EFFECT OF PRESSURE ON IMPURITY-IMPURITY INTERACTIONS
IN SPIN GLASS ALLOYS

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ABSTRACT

The electrical resistivity of dilute (c<1at%) spin glass alloys such as Au:Fe, Au:Mn, Cu:Mn, and Mo:Fe has been measured from 1.2–40K at pressures between 0 and 100 kbar. In these alloys the cooperative locking-in of the impurity spins at a temperature \( T_0 \) leads to a resistivity maximum at \( T = T_M(\Delta_c, T_K) \) which is a function of both the impurity-impurity interaction strength \( \Delta_c \) and the Kondo temperature \( T_K \). Whereas \( T_M \) always increases with the impurity concentration, both the sign and magnitude of the pressure dependence of \( T_M \) are found to depend in a complicated way on the particular system studied. From \( T_M(P) \) and the known positive pressure dependence of \( T_K \), it is possible using a theory of Larsen to derive the pressure dependence of the average interaction strength \( \Delta_c(P) \). The analysis lends support to the view that in these systems the long range RKKY-oscillations represent the dominant interaction mechanism.
We have recently found that the high pressure technique is an important complement to studies of the concentration dependence of magnetic alloys. Varying the concentration of the magnetic component frequently leads to a drastic change in its magnetic state as can be seen for example in Au:Fe where one observes changes from paramagnetic to spin glass and finally to ferromagnetic behavior. However, once concentration studies have established the general "lay of the land," pressure measurements can then supply detailed information about the nature of the impurity-conduction electron and the impurity-impurity interactions in the alloy. By using pressure we are able to vary the basic system parameters in a reversible manner. This, together with the fact that a single sample with a unique configuration of magnetic impurities is used, is an important advantage of the technique allowing a meaningful comparison between experiment and theory.

As an example of the application of the high pressure technique, let us briefly consider the effect of pressure on the interaction between conduction electrons and magnetic impurities in very dilute Kondo alloys. The spin-scattering resistivity \( \rho_{\text{kondo}} \) in such alloys is a function of a number of parameters, among then, \( J \) the effective exchange parameter, \( S \) the impurity spin, \( \delta_V \) the potential scattering at the impurity site, and \( n \) the density of states. Theory in general predicts a universal resistivity law \( \rho=\rho(T/T_K) \), where \( T_K=\frac{T_F\exp(1/nJ)}{1} \). The temperature dependence of \( \rho_{\text{kondo}} \) is shown in the lower part of Fig. 1. The inflection point of this curve marks the Kondo temperature \( T_K \) but is in practice difficult to determine accurately either because it lies below the accessible temperature range or is masked by the rising phonon scattering. On the other hand, changes in \( T_K \) on a particular alloy, such as for instance are caused by application of high pressures, can be determined quite accurately. In a study of the resistivity of Cu-110 ppm Fe under pressure, \( \rho_{\text{kondo}} \) is found to shift bodily on a logarithmic temperature scale to higher temperatures, confirming the law \( \rho=\rho(T/T_K) \). This is shown in Fig. 2. The change in \( T_K \) with pressure is given by \( \frac{d\ln T_K}{dP}=+1.1%/\text{kbar} \), and is due to an increase in \( J \) with pressure, while \( \delta_V \), \( S \), and \( n \) stay essentially constant. Similar studies have been carried out on a wide number of dilute alloys (e.g. Au:Mn, Ag:Fe, Cu:Mn, Y:Ce, and La:Ce) and in all cases \( T_K \) and \( |J| \) are found to increase with pressure. This information will be of importance in subsequent studies of the pressure dependence of interactions between impurities in spin glasses.