in the magnetic state of the sample. The inset in Fig. 3 shows the

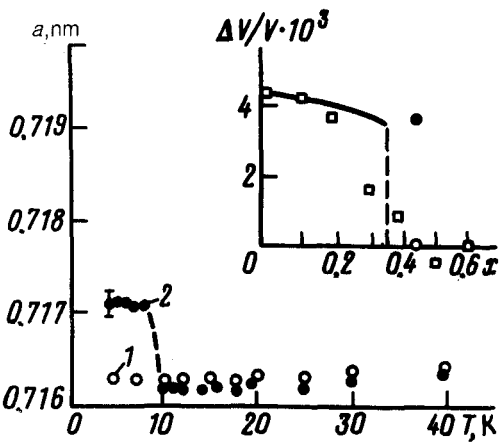

FIG. 2. Temperature dependence of the lattice constant of $Er_{0.55}Y_{0.45}Co_2$ ○—$H = 0$; ●—$H = 4$ kOe. The inset shows the concentration dependence of the magnetic-exchange anomaly $\Delta V/V$. □—Data of Ref. 5; ○ and ●—data of the present study, obtained at $H = 0$ and $H = 4$ kOe, respectively.

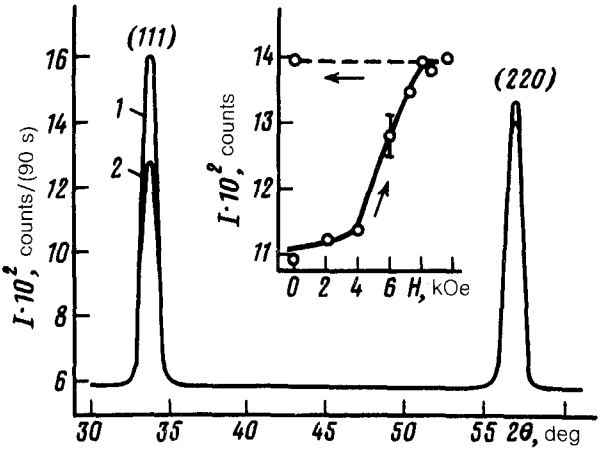

FIG. 3. Fragments of neutron diffraction patterns of the compound $Er_{0.55}Y_{0.45}Co_2$. 1—Measured at 4.2 K without the imposition of a field; 2—measured at the same temperature, after the imposition of a field $H = 9.5$ kOe. The inset shows the field dependence of the peak intensity of the (111) reflection at $T = 4.2$ K.

field dependence of the peak intensity of the (111) reflection. The shape of this dependence is evidence that the transition which occurs in $Er_{0.55}Y_{0.45}Co_2$ under the influence of a field of a metamagnetic nature. Interestingly, the magnetic state which is established in the sample at $H \geqslant 8$ kOe persists even after the field is turned off.

A quantitative analysis of the neutron diffraction patterns revealed that the magnetic moments of the Er and Co ions are $\langle \mu_{Er} \rangle = 7.4 \pm 0.1\mu_B$ and $\mu_{Co} = 0.3 \pm 0.1\mu_B$ in the initial state and $\langle \mu_{Er} \rangle = 8.1 \pm 0.1\mu_B$ and $\mu_{Co} = 0.9 \pm 0.1\mu_B$ in the final state. The value found for μ_{Co} is essentially the same as that which has been found for μ_{Co} at $H = 0$ in compounds $Er_{1-x}Y_xCo_2$ with $x \leqslant 0.3$ (Refs. 1 and 2).

In summary, a weak external field can produce in $Er_{0.55}Y_{0.45}Co_2$ the same magnetic state of the *d* system as occurs in erbium-rich compounds $Er_{1-x}Y_xCo_2$, for which the relation $H_{eff} > H_{eff}^{cr}$ holds even at $H = 0$.

Using the relation given above, we can explain the H dependence of μ_{Co}. According to the neutron diffraction, the imposition of an external field has an ordering effect on the R subsystem, which is accompanied by an increase in $\langle \mu_{Er} \rangle$ and thus in the effective field acting on the *d* subsystem. According to our estimate, the field H_{eff} increases from 660 kOe to 720 kOe (we took the value of λ_{R-Co} from Ref. 6); this increase is apparently sufficient to satisfy the condition $H_{eff} > H_{eff}^{cr}$.

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