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ELECTRICAL RESISTIVITY OF AMORPHOUS $Zr_{70}Cu_{30}$ AND THE KONDO LIKE MODEL

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Electrical resistivity measurements of amorphous $Zr_{70}Cu_{30}$ as a function of the concentrations of two level systems show that a Kondo like theory cannot explain the observed temperature dependence.

THE ELECTRICAL RESISTIVITY ρ of many amorphous metals is characterized [1] by a weak negative temperature coefficient. This anomalous behavior has been the object of recent interest [1, 2]. Different theoretical models [1–3] for electron scattering have been proposed to explain these results, although there is no experimental evidence indicating without ambiguity which of them describes most adequately the electrical transport properties of highly disordered materials. The fitting of theory to experiment is not simple because there is more than one possible choice of free parameters (or, equivalently, unknown material properties) in the different theories, which fit the weak temperature dependence of ρ equally well.

Let us describe briefly the basic ideas that underlie the commonly used theoretical formulas. The Faber–Ziman theory for liquid metals has been modified [1] to explain the electrical resistivity coefficient in amorphous metals. The theory is based on a free electron model, where the electrons are scattered by the disorder represented by the structure factor of the material. In this model [1] the temperature dependence of ρ is related to the temperature induced variation of the structure factor. The sign of the coefficient is essentially determined by the position of the scattering vector $K = 2k_F$, where k_F is the Fermi momentum, relative to that of the peak of the structure factor, K_P.

Another completely different approach is based on the interaction [2] between the electrons and those excitations characteristic of disorder described by a two level system, TLS. In this model the main electron interaction responsible for the temperature dependence of ρ is described by a Kondo like Hamiltonian.

Finally, a third possibility is that incipient electron localization might induce the negative resistance coefficient [3].

In this report we investigate the Kondo model and its relation to precise ρ measurements in amorphous $Zr_{70}Cu_{30}$.

In this model the electron relaxation time is inversely proportional to P, the density of states of the TLS [2]. This result suggests that the model could be verified by systematically changing P and measuring the corresponding variation in ρ.

Recently we have shown [4] that the thermal conductivity κ of amorphous $Zr_{70}Cu_{30}$ can be modified by means of isothermal heat treatment below the crystallization temperature. In particular κ shows the T^2 dependence characteristic of amorphous metals for temperatures well below the critical one ($T_c \simeq 2.5$ K), with a coefficient inversely proportional to $P\gamma^2$, where γ is an average coupling [5] constant of the TLS with phonons. By means of successive heat treatments [4] the coefficient of the T^2 term of the thermal conductivity was systematically increased by a factor ranging from one to three. However, thermal conductivity measurements alone are not enough to determine the behavior of P. On the other hand specific heat and thermal conductivity measurements [6] in a similar system, $Zr_{76}Ni_{24}$, suggest that the increase in κ induced by heat treatment is in qualitative agreement with a decrease in P. It would then be reasonable to assume that the enhancement in the low temperature conductivity is at least partially due to a change in the density of states of the TLS.

Resistivity measurements were made in samples similar to those used in the thermal conductivity experiments [4], prepared by the same splat cooling technique [7]. The heat treatment of 250°C, was similar to that of [4]. The samples were ribbons 20 mm long, 0.5 mm wide and 10 μm thick.

Figure 1 shows the electrical resistivity of $Zr_{70}Cu_{30}$ as a function of temperature. Curve A corresponds to a sample without thermal annealing. Curve B corresponds to the same sample after 9 hr of annealing. All the other curves obtained for different heat treatments, see Table 1,

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Table 1. Annealing period, superconducting critical temperature T_c *and electrical resistivity at* 10 *and* 273 K *for amorphous* $Zr_{70}Cu_{30}$. *The annealing temperature for all data is* 250°C

Annealing period (hours)	T_c (K)	$\rho_{(10K)}$($\mu\Omega$-cm)	$\rho_{(273K)}$($\mu\Omega$-cm)
0	2.758	182.3	173.5
1	2.420	182.8	174.5
5	2.383	182.4	174.8
9	2.374	182.4	175.0
18	2.362	182.3	174.9

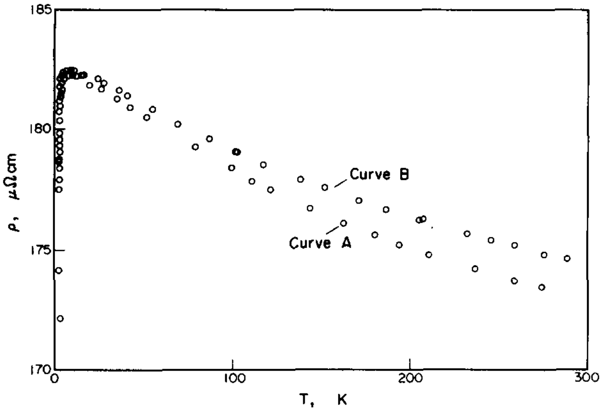

Fig. 1. Electrical resistivity of amorphous $Zr_{70}Cu_{30}$ as a function of temperature. Curve A corresponds to a sample as-quenched from the liquid state. Curve B is for the same sample after 9 hr of isothermal annealing at 250°C.

coincide within 1% with those shown in Fig. 1 and have been omitted for clarity. The absolute value of ρ is measured with an error of 10% due to the error in determining the geometrical factor.

It is seen in Fig. 1 that neither the absolute value nor the temperature dependence of ρ changes by more than 1%. As was mentioned earlier, samples with similar ρ behaviour and heat treatment show variations in the coefficient of the T^2 term of κ, up to a factor of three. Figure 2 shows the normalized change in ρ at 10 K as a function of relative changes [4] in κ below T_c.

In conclusion, the assumption of a Kondo like theory seems irreconcilable with the results shown in Figs. 1 and 2.

We note, however, that although ρ is constant in the range of heat treatment discussed here, the superconducting critical temperature T_c changes [8] with annealing (see Table 1). It is necessary to investigate the origin of this variation at almost constant ρ and $d\rho/dT$ before reaching final conclusions about the microscopic mechanism that determines the electrical transport properties.

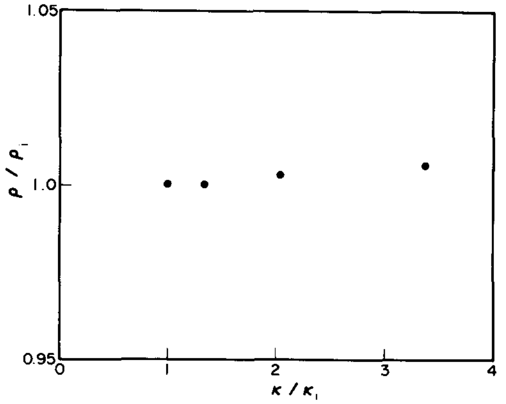

Fig. 2. Electrical resistivity at 10 K as a function of the T^2 coefficient of the low temperature thermal conductivity of amorphous $Zr_{70}Cu_{30}$. The data are normalized by the corresponding value of the as-quenched sample.

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