# Field effect on itinerant electron magnetism of $Y_{1-x}Er_xCo_2$ compounds


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**Abstract**

Thermopower $S$ and electrical resistivity $\rho$ of cubic Laves phase pseudo-binary compounds $Y_{1-x}Er_xCo_2$ were measured from 2 K to 300 K in magnetic fields up to 15 T. $S$ and $\rho$ show a strong field dependence in a vicinity of the magnetic ordering temperature. The reduction of the exchange magnetic field $B_{exc}$ acting on Co 3d electrons by Y substitution for Er results in a separation of magnetic transition temperatures of Er and Co subsystems in $Y_{0.4}Er_{0.6}Co_2$. The collapse of the itinerant Co 3d moments of $Y_{0.4}Er_{0.6}Co_2$ is induced by applying external magnetic field about 10 T.



*Key words:* spin fluctuation; thermopower; electrical resistivity; itinerant electron metamagnetism


The cubic Laves phase compounds $RCo_2$ (R stands for rare earth elements) with magnetic heavy R elements, except $TmCo_2$, are ferrimagnets. The first-order magnetic phase transition observed in $ErCo_2$, $HoCo_2$, and $DyCo_2$ is explained as the metamagnetic behavior of Co 3d itinerant electrons, which are magnetized by the internal exchange field $B_{exc}$ of the ordering rare earth magnetic moments; $B_{exc} = n_{fd}M_R$, where $n_{fd}$ and $M_R$ are the exchange coupling constant and the rare earth magnetic moments, respectively [1,2]. When the external magnetic field $\mu_0 H$ is applied, the effective molecular field $B_{eff}$ acting on Co 3d itinerant electrons in $Y_{1-x}Er_xCo_2$ can be expressed as $B_{eff} = xn_{fd}M_R - \mu_0 H$. It was reported that the separation of Er and Co magnetic ordering temperatures takes place in $Y_{1-x}Er_xCo_2$ system with Er concentration of $x = 0.6$, in which the magnetic ordering temperature $T_C^{Co}$ of the Co subsystem is lower than $T_C^{Er}$ of R subsystem [3]. In pure $ErCo_2$ the separation of the ordering temperatures was observed in external magnetic field [4]. The sensitivity of magnetism of Co 3d itinerant electrons to the external magnetic field, due to reduction of $B_{eff}$, is expected to be much stronger in $Y_{1-x}Er_xCo_2$ compounds within a limited range of $x$. In this paper we present the results on electrical resistivity $\rho$ and thermopower $S$ of $Y_{0.4}Er_{0.6}Co_2$, measured in magnetic fields up to 15 T.

The sample preparation and measurement procedures have been described in ref. [5]. Figure 1 shows the temperature dependencies of $\rho$ and $S$ of $Y_{0.4}Er_{0.6}Co_2$ in zero magnetic field. $\rho(T)$ curve has an up-turn around the magnetic ordering temperature and a sudden decrease with decreasing temperature. $S(T)$ reveals a peak at $T \approx 13$ K, having a minimum around 25 K and a broad peak around 60 K. We determined the magnetic phase transition temperatures of Er ($T_C^{Er}$) and Co ($T_C^{Co}$) subsystems as the temperatures where $d\rho/dT$ takes a minimum and maximum, respectively [3]. Below the magnetic ordering temperature of $T_C^{Er} \approx 16$ K, the itinerant d electrons subsystem orders magnetically at $T_C^{Co} \approx 11$ K where $B_{exc}$ exceeds the metamagnetic critical field $B_c$. Figure 2 depicts the


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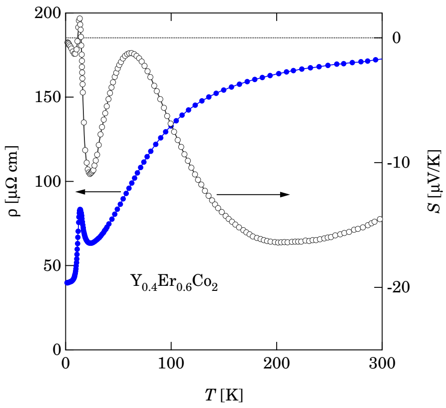


Fig. 1. The temperature dependencies of electrical resistivity $\rho$ and thermopower $S$ in zero magnetic field.

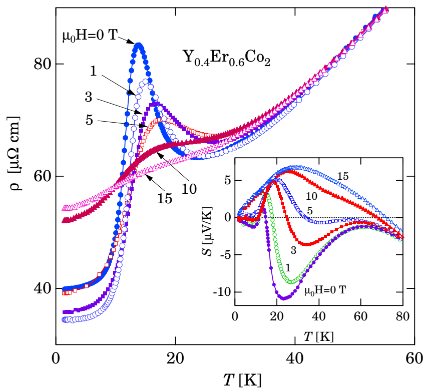


Fig. 2. The temperature dependencies of $\rho$ and $S$ (inset) for the compound of $Y_{0.4}Er_{0.6}Co_2$ in several magnetic fields up to 15 T.

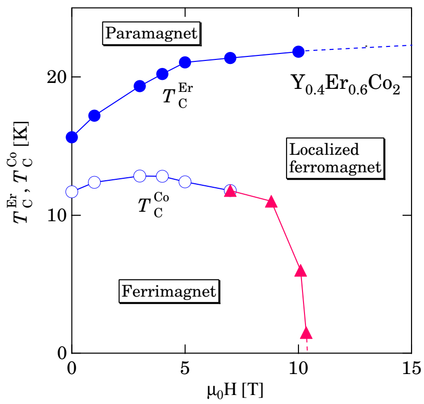


Fig. 3. The field dependencies of the magnetic phase transition temperatures of Er ($T_C^{Er}$) and Co ($T_C^{Co}$ ) subsystems in $Y_{0.4}Er_{0.6}Co_2$.

behavior of $\rho$ and $S$ (inset) around the magnetic phase transition temperature in several magnetic fields up to 15 T. At the temperatures above $T \approx 100$ K, both $\rho$ and $S$ curves show almost no field dependencies. A large field effect is observed in the temperature region of magnetic phase transition. The temperature, where $\rho$ attains a maximum, increases with increasing $\mu_0 H$. However the magnitude of the resistivity at the maximum decreases with increasing $\mu_0 H$ and the maximum of $\rho$ almost disappears in the field of $\mu_0 H = 15$ T. This implies that the spin fluctuations of Co 3d itinerant electrons, enhanced by the fluctuating exchange field of 4f moments above magnetic ordering temperature [5], become suppressed by external magnetic field.

The field dependencies of the magnetic phase transition temperatures of $T_C^{Er}$ and $T_C^{Co}$are shown in fig. 3. $T_C^{Er}$ and $T_C^{Co}$ in $\mu_0 H \leq 7$ T were determined by using the temperature derivative of $\rho$. $T_C^{Co}$ in $\mu_0 H \geq 7$ T was obtained from the magnetic field dependencies of $\rho$ and $S$. As shown in fig. 3, $T_C^{Er}$ increases with increasing $\mu_0 H$ below 5 T, and shows the saturation in magnetic fields above 5 T. On the other hand, $T_C^{Co}$ shows a small change in magnetic field of $\mu_0 H \leq 7$ T, however a sudden drop of $T_C^{Co}$ above 9 T and no sign of long range magnetic order at $\mu_0 H > 10$ T are observed. In magnetic field region of $\mu_0 H > 10$ T, the effective molecular field acting on Co subsystem $B_{\rm eff}$ is lower than the metamagnetic critical field $B_c$ of Co 3d electron subsystem; $B_{\rm eff} < B_c$ at $T = 0$.

From the results described above, we can obtain the exchange molecular field of $B_{\rm exc} \approx 185$ T for $ErCo_2$ from the condition of $B_c = x n_{\rm fd} M_{\rm R} - \mu_0 H$ by using the values of $\mu_0 H = 10.5$ T and $B_c = 100$ T [4]. And the critical Er concentration can be estimated as $x_{\rm cr} \approx 0.55$. Below this Er concentration, it is observed no long range magnetic order of Co 3d itinerant electrons in $Y_{1-x}Er_xCo_2$. These values of $B_{\rm exc}$ and $x_{\rm cr}$ show a good agreement with the literature data [3,6].

In summary, electrical resistivity and thermopower of $Y_{0.4}Er_{0.6}Co_2$ were measured from 2 K to 300 K in magnetic fields up to 15 T. The reduction of the exchange molecular field by Y substitution for Er results in a separation of magnetic ordering temperatures of Er and Co subsystems. The collapse of the itinerant Co 3d moments by external field about 10 T was observed. The exchange molecular field $B_{\rm exc}$ for $ErCo_2$ and the critical concentration $x_{\rm cr}$ were obtained.

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