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High Field c-axis Magnetotransport of Single Crystal $YbNi_2B_2C$

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Abstract

We have measured c-axis magnetotransport properties of the tetragonal $YbNi_2B_2C$ compound down to 2 K and up to 18 T. Transverse and longitudinal magnetoresistance have been measured with current applied along the c-axis of the tetragonal structure. A well-defined maximum in the magnetoresistance is observed at temperatures below 10 K at approximately 5 T. At higher temperatures the magnetoresistance is always negative and weakens as the temperature is increased.

Keywords: Magnetotransport; Heavy electron system; $YbNi_2B_2C$

1. Introduction

The intermetallic borocarbides $RENi_2B_2C$ (RE = Dy-Lu,Y) have generated great interest due to their display of such diverse phenomena as superconductivity, magnetic order and correlated electron behavior[1]. $YbNi_2B_2C$ is the only compound in the series that does not order or become superconducting down to 50 mk[2]. $YbNi_2B_2C$ exhibits strongly correlated electron behavior at low temperature with a Sommerfeld coefficient of 530 $mJ/molK^2$[2]. Specific heat measurements indicate an estimated Kondo temperature (T_K) of ~10 K, while inelastic neutron measurements indicate a T_K of ~3.8 K[2,3]. Strong anisotropy was observed in previous investigations of the magnetotransport of $YbNi_2B_2C$ when the magnetic field (H) was applied parallel or perpendicular to the c-axis[4]. However, in none of these studies was the current applied along the c-axis. In addition, whereas non-magnetic and local moment members of the family have been found to have virtually isotropic resistivity up to now (an)isotropy of the resistivity of $YbNi_2B_2C$ has not been determined[5].

2. Experimental Details

Single crystals of $YbNi_2B_2C$ were prepared using a modified Ni_2B flux growth technique[1]. The crystal structure is tetragonal (space group I4/mmm). The crystals grow in plate-like planes with the c-axis perpendicular to the plane. A cylindrical sample was cut from a larger single crystal by means of the spark-erosion technique, and had dimensions r = 0.99 mm and h = 1.42 mm, with the c-axis along the axis of cylindrical symmetry.

The c-axis magnetoresistance measurements were performed using a standard 4-probe ac technique. Electrical contact was made using 51 μm platinum wire and Epo-tek H20E sliver epoxy, with typical contact resistances of 1-2 Ω. Measurements were preformed down to 2 K using a variable flow cryostat. Magnetic fields up to 18 T were provided by a 20 T superconducting magnet. All magnetotransport measurements were performed at the National High Magnetic Field Laboratory, Los Alamos Facility.

3. Results and Discussion

Fig. 1 displays the resistivity as a function of temperature for various applied magnetic fields. The magnetoresistance is negative down to approximately 5 K. Further, the magnetoresistance for the current (i) parallel (Fig. 1(a)) and perpendicular (Fig. 1(b)) to H is very close to the same value. The magnetoresistance is qualitatively similar to that obtained by Yatskar *et al.*[4]. At 100 K the ratio of the resistivity obtained by Yatskar *et al.* to the value reported here is ~1.6, this ratio is nearly constant down to 5 K.

Fig. 2 displays the normalized magnetoresistance, $\Delta\rho(H)/\rho(0) = [\rho(H,T) - \rho(0,T)]/\rho(0,T)$, as a function of magnetic field for several temperatures. Comparing Fig. 2(a) (H||c) to Fig. 2(b) (H⊥c), the maximum is shifted to a slightly higher field. The insets in both Fig. 2(a) and Fig. 2(b) display the high temperature normalized magnetoresistance. A previous study by Yatskar *et al.* reported qualitatively similar behavior with i in the ab plane and H⊥i and H⊥c. However, the maximum at 2 K is located at a significantly higher field (~9 T) while the maximum in either one of our configurations is located at lower field (~5 T or less). This might be due to the field dependence of the scattering rate along the crystallographic structure.

An attempt to try to scale the magnetic field scattering mechanism can be obtained by plotting $-\Delta\rho(H)/\rho(0)$ vs. H (Fig. 3) on a log-log plot. A series of parallel lines is obtained, except for the 10 K magnetoresistance, which deviates from the main scaling behavior, except possibly at fields higher than ~12 T as in Fig. 3(a) and fields higher than ~5 T as in Fig. 3(b). It is important to notice that if the f-electrons are somewhat localized at higher temperatures it may be possible to scale the magnetoresistance to the spin-1/2 single impurity Kondo model.

In conclusion we have measured transverse and longitudinal c-axis magnetotransport of $YbNi_2B_2C$. The current was placed along the c-axis in contrast to previous investigations of the magnetoresistance of $YbNi_2B_2C$[4]. A well-defined maximum is observed in the normalized magnetoresistance at temperatures below 10 K at around 5 T. The magnetoresistance at higher temperatures is always negative and weakens as the temperature is increased. The partial attempt to scale the scattering rate data with a one parameter energy scale was done by plotting $-\Delta\rho(H)/\rho(0)$ vs. H. The scattering rate scaling failed at low temperature, however a good agreement could be found at higher temperature, this might possibly be due to a more localized interaction.

Acknowledgements

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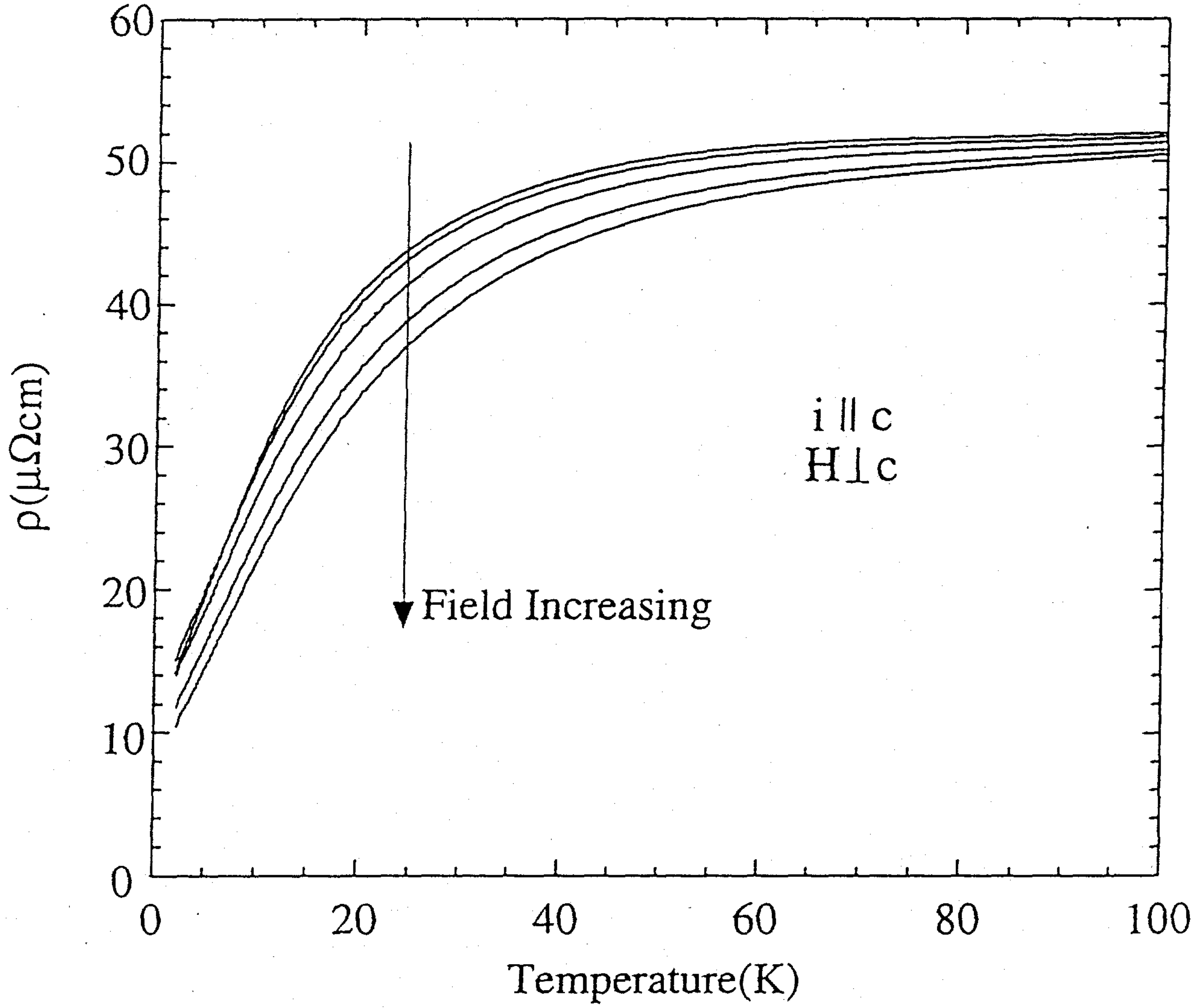
Figure Captions:

Figure 1. Temperature dependence of the resistivity for $YbNi_2B_2C$ with applied magnetic fields of 0, 5, 10, 15, 18 T. In both (a) and (b) the current is applied along the c-axis. In (a) the magnetic field is applied parallel to the c-axis and in (b) the magnetic field is applied perpendicular to the c-axis.

Figure 2. The normalized magnetoresistance, $\Delta\rho(H)/\rho(0) = [\rho(H,T) - \rho(0,T)]/\rho(0,T)$, as a function of the applied magnetic field for $YbNi_2B_2C$. In both (a) and (b) the current is applied along the c-axis. In (a) the magnetic field is applied parallel to the c-axis and in (b) the magnetic field is applied perpendicular to the c-axis. The insets in (a) and (b) show the high temperature normalized magnetoresistance.

Figure 3. $-\Delta\rho(H)/\rho(0)$ as a function of H on a log-log scale for $YbNi_2B_2C$. In both (a) and (b) the current is applied along the c-axis. In (a) the magnetic field is applied perpendicular to the c-axis and in (b) the magnetic field is applied parallel to the c-axis.

Figure 1(a)



60
50
40
30
20
10
0
0
20
40
60
80
100
ρ(μΩcm)
Temperature(K)
Field Increasing
i ∥ c
H⊥c

Figure 1(b)

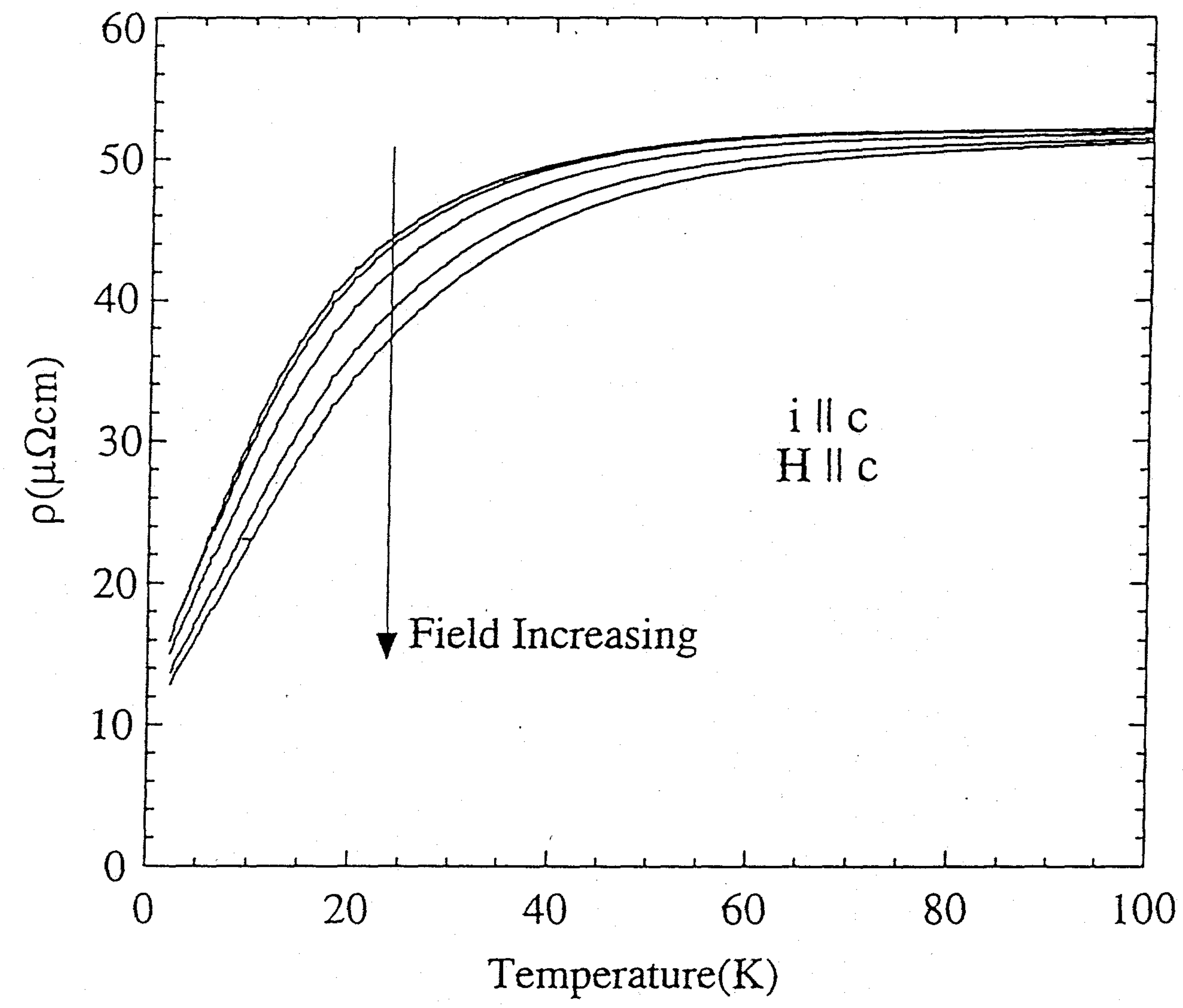
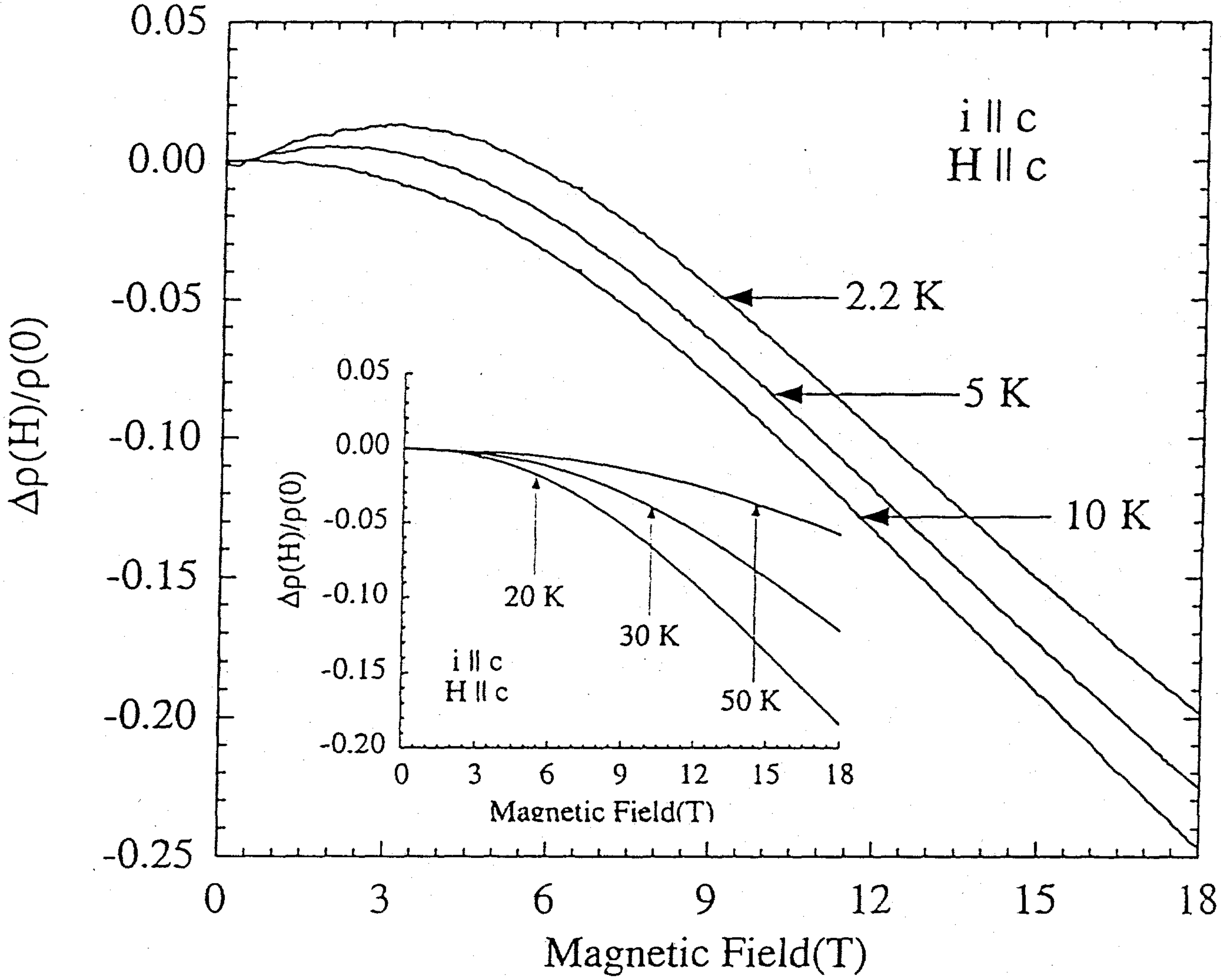
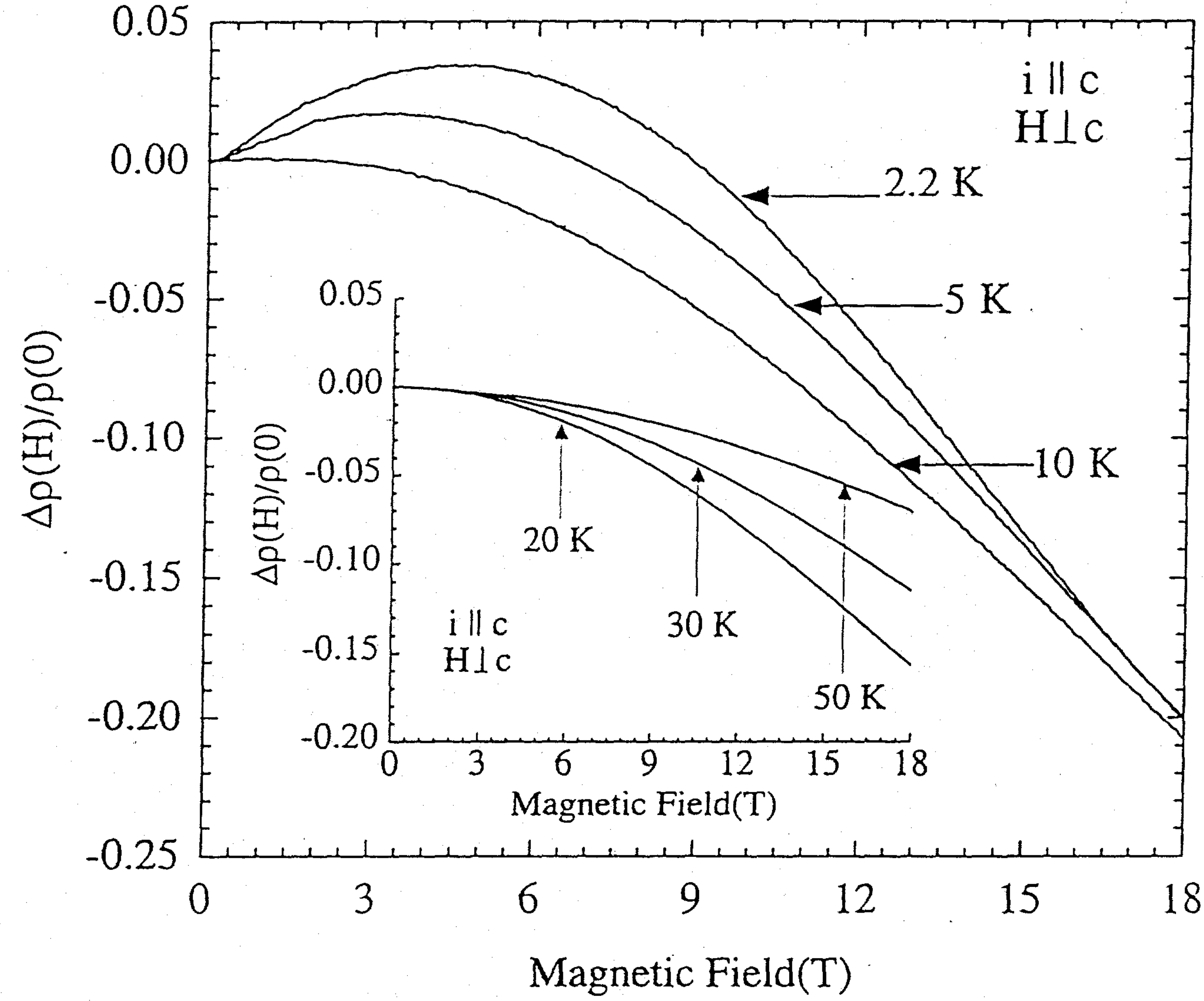

60
50
40
30
20
10
0
ρ(μΩcm)
0
20
40
60
80
100
Temperature(K)
Field Increasing
i || c
H || c

Figure 2(a)



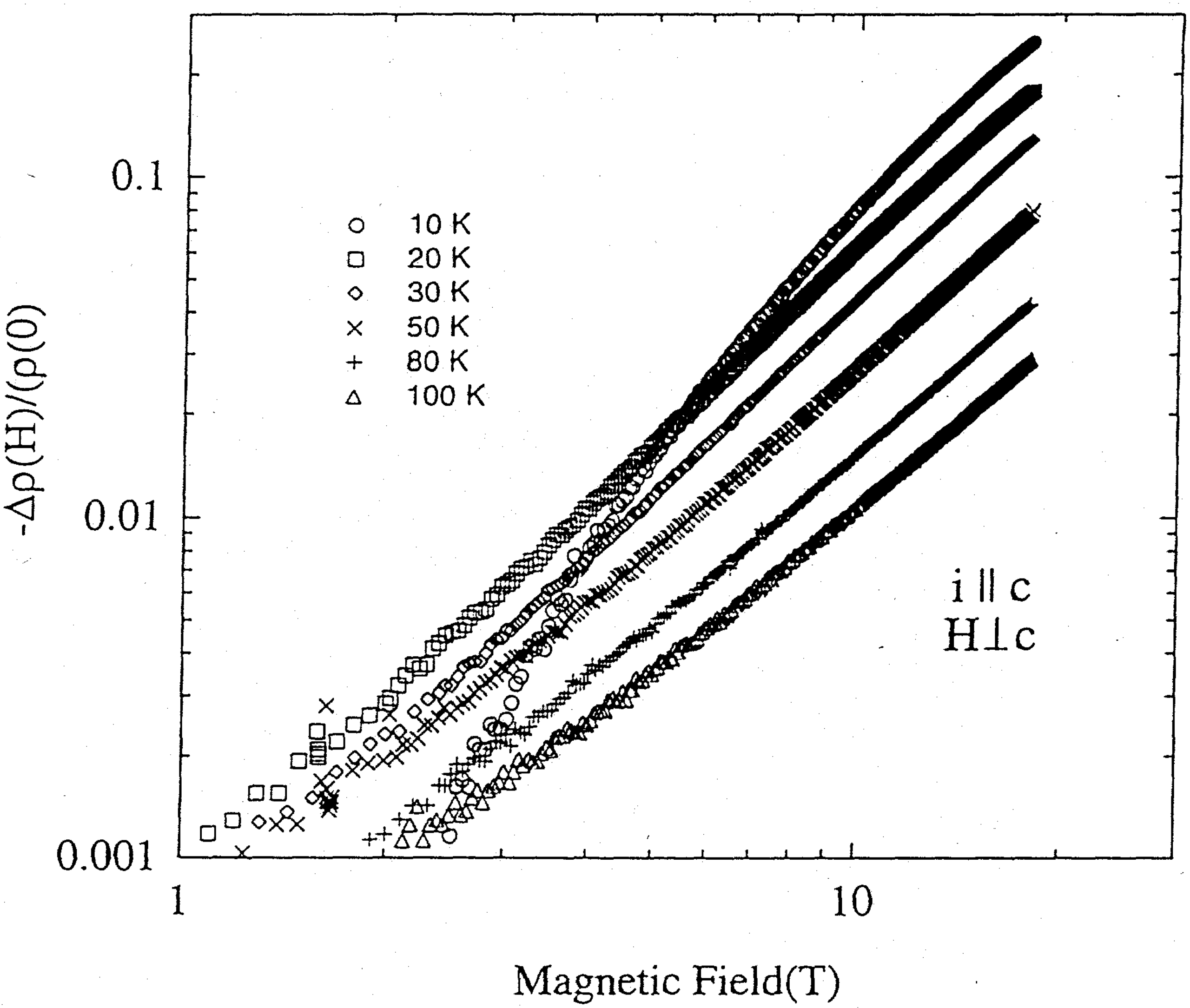
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
Δρ(H)/ρ(0)
i || c
H || c
2.2 K
5 K
10 K
0
3
6
9
12
15
18
Magnetic Field(T)
0.05
0.00
-0.05
-0.10
-0.15
-0.20
Δρ(H)/ρ(0)
20 K
30 K
50 K
i || c
H || c
0
3
6
9
12
15
18
Magnetic Field(T)

figure 2(b)



0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
Δρ(H)/ρ(0)
0
3
6
9
12
15
18
Magnetic Field(T)
i || c
H⊥c
2.2 K
5 K
10 K
20 K
30 K
50 K

fig 3a



0.1
0.01
0.001
-Δρ(H)/(ρ(0)
1
10
Magnetic Field(T)
10 K
20 K
30 K
50 K
80 K
100 K
i ∥ c
H⊥c

fig. 3b