Electrical Properties of Exchange-Enhanced Systems: Fe in (Pd_{95}Rh_{5})

M. E. Colp, R. M. Roshko, and Gwyn Williams

Department of Physics, University of Manitoba, Winnipeg, Manitoba, Canada

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The electrical resistivity of the giant moment system Pd_{95}Rh_{5} containing between 0.8 and 1.85 at\% Fe has been measured from 1.4 to 300 K. The incremental resistivity in alloys containing more than 1.25 at\% Fe is found to exhibit a T^2 limiting low-temperature form; however for the 0.8 and 1.1 at\% Fe alloys such a T^2 form is not clearly discernible, with \Delta\rho(T) exhibiting a temperature dependence intermediate between T^2 and T^{3/2}. The former result is predicted from conduction electron–magnon scattering for which wave vector conservation holds, from which it is inferred that the criterion for wave vector conservation in this type of alloy is not determined by mean free path effects. Estimates of the acoustic spin-wave stiffness D are derived from the measured T^2 coefficients. These resistivity data also enable estimates of the exchange coupling parameter J_{s-local} to be made. The magnetic ordering temperature T_c is considerably less discernible than in single-component hosts but approximate values have been derived for the various alloys, from which estimates of the exchange coupling parameter J_{s-local} have been made. In the disordered phase the measured incremental resistivity is found to contain a term which decreases approximately linearly with increasing temperature, at a rate of \((1.1 \pm 0.45) \times 10^{-3} \mu\Omega \text{cm/K}\) at\% Fe. Using existing pressure data on both Pd- and PdRh-based alloys, it is shown that both the sign and magnitude of this term can be accounted for in terms of the volume dependence of the potential and exchange terms, in conjunction with a large coefficient of thermal expansion.

1. INTRODUCTION

The occurrence of giant moments associated with small amounts of the transition metal impurity in exchange-enhanced matrices has been known for many years,\(^1,^2\) yet the nature of the ordered ground state of such alloy

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systems and especially the elementary excitations from it are currently far from well understood.\textsuperscript{3–6} In particular, the interpretation of transport measurements at low temperatures on the ordered phase of these and related systems\textsuperscript{6–13} appears to indicate that wave vector conservation may not hold for electron–local moment scattering, even when the local moment dynamics are represented by collective modes.\textsuperscript{13–15}

For the giant moment alloys of Pd containing less than 1 at.\% Fe or Co, the incremental resistivity $\Delta \rho(T)$ at low temperatures follows a $T^{3/2}$ limiting form,\textsuperscript{7,9} as would be predicted on the basis of electron–spin wave scattering with nonconservation of $k$ vector. As the concentration $c$ of Fe or Co is increased above 1 at.\%, however, a $T^2$ limiting low-temperature form for $\Delta \rho(T)$ is observed; such a temperature dependence would result from electron–magnon scattering with $k$ vector conservation.\textsuperscript{16,17} For Mn in Pd the situation is somewhat different, with the $T^{3/2}$ limiting form for $\Delta \rho(T)$ persisting up to 3 at.\% Mn;\textsuperscript{8,10} however, the rapid decrease in $dT_c/dc$, along with the transition from a predominantly ferromagnetic to a "disordered" antiferromagnetic ground state, as the impurity concentration $c$ increases undoubtedly complicates this system.

In the isolated impurity (single impurity) limit, the impurity potential clearly lacks translational symmetry, and calculations of the incremental resistivity based on conduction electron scattering from such a potential should consequently proceed without conservation of $k$ vector. As the impurity concentration increases, however, it is not clear at what point, or on what basis, $k$ vector conservation is restored. In this context Skalski\textit{ et al.}\textsuperscript{11} point out that above about 2 at.\% Fe in Pd, where the $T^2$ limiting form for $\Delta \rho(T)$ is "restored," the induced $d$-band polarization displays considerable homogeneity.

Here we report on electrical resistivity measurements on dilute alloys of Fe in (Pd\textsubscript{95}Rh\textsubscript{5}); in this host the effects of exchange enhancement (for second transition series alloys) reaches a maximum.\textsuperscript{18} This implies that a homogeneous polarization should be induced in the $d$ band of the host at Fe concentrations rather less than 2 at.\%; the effect of 5 at.\% Rh should, however, substantially reduce the electronic mean free path. The data indicate that a $T^2$ limiting form for $\Delta \rho(T)$ is established at about 1.25 at.\% Fe, from which we infer that the restoration (or removal) of $k$ vector conservation in this type of alloy is not a mean free path effect.

We also present a comparison of various parameters deduced from the spin disorder resistivities of these alloys and alloys of Pd containing comparable amounts of Fe. A possible interpretation of the temperature-dependent incremental resistivity of (Pd\textsubscript{95}Rh\textsubscript{5})-based alloys in the paramagnetic regime is also presented.