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ELECTRICAL RESISTIVITY OF $CeFe_2$

by

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ABSTRACT

Electrical and magnetic properties of $CeFe_2$ were investigated from the temperature dependence of electrical resistivity in the range of 1,5 to 300ºK. The critical temperature, determined from the maximum of $d\rho/dT$, gives T_c = 220ºK and the temperature independent magnetic resistivity is 87μΩcm. This value is compared with the corresponding in YFe_2. At low temperature the resistivity shows a fairly large variation proportional to AT^2 up to about 32ºK with A = $1,2\times10^{-2}$ μΩcm/ºK^2.

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Abstract. Electrical and magnetic properties of $CeFe_2$ were investigated from the temperature dependence of electrical resistivity in the range of 1,5 to 300ºK. The critical temperature, determined from the maximum of $d\rho/dT$, gives T_c = 220ºK and the temperature independent magnetic resistivity is 87μΩ cm. This value is compared with the corresponding in YFe_2. At low temperature the resistivity shows a fairly large variation proportional to AT^2 up to about 32ºK with A = 1,2x10^{-2} μΩ cm/ºK^2.

Intermetallic alloys AFe_2 has been investigated very little from transport phenomena measurements. The electrical resistivity for A transition metal as Sc,Y,Ti,Zr,Hf,Nb,Ta (Ikeda et al 1975) and Ti (Ikeda et al 1972) was reported and also for A rare-earth as Tb (Savage 1974). As the short-range ($T > T_c$) and long-range ($T < T_c$) order affects strongly the temperature dependence of the electrical resistivity it provides a good means to study magnetic interactions. However, the measurements of rare-earth compounds are specialy hard for the brittleness of the samples.

The compound $CeFe_2$, cubic with $MgCu_2$ type Laves phase is ferromagnetic and has the iron moment and ordering temperatu re lower than others rare-earth-Fe_2 compounds. Also, in $CeFe_2$ Ce is quadrivalent and the itinerant electron concentration must be greater. In this paper electrical and magnetic properties of $CeFe_2$ are investigated from results of electrical resistivity measurements.

The sample preparation follows the usual arc furnace cast (1,5 mm diameter and 1,2 cm long), of elements in stoichiometric composition followed by annealing at 700ºC in an argon atmosphere during one week. X-ray using CuK_α radiation shows a single phase with a lattice parameter of 7,302 Å, derived by least squares analysis using Nelson-Riley's extrapolation. This reduced value is due to the +4 valence of Ce.

Electrical resistivity was measured by DC four-points probe method and over a temperature range of 1.5-300ºK measured with Ge and Pt sensors. Pressure contacts are used. No thermal hysteresis was observed. Uncertainties in values of ρ are estimated to be about 1% max. due mainly to difficulties in measuring sample dimensions.

The residual resistivity ρ_o of 4,19$\mu\Omega$ cm is consistent with that observed in YFe_2 (Ikeda et al 1975) and others AFe_2.

In Fig. 1 the resistivity ρ versus temperature T curve and the plot of $d\rho/dT$ versus T, computed point by point in a three point span to a fit of third-order-polynomium show a ferromagnetic behavior. A sharp break in the slope of ρ vs T at 230ºK is observed. The Curie temperature determined from magnetization data range from 230 to 237ºK (Buschow et al 1970, Farrell et al 1964, da Cunha et al 1980). But the derivative curve shows a maximum at T = 220ºK, the "resistivity

Curie temperature", this difference of T_c been observed for others Laves phases (Kawatra et al 1970).

From low temperature $d\rho/dT$ increases linearly with T until 27ºK, followed by a broad maximum. Then $d\rho/dT$ decreases nearly until the vicinity of the transition region. This decrease reflets the negative curvature of ρ vs T curve in this range of temperature, and shows clearly that another scattering mechanism takes place. There is very little theoretical investigations for this behavior of ρ versus T.

The linear part in ρ above T_c gives $d\rho/dT = 9x10^{-2} \mu\,\Omega\,cm/ºK$ value some higher than that of YFe_2 ($3x10^{-2}$) (Ikeda et al 1975). It should be said that such a value was otained from measurements made only 70 degrees above T_c, as compared to about 300 degrees in the case of YFe_2. As the short-range order participates of the scattering mechanism, we need to know δ, the extend of the short-range order. If we take the tail in the $d\rho/dT$ above T_c as a measure of δ this gives $\sim$25 degrees.

Assuming the Mathiessen's rule the magnetic resistivity ρ_m due to spin disorder was estimated by extrapolating the linear high temperature part of the resistivity curve to T=0 and substracting the residual resistivity. This yield a value of $87\mu\,\Omega\,cm$ which is of the same order of magnitude as that of others AFe_2. A check of this value can be estimated in the following way.

In the isostructural compound YFe_2 we have a similar electronic structure (few d electrons in the A site) and nearly the same ρ vs T behavior (Ikeda et al 1975). Although $CeFe_2$ is itinerant, at high temperatures ($T>>T_c$) we can apply (Ueda et al 1975), the spin disorder resistivity for ferromagnetic metals given by the Kasuya (1956) expression. Comparing ρm_1 for $CeFe_2$ with ρm_2 for YFe_2 we have:

$$\frac{\rho m_1}{\rho m_2} = \frac{A_1}{A_2}\left(\frac{J_1}{J_2}\right)^2 \frac{S_1(S_1+1)}{S_2(S_2+1)}$$

where

$$A = \frac{3\pi\, m^*}{e^2\, \hbar^2} \frac{1}{NE_F}$$

J is the s-d exchange integral and $S(S+1) = \langle s^2 \rangle$ is the iron's spin.

We can suppose $J_1 \simeq J_2$ and $m_1^* \simeq m_2^*$.

Then

$$\frac{\rho m_1}{\rho m_2} = \frac{N_2}{N_1} \frac{E_{F_2}}{E_{F_1}} \frac{S_1(S_1+1)}{S_2(S_2+1)}$$

Taking $S_1(S_1+1) = 0{,}96$, $S_2(S_2+1) = 1{,}226$ and $N = 24/a^3$ Å^{-3}, $a_1 = 7{,}302$ Å for $CeFe_2$ and $a_2 = 7{,}359$Å for YFe_2 (da Cunha et al 1980) we have:

$$\frac{\rho m_1}{\rho m_2} = 0{,}8\, \frac{E_{F_2}}{E_{F_1}}$$

Measurements made by Ikeda and al (1975) in YFe_2 gives a value of the $\rho m_2 = 140\mu\,\Omega$ cm. Then

$$E_{F_1} = 1{,}3\, E_{F_2}$$

As is known that Ce is quadrivalente in $CeFe_2$ by transfering a f electron to the d-band of the compound is reasonable that Fermi energie in $CeFe_2$ be larger than in YFe_2. The iron magnetic moment in YFe_2 is larger than in $CeFe_2$. Assuming a common density of states curve for both YFe_2 and $CeFe_2$, the f electron transfer to the d-band amounts to displacing the Fermi level to higher energies. If one has a decreasing density of states in this region, the Fe magnetic moments can be also consistent with the f electron transfer.

In Fig. 2 the logarithmic plot of $\rho - \rho_o$ versus T shows a T^2 dependence up to 32ºK. The best computer fitting of the low temperature curve ρ versus T uses the expression

$$\rho - \rho_o = AT^2 + BT^5$$

giving also a predominating term in T^2 up to 32ºK with a coeficient $A = 1,2 \times 10^{-2} \mu\Omega \, cm/ºK^2$ and $B = 2 \times 10^{-7} \mu\Omega \, cm/ºK^5$. The high value of the coeficient A only compares with those obtained in strong paramagnets like YCo_2 or in weak ferromagnets like $ZrZn_2$ and Sc_3In were A is approximately equal to $5 \times 10^{-2} \mu\Omega \, cm/ºK^2$ (Moriya 1979). Then, remains the problem of explaining this order of magnitude of coeficient A in $CeFe_2$.

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REFERENCES

1) Buschov K H J and Wieringer J S van 1970 Phys. Stat. Sol. 42 231.

2) da Cunha S F, Guimarães A P and Livi F P 1980 J. Phys. Chem. Solids 41 761.

3) Farrel J and Wallace 1964 J. Chem. Phys. 41 nº 5 1524.

4) Ikeda K and Nakamichi T 1975 J. Phys. Soc. of Japan 39 nº 4 963.

5) Ikeda K, Nakamichi T and Yamamoto M 1972 Phys. Stat. Solidi (a) 12 595.

6) Kasuya T 1956 Progr. Theor. Phys. 16 58.

7) Kawatra M P, Mydosh J A and Budnick J I 1970 Phys. Rev. B 2 nº 3 665.

8) Moriya T 1979 J. Magn. and Magn. Mat. 14 1.

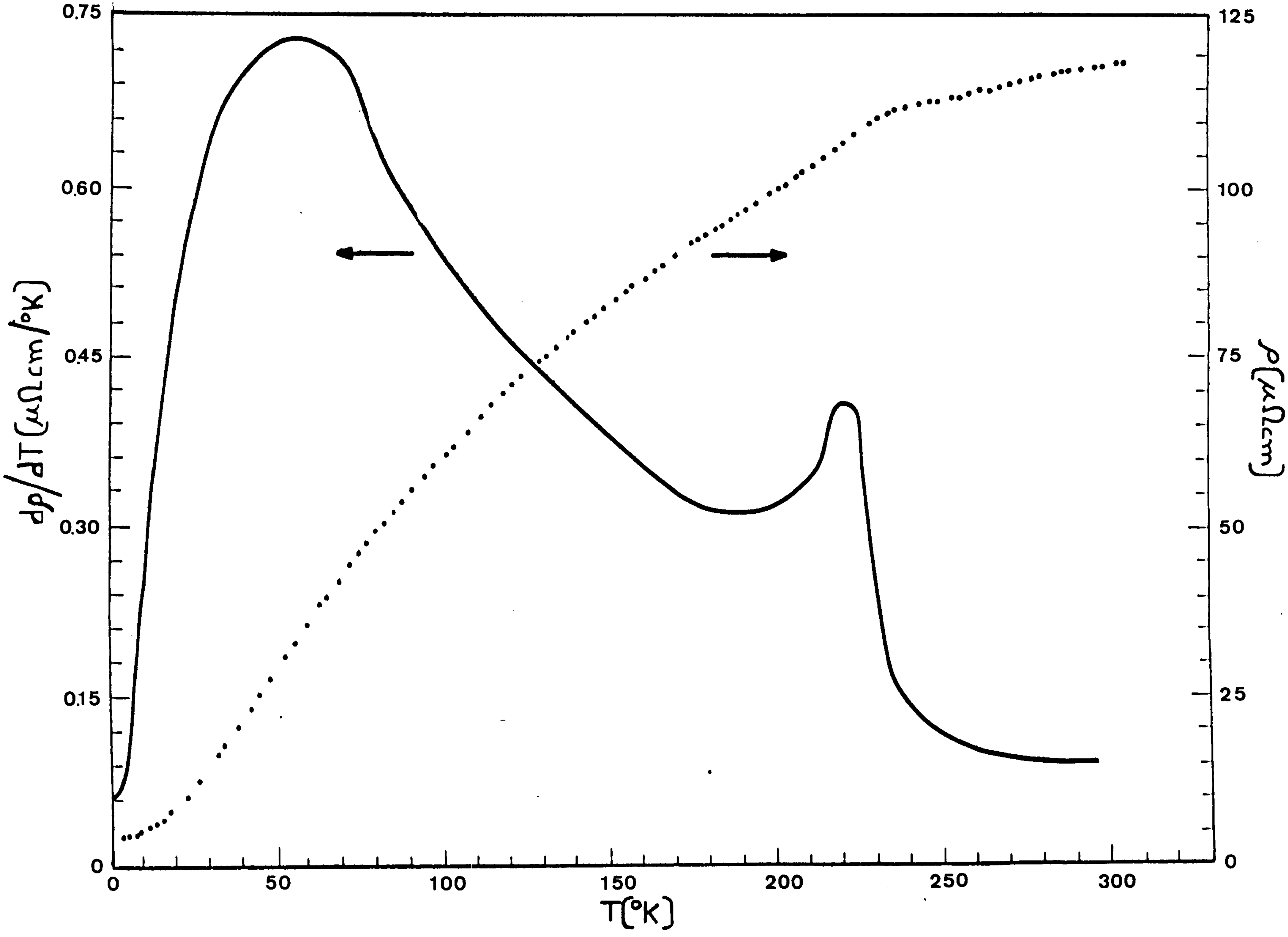
9) Savage H T See CLARK A E 1974 AIP Conf. Proc. nº 18 1015.

10) Ueda K and Moriya T 1975 J. Phys. Soc. of Japan 39 nº 3 605.

CAPTIONS

Figure 1 - The temperature variation of the electrical resistivity $\rho(T)$ and of its coeficient $d\rho/dT$.

Figure 2 - Logarithmic plot of $\rho - \rho_o$ versus T at low temperature.



0,75
0,60
0,45
0,30
0,15
0
125
100
75
50
25
0
0
50
100
150
200
250
300
T[°K]
dρ/dT [μΩcm/°K]
ρ[μΩcm]

Fig. 1

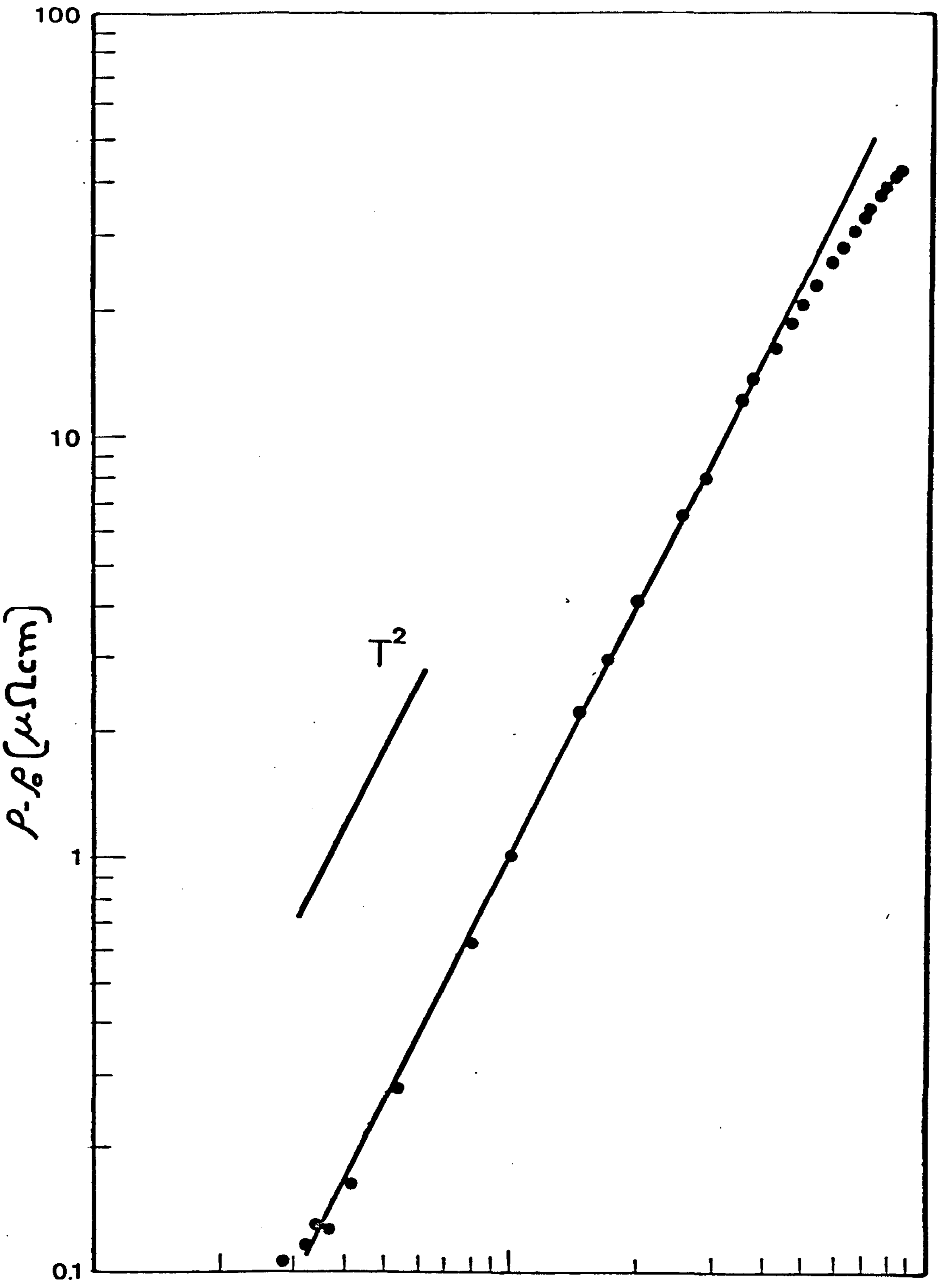


Fig. 2