Studies of single crystal $ErCo_2$ under pressures and magnetic fields

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Abstract

We measured the resistivity, magnetization, and neutron diffraction under pressures (12 kbar) and magnetic fields (18 Tesla) in order to investigate the first order magnetic transition of $ErCo_2$ using a single crystal sample. With increasing pressures, the ferrimagnetic transition moves towards lower temperatures while it increases in temperature with magnetic fields. We note that the first order nature of the magnetic transition is suppressed by pressures or fields.

Key words: $ErCo_2$; first order phase transition; hydrostatic pressure

1. Introduction

Of rare earth transition metal compounds, RCo_2 forming in the cubic Laves phase has attracted much interest because the Co atoms show an unusual magnetic instability depending on the rare earth elements. On the other hand, for all rare earth elements the Ni atoms of RNi_2 are nonmagnetic while the Fe atoms of RFe_2 have stable magnetic moments. The Co atoms of RCo_2 experience a strong exchange field from the rare-earth magnetic moments, which exceeds a critical value and induces a first order phase transition with magnetic moments at the Co atoms for R = Dy, Ho, and Er[1]. Among the three compounds, $ErCo_2$ is particularly interesting since it is believed to have the exchange field very close to the critical value so the formation of the Co moments is very sensitive to external parameters.

$ErCo_2$ is known to have a first order phase transition at 32 K from previous bulk measurements[1,2]. It should be noted, however, that most of these measurements were performed on polycrystalline samples. To the best of our knowledge, there has been no previous report, which addresses the magnetic properties of $ErCo_2$ using a single crystal sample with varying pressures and external magnetic fields at the same time.

In this study, we measured the resistivity, magnetization, and neutron diffraction of the $ErCo_2$ single crystal in order to understand better the magnetic phase transition and the magnetic instability of the Co moments under pressures and magnetic fields.

2. Experimental Details

A single crystal $ErCo_2$ was prepared at Ural State University, Russia, by remelting $ErCo_2$ ingot in a resistance furnace with a high temperature gradient. We checked the crystallinity of the sample with X-ray diffraction. We measured the magnetization using a commercial SQUID magnetometer (Quantum Design, MPMS7) with fields up to 7 Tesla. Electrical resistivity measurements were made using a standard four-probe

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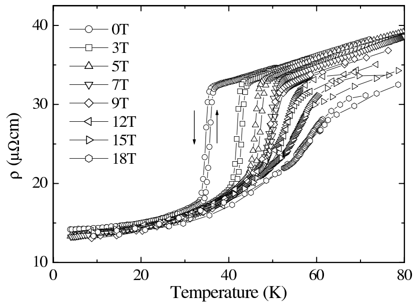

Fig. 1. Temperature-dependent resistivity of $ErCo_2$ measured with different fields.

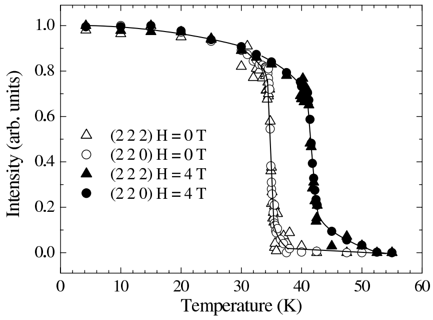

Fig. 2. Temperature dependence of the normalized intensity of (220) and (222) magnetic peaks.

DC method with current along the [1 1 1] axis from 1.8 to 300 K with fields up to 18 Tesla and pressures up to 12 kbar by using a Cu-Be cell[3]. We also measured the neutron diffraction at the TriCS four-circle diffractometer at SINQ, Switzerland, with a neutron wavelength $\lambda = 1.179$ Å from 4 to 55 K using a 4 Tesla superconducting magnet.

3. Data and Discussion

As one can see in figure 1, the resistivity falls sharply at the transition temperature as observed previously. One noteworthy point is that the transition temperature obtained from our sample is $T_C = 35$ K, slightly higher than $T_C = 32$ K obtained from a polycrystalline sample[1]. There is also a small but clear thermal hysteresis at the transition temperature with $\Delta T = 0.9$ K, indicative of a first order transition. Upon increasing magnetic fields, the drop in the resistivity, $\Delta\rho$, becomes reduced while the thermal hysteresis remains about the same up to 7 Tesla. With further increasing magnetic fields, however the thermal hysteresis becomes less clearly visible and, simultaneously, $\Delta\rho$ gets smaller. Based on the field dependence of $\Delta\rho$, we estimated that above 20 Tesla $\Delta\rho$ becomes negligible and there exists a crossover of a first-to-second order transition.

In order to see how the crossover behavior changes by external pressures, we measured the resistivity with varying pressures up to 12 kbar and magnetic fields up to 18 Tesla. Our $\rho(T)$ data for $ErCo_2$, measured at several selected pressures up to 12 kbar, are in good agreement with previously reported data [1]. Applied pressure affects considerably both the T_C and the resistivity values above T_C. The value of T_C decreases approximately linearly with increasing pressures. From these data we estimated the values of $\Delta T_C/\Delta P = 0.75$ K/kbar and the magnetic ordering is expected to disappear at $P_c = 46$ kbar.

Figure 2 shows the temperature dependence of the normalized intensity of (220) and (222) magnetic peaks of $ErCo_2$ single crystal for H = 0 and 4 T. The square roots of the (220) and (222) magnetic intensities are directly proportional to the Er- and Co- sublattice magnetic moments, respectively. Then it follows from Fig. 2 that both magnetic moments increase sharply at $\sim$ 35 K for H = 0 and at $\sim$ 42 K for H = 4 T. The width of the jump in Fig. 2 does not exceed $\Delta T = 1$ K for H = 0 and $\Delta T = 2$ K for H = 4 T. These data clearly show that both Er and Co moments order at the same transition temperature. Since the resistivity and neutron measurements show the same transition temperature, scattering of conduction electrons, in particular the drop in the resistivity at T_C, is more likely to be due to spin density fluctuations.

The field dependence of the magnetization shows a saturation behavior below 35 K while it has a metamagnetic transition up to 50 K where the metamagnetic transition is seen near 7 Tesla. Our neutron diffraction data taken at 36 K show that the metamagnetic transition is accompanied by an increase in both Er and Co moments although the field dependence of the Co moments is more close to that of the magnetization as well as the lattice constant as shown in the powder neutron diffraction experiment[4].

In this study, we used a single crystal $ErCo_2$ in order to investigate the magnetic transition as well as the metamagnetic transition above T_C. Our single crystal data suggest that the Co moments become unstable with increasing magnetic fields and pressures.

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