CBPF-NF-016/82

ELECTRICAL RESISTIVITY OF THE PSEUDO-BINARY $Ce(Fe_{0,8}Al_{0,2})_2$

by

A. Y. TAKEUCHI and S. F. da CUNHA

Centro Brasileiro de Pesquisas Físicas - CBPF/CNPq
Rua Xavier Sigaud 150 - Urca
22290 - Rio de Janeiro, RJ - Brasil

ELECTRICAL RESISTIVITY OF THE PSEUDO-BINARY $Ce(Fe_{0.8}Al_{0.2})_2$

Running Title: Electrical Resistivity of $Ce(Fe_{0.8}Al_{0.2})_2$

A.Y. TAKEUCHI and S.F. DA CUNHA
Centro Brasileiro de Pesquisas Físicas
Rua Xavier Sigaud, 150
22290 Rio de Janeiro - RJ - Brasil

Abstract. Electrical resistivity measurements of the alloy $Ce(Fe_{0.8}Al_{0.2})_2$ as a function of temperature in the range of 1.5 to 300K shows that the long range magnetic order of the $CeFe_2$ is destroied and that the spin glass phase appear with a negative coefficient of $T^{3/2}$. The high residual resistivity is also discussed.

Intermetallic pseudo-binary systems $M(Fe_{1-x}Al_x)_2$ with rare earth M = Dy, Gd, Ho and Y have been investigated by means of magnetic experiments |1|. Characteristics of a possible freezing like remanence and irreversible effects in magnetic behavior are present in almost all of them.

There is little work done on these compounds, to our knowledge, using electrical resistivity technique, the majority being in canonical binary spin glasses of noble metal with 3d transition metal |2|. Some results in $M(Fe_{1-x}Al_x)_2$ for Gd and Dy, in the Al rich side have been reported |3|.

In a previous paper |4| we presented some results of magnetization measurements as a function of temperature and field for $Ce(Fe_{0.8}Al_{0.2})_2$. In this work we report electrical resistivity experiments on the same sample. The results are in agreement with the magnetic behavior observed in |4| and the spin glass or mictomagnetic resistivity dependence on tem perature is discussed.

Arc furnace casting was used for the sample preparation (1.5 mm diameter and 1.2 cm long) with elements in stoi - chiometric composition. Casting was followed by annealling at 700C in argon atmosphere for one week. X-ray diffraction using CuK_α radiation shows that $Ce(Fe_{0.8}Al_{0.2})_2$ crystallises in cubic $MgCu_2$ (C15) structure with small amount of others phases. The lattice parameter of 7.346 Å was derived by least-square analysis using Nelson-Riley's extrapolation. This value is of the same order of those found by Dwight |5|.

The electrical resistivity ρ(T) was measured using DC four-points probe method and over the temperature range 1.5 - 300K using Ge and Pt temperature sensors. Pressure contacts are used. Measurements are made for decreasing and increasing temperature and no thermal hysteresis was observed. Values of ρ have uncertainties estimated to be about 1% maximum due mainly to difficulties in measuring sample dimensions.

In the figure 1, the resistivity ρ versus temperature T curve and the lot of $d\rho/dT$ versus T for $Ce(Fe_{0.8}Al_{0.2})_2$ are shown. $d\rho/dT$ was computed point by point in a three-point span to a third-order polynomial fit.

The first point to observe is the strong contrast in the overall behavior of ρ versus temperature for 20% Al if compared with that of $CeFe_2$ |6|. Also, the total variation is of

116 μΩ cm for $CeFe_2$ and of only 4.6 μΩ cm for the compound with 20% Al. Whereas the residual resistivity of $CeFe_2$ is 4.2 μΩ cm it reaches to 146.3 μΩ cm for $Ce(Fe_{0.8}Al_{0.2})_2$.

As the temperature decreases from 300K, the resistivity drops till 152K and increases with further decreasing of temperature, with the appearance of a minimum at this temperature. By the dρ/dT curve we can see that no transition from long range order to paramagnetic phase was observed. We can explain this behavior in the following way. With initial decreasing of temperature the alloy shows a tendency to order magnetically, but without reaching a true long range magnetic order and, as the temperature is lowered, this process is inhibited by a mechanism that introduces disorder and the resistivity increases. These results are in accordance with previous magnetization measurements in the same sample |4|.

It is known that, in general, critical temperatures determined by magnetic experiments are slightly larger than that by electrical resistivity |7|. With this fact in mind, we can say that the magnetic features of the ρ versus T curve are the same as those evidenced by the magnetization versus temperature curve |4| , where a broad peak appears at 165K, and where linear variation of magnetization with field, between 85 and 165K, is observed.

Also, in the high temperature range, we can remark the very spread maximum in dρ/dT as a reflex of the negative curvature of the ρ versus T curve, this behavior has been already observed in $CeFe_2$ |6|.

The ρ versus T curve at low temperature is shown in figure 2. Magnetization measurements in the same sample have shown the existence of freezing, spin glass or mictomagnetic phase, characterized by a peak at T_f = 12.5K with remanence and irreversible effects below this temperature.

Usually, in the dilute spin glass or mictomagnetic systems and also in some concentrated alloys |8| the resistivity behaves initialy as $T^{3/2}$ followed by a broad maximum. The correlation between the maximum of dρ/dT and the temperature of freezing is also observed. Our results show the inverse of this behavior. In decreasing temperature, the resistivity passes through a minimum at 40K, increase as $-T^{3/2}$ and a maximum appears at lower temperature. The freezing temperature of 12,5K, given by the peak in the susceptibility, corresponds to a minimum in dρ/dT. An example of a negative coefficient is discussed by Rivier |9| as an effect of the additional electrostatic potential in more dilute alloys.

Another effect of the existence of the spin glass or mictomagnetic phase is that the ρ versus T curve presents some values below the residual resistivity. This means that the contribution of this phase to the residual resistivity must be considered. An estimate calculation based on the $CeFe_2$ resistivity and on some hypothesis about the phonon scattering variation and in magnetic resistivity was made |10|. From this estimate we obtain that 22.8 μΩ cm of the residual resistivity is due to the clusters in the freezing phase and that the normal residual resistivity is of 123.5 μΩ cm. This large value is due to the addition of Al to $CeFe_2$ which introduces a large potential V_{dd}

increasing, consequently, the electrical resistivity.

On the other hand at high temperature where these clusters do not exist, and using the Matthiessen rule with the corrected residual resistivity, a spin disorder resistivity of 17.3μΩ cm was obtained. As expected this value is much lower than that of 87 μΩ cm for $CeFe_2$.

In conclusion, the substitution of 20% Fe by Al in $CeFe_2$ not only destroys the long range magnetic order, but also gives rise, at low temperature, to a spin glass or mictomagnetic phase. We note that this concentration is lower than that for $Y(Fe_{1-x}Al_x)_2$ where irreversible effects occur, that is, about $x \geq 0.25$.

We intend to study next how this behavior of the resistivity varies with Al concentration.

REFERENCES:

[1] W. Steiner, J. Magn. and Magn. Mat. 14, (1979) 47

[2] P.J. Ford and J.A. Mydosh, Phys. Rev. B14, (1976), 2057

[3] E.Grats, R. Grössinger, H. Oesterreicher and F.T. Parker, Phys. Rev. B23, (1981), 2542

[4] S.F. da Cunha, D.F. Franceschini, S. Senoussi and A.Y. Takeuchi, to be published in J. Phys. F: Metal Phys.

[5] A.E. Dwight - private communication

[6] A.Y. Takeuchi and S.F. da Cunha, J. Phys. F: Metal Phys. 11, (1981) L 241

[7] M.P. Kawatra, J.A. Mydosh and J.I. Budnick, Phys. Rev. B2, (1970), 665

[8] J.A. Mydosh, P.J.Ford, M.P. Kawatra, T.E. Whall, Phys. Rev. B10, (1974) 2845

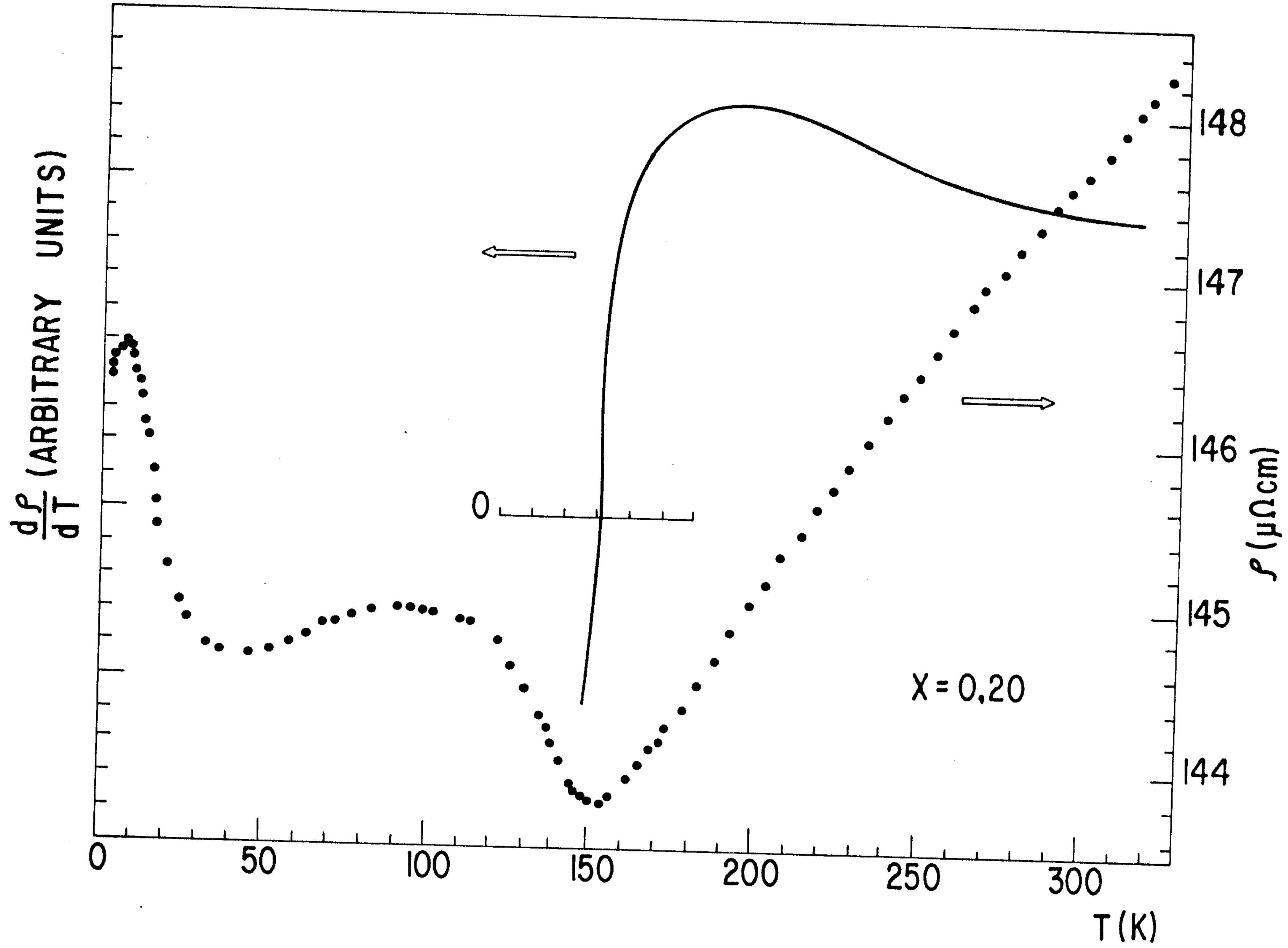
[9] N. Rivier, J. Phys. F: Metal Phys, 4, (1974), L 249

[10] A.Y. Takeuchi and S,F. da Cunha, to be published

CAPTIONS

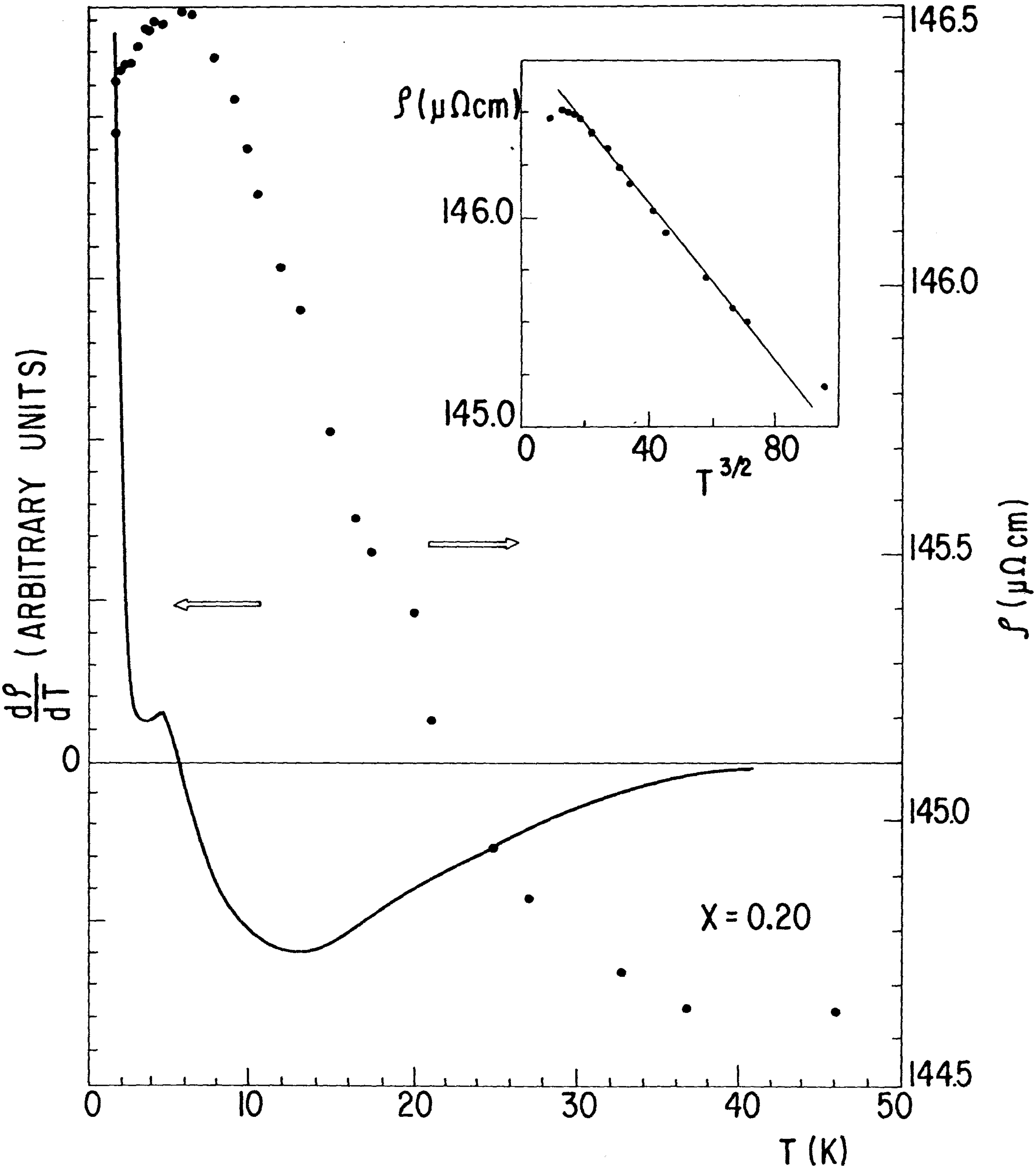
Fig. 1 - Temperature variation of the electrical resistivity of $Ce(Fe_{0,8}Al_{0,2})_2$ and its coefficient $d\rho/dT$.

Fig. 2 - Low temperature ρ versus T curve and $d\rho/dT$. Insert, the ρ versus $T^{3/2}$ curve.



dρ/dT (ARBITRARY UNITS)
ρ (μΩcm)
0
148
147
146
145
144
X = 0.20
0
50
100
150
200
250
300
T (K)

Fig. 1



$\frac{d\rho}{dT}$ (ARBITRARY UNITS)
0
ρ ($\mu\Omega$cm)
146.5
146.0
145.5
145.0
144.5
ρ ($\mu\Omega$cm)
146.0
145.0
0
40
80
$T^{3/2}$
X = 0.20
0
10
20
30
40
50
T (K)