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Low-Field Magnetoresistance of Palladium Alloys*

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Observations are reported of a negative contribution to the magnetoresistance of a paramagnetic transition metal, palladium, with nonmagnetic impurities. The longitudinal magnetoresistance of some polycrystalline palladium alloys which show a resistance minimum is compared with the magnetoresistance of palladium alloys with no resistance minimum. Kondo scattering in these alloys cannot account for the results, but we suggest that the energy dependence of Mott *s-d* scattering, used successfully to explain the temperature dependence of resistivity of these alloys, is also responsible for the negative magnetoresistance. A positive contribution to the magnetoresistance which, unlike the negative component, obeys Kohler's rule is also present. We attribute this component to anisotropy of scattering on the Fermi surface. It proves to be surprisingly sensitive to the impurity type, suggesting that this may be a profitable way to study the anisotropy of scattering in other paramagnetic transition metals.

INTRODUCTION

In a recent letter Rowlands *et al.*[1] described experiments on the electrical resistivity of dilute *Pd*-Rh[2] alloys which showed a resistance minimum. Other workers[3] have found resistance minima in some concentrated *Pd*-Ag alloys. However, no minimum is seen in dilute *Pd*-Ag or *Pd*-Pt alloys. Rowlands *et al.* explained these results on the basis of the energy dependence of Mott *s-d* scattering, which gives rise to a resistance of the form

$$\rho_T = \rho_0 (1 - A T^2) , \qquad (1)$$

where A is a term related to the energy dependence of the density-of-states curve.

This mechanism was first applied to impurity resistivity by Coles and Taylor,[4] who successfully explained the peculiar concentration dependence of the room-temperature resistivity of *Pd*-Ag alloys on this basis. It was extended and applied to other electronic properties by Dugdale and Guenault.[5]

There is no evidence that the impurity exhibits a local moment in any of the alloys we have mentioned[6]; therefore, the Kondo effect can be ruled out. Rowlands and Greig[7] in a forthcoming paper discuss further evidence to support the contention that even in some *Pd*-Cr and *Pd*-Np alloys, where it is possible that the impurity is magnetic, the resistance minimum that has been observed is due to a virtual bound state with a strongly energy-dependent density of states. If the energy dependence of the final *d* states in our alloys is responsible for the resistance minimum, then the effect of a magnetic field on the alloys should also be marked. A component of the magnetoresistance, which we shall call "band" magnetoresistance will arise from the splitting of the *d* band into two spin bands. The band magnetoresistance may be evaluated from the density-of-states curves for pure palladium derived from magnetic-susceptibility data. It turns out that it is negative and proportional to the solute concentration for sufficiently dilute alloys. "Anisotropy" magnetoresistance, arising from the anisotropy of scattering processes on the Fermi surface,[8] is the other component to be expected in these alloys. In alloys where the band component is small, it is demonstrated experimentally that the magnetoresistance obeys Koh-

TABLE I. List of alloys and experimental magnetoresistance and resistance parameters.

Alloy nominal concentration (at.%)	ρ_0 ($\mu\Omega$ cm)	10^3k [a]	x	T_m [b] (K)
Pd-$\frac{1}{5}$% Rh	0.661	0.78	1.6	None [c]
Pd-$\frac{1}{2}$% Rh	1.225	0.70	1.6	None [c]
Pd-1% Rh	2.39	0.40	1.6	None [c]
Pd-2% Rh	4.09	0	... [d]	5.5
Pd-4% Rh	7.44	−2.0	−2.4	7.5
Pd-7% Rh	12.08	−2.0	−2.2	2.8
Pd-$\frac{1}{2}$% Ag	0.512	1.25	1.6	None [c]
Pd-1% Ag	1.066	1.40	1.8	None [c]
Pd-2% Ag	1.877	1.60	1.8	None [c]
Pd-$\frac{1}{10}$% Ru	0.773	1.27	1.6	None [c]
Pd-$\frac{1}{2}$% Ru	2.44	1.00	1.9	4
Pd-$\frac{1}{2}$% Pt	0.737	0.44	1.9	None [c]
Pd-43% Pt	20.65	... [d]	... [d]	3.5
"Pure" Pd	0.0624	0.48	1.5	None [c]

[a] Data taken from graph where units of H and ρ_0 are, respectively, kOe and $\mu\Omega$ cm.

[b] T_m is the temperature of the resistance minimum, measured on the same specimens and published in full in Ref. 7.

[c] No fractional change in resistivity of negative sign larger than the experimental resolution ($1/10^5$) down to 1 K.

[d] Errors too large to make a meaningful estimate.

ler's rule. When the results for all the alloys are analyzed assuming that anisotropy magnetoresistance follows Kohler's rule, not only is a band component with the expected properties demonstrated to exist, but interesting information about the scattering anisotropy in palladium is adduced.

EXPERIMENTAL

The specimens were prepared by M. J. Walker at Leeds University from palladium kindly loaned by Englehard Industries and are the same ones used in resistivity measurements reported elsewhere.[1,7] They were melted in an argon arc furnace, then rolled and swaged until they were rods 2 mm in diam and about 10 cm long. The rods were annealed for 24 h at 850 °C in vacuum and cooled slowly.

The longitudinal magnetoresistance of the alloys listed in Table I was measured in the residual resistance regime. To do this the specimens were completely immersed in liquid helium and mounted axially in a superconducting solenoid capable of attaining a field of 35 kOe. A current of 1 A regulated to one part in 10^5 was maintained through the specimen, and a standard resistor was connected in series with it during each measurement. Standard techniques were employed to minimize the effect of thermal emf's in the leads and measuring equipment; a potentiometer and galvanometer amplifier system were used with which a change of 10^{-8} V could be detected. The magnetic field was reproducible to within ±1% and was estimated to be 3% less at the potential probes than at the center of the specimen. It is believed that this nonuniformity will make no essential difference to our measurements, especially as it is identical (within ±1%) for each specimen. The field was calculated from the field factor of the solenoid and the measured current, and was independently checked by a copper magnetoresistance probe mounted close to the specimen. The data of Benz[9] for the magnetoresistance of copper were used. The two methods agreed within the accuracy stated.

We define the magnetoresistance of the specimens in magnetic field H to be

$$\Delta\rho(H)=\rho(H)-\rho(0)\,, \tag{2}$$

where $\rho(H)$ is the specimen resistivity. It is convenient to express the results in terms of Kohler's rule, that is,

$$\Delta\rho(H)/\rho(0)=f[H/\rho(0)]\,. \tag{3}$$

The function f should be the same for those alloys of a particular host in which the character of the electron scattering is not a function of the solute kind or concentration. Thus Kohler's rule may hold not only for alloys in which the scattering is isotropic over the Fermi surface, but also for those in which the anisotropy is characteristic of the host metal. If we confine our attention to a limited range of field and temperature, we may write instead

$$\Delta\rho(H)/\rho(0)=k[H/\rho(0)]^x\,. \tag{4}$$

The parameters k and x may be evaluated by plotting the data on Kohler diagrams as we have done in Figs. 1–4 for the various alloys. It is clear at a glance that the data cannot be fitted by one curve; therefore, Kohler's rule is not obeyed, but a straight line can be drawn through the data for each specimen with the possible exception of pure Pd ($\rho_{295}/\rho_0=169$), which shows some curvature towards saturation at high H/ρ values. With this single exception all specimens were well within the low-field magnetoresistance region where the product of the cyclotron frequency and the electron relaxation time is less than 1, and the data on a Kohler diagram may be expected to lie on straight lines. The values of k and x determined from these lines are given in Table I. Although we might expect on somewhat naive theoretical grounds that $x=2$, it is interesting to note that for the lines with positive slope (Figs. 1, 2,

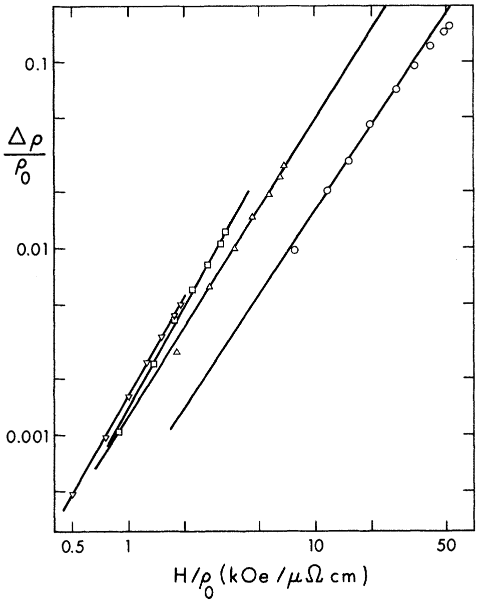

FIG. 1. Magnetoresistance of pure Pd and *Pd*-Ag alloys: ○, pure Pd; △, *Pd*-½% Ag; □, *Pd*-1% Ag; ▽, *Pd*-2% Ag.

and 4) $x < 2$.

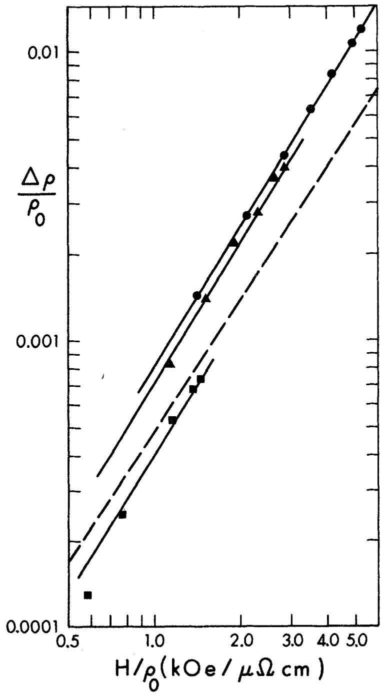

FIG. 2. Magnetoresistance of dilute *Pd*-Rh alloys: ●, *Pd*-⅕% Rh; ▲, *Pd*-½% Rh; ■, *Pd*-1% Rh; dashed line, extension of the line through the pure Pd results shown on Fig. 1.

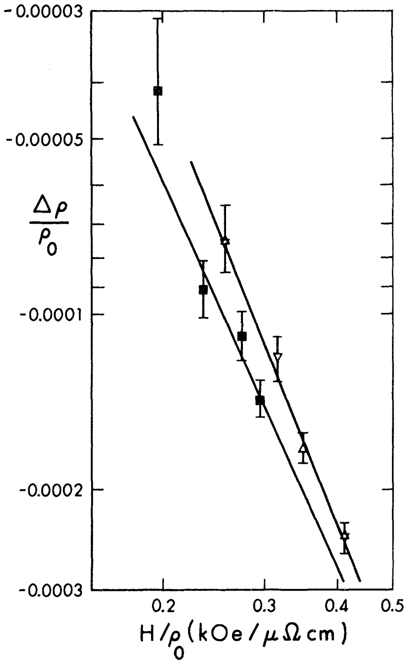

FIG. 3. Negative magnetoresistance of less dilute *Pd*-Rh alloys: *Pd*-4% Rh, △ at 4 K, ▽ at 2 K; *Pd*-7% Rh, ■; magnetoresistance of a *Pd*-2% Rh alloy was zero within experimental error.

The temperature dependence of the magnetoresistance was measured for the *Pd*-4% Rh alloy, which exhibited the larger negative magnetoresistance. This was done in an insert Dewar in the magnet which enabled the temperature of the specimen to be varied from 4.2 to 2 K by pumping the liquid helium in which the specimen was immersed. In this temperature range there was no visible change in the magnetoresistance; values at different temperatures fall on the same line in Fig. 3. This clearly demonstrates that ferromagnetic effects are not responsible for the magnetoresistivity of these alloys because if they were, $\Delta\rho$ should be proportional to H/T and the temperature variations would be substantial.[10] Schindler and LaRoy[11] have measured the magnetoresistance of nearly ferromagnetic *Pd*-Ni alloys and separated it into a normal and an electron-paramagnon scattering contribution which is negative; but unlike the magnetoresistance of the *Pd*-Rh alloys, it varies quadratically with the temperature.

THEORETICAL BACKGROUND

The *anisotropy* magnetoresistance $\Delta\rho_A$ and the *band* magnetoresistance $\Delta\rho_B$ are independent contributions to the total magnetoresistance $\Delta\rho$, and we may write

$$\Delta\rho = \Delta\rho_A + \Delta\rho_B .$$

The characteristics of $\Delta\rho_A$ have been studied[8] recently in dilute noble-metal alloys, and although

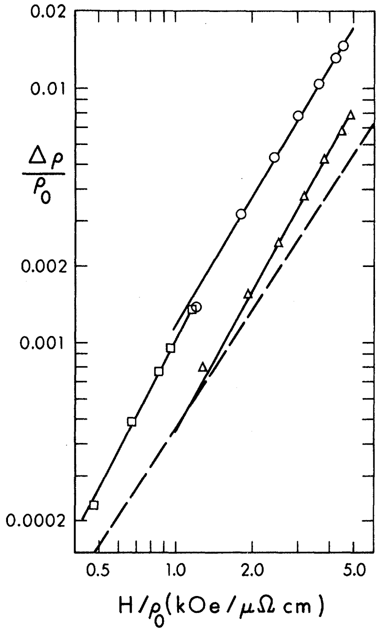

FIG. 4. Magnetoresistance of *Pd*-Ru and *Pd*-Pt alloys: ○, *Pd*-$\frac{1}{10}$% Ru; □, *Pd*-$\frac{1}{2}$% Ru; Δ, *Pd*-$\frac{1}{2}$% Pt; dashed line, extension of the line through the pure Pd results shown in Fig. 1.

the results for a particular host metal do not follow a general Kohler's function, a more restricted Kohler's rule is obeyed, in that in each host $\Delta\rho_A/\rho$ is a different function of H/ρ for each impurity, independent of its concentration. At low temperatures where $\rho(0)=\rho_0$, the residual resistivity of the alloy, we may write $\rho(0)\propto c$, the solute concentration, and then from Eq. (4) we find $\Delta\rho_A \propto c^{1-x}$ at a fixed magnetic field. Since generally $x>1$, the anisotropy magnetoresistance may be expected to decrease with alloy concentration.

Band Magnetoresistance

When a magnetic field H is applied to a band containing electrons of magnetic moment μ, each of the doubly degenerate states of energy ϵ_i is split into a spin-up (parallel to H) state of energy $\epsilon_i-\mu H$ and a spin-down state of energy $\epsilon_i+\mu H$. Spin-down electrons near the top of the band will lower their energy by dropping into vacant spin-up states near the top of that distribution. If the density of states $N(\epsilon)$ in the band is energy dependent, the Fermi energy, when equilibrium is re-established, will have shifted by an amount, say Δ, from its zero-field value ζ. It is easy to show that, to terms of order H^2,

$$\Delta=-\frac{1}{N(\epsilon)}\frac{dN(\epsilon)}{d\epsilon}\frac{(\mu H)^2}{2}, \tag{5}$$

provided that $\Delta\, dN(\epsilon)/d\epsilon \ll N(\zeta)$. As a further consequence of the splitting of the band, the contribution to the total conductivity σ from each sub-band is different and is field dependent. If we assume that most electron scattering events do not involve a spin flip, the sub-bands contribute almost independently to the conductivity, and we may write[12]

$$\sigma=\sigma_\uparrow+\sigma_\downarrow\,. \tag{6}$$

We now expand $\sigma_\uparrow$ and $\sigma_\downarrow$ in a Taylor series about ζ:

$$\sigma_\uparrow=\tfrac{1}{2}\sigma(\zeta)+\frac{1}{2}\left(\frac{d\sigma}{d\epsilon}\right)_\zeta(\mu H+\Delta)+\frac{1}{4}\left(\frac{d^2\sigma}{d\epsilon^2}\right)_\zeta(\mu H+\Delta)^2+\cdots, \tag{7}$$

$$\sigma_\downarrow=\tfrac{1}{2}\sigma(\zeta)+\frac{1}{2}\left(\frac{d\sigma}{d\epsilon}\right)_\zeta(-\mu H+\Delta)+\frac{1}{4}\left(\frac{d^2\sigma}{d\epsilon^2}\right)_\zeta(-\mu H+\Delta)^2+\cdots. \tag{8}$$

Again to terms of order H^2, from Eqs. (6), (7), and (8) we obtain for the total conductivity in a magnetic field

$$\sigma=\sigma(\zeta)+\Delta\left(\frac{d\sigma}{d\epsilon}\right)_\zeta+\tfrac{1}{2}(\mu H)^2\left(\frac{d^2\sigma}{d\epsilon^2}\right)_\zeta. \tag{9}$$

Using Eq. (5), $\Delta\sigma(H)$, the change in conductivity due to a magnetic field, is

$$\Delta\sigma(H)=\left(\frac{d^2\sigma}{d\epsilon^2}-\frac{1}{N(\epsilon)}\frac{dN(\epsilon)}{d\epsilon}\frac{d\sigma}{d\epsilon}\right)_\zeta\frac{(\mu H)^2}{2}. \tag{10}$$

It is interesting to compare this equation with the following one from Jones,[13] which expresses the change in conductivity due to a shift from zero temperature to temperature T:

$$\Delta\sigma(T)=\left(\frac{d^2\sigma}{d\epsilon^2}-\frac{1}{N(\epsilon)}\frac{dN(\epsilon)}{d\epsilon}\frac{d\sigma}{d\epsilon}\right)_\zeta\frac{\pi^2}{6}(\kappa T)^2. \tag{11}$$

We may follow Jones and suppose that in a transition metal the amount of s-d scattering, which produces the electrical resistance, is proportional to the (high) density of d states N_d at the Fermi level. We may then substitute $\sigma=\text{const}\times N_d^{-1}$; hence at sufficiently low temperatures, where $\rho(0)=\rho_0$, we obtain

$$\frac{\Delta\rho(H)}{\rho_0}=-\frac{\Delta\sigma(H)}{\sigma}=-\left[3\left(\frac{1}{N_d}\frac{dN_d}{d\epsilon}\right)^2-\frac{1}{N_d}\frac{d^2N_d}{d\epsilon^2}\right]_\zeta\frac{(\mu H)^2}{2}. \tag{12}$$

In order to evaluate N_d and its energy derivatives so that we can compare the predictions of this model with experimental results, we must make some more particular assumptions than the ones that have been used so far. In the spirit of Coles and Taylor's[4] calculations, we assume that the rigid-band model is valid and use measurements of the Pauli spin susceptibility χ on alloys of Pd with its neighbors in the Periodic Table to obtain $N_d(\epsilon)$. Using

$$\chi = \mu^2 N_d(\epsilon) \tag{13}$$

from, e.g., Ziman[14] and the expressions[15] from Coles and Taylor for the dependence on the solute concentration c,

$$\frac{1}{N_d}\,\frac{dN_d}{d\epsilon} = \frac{dN_d}{dc} \tag{14}$$

and

$$\frac{1}{N_d}\,\frac{d^2N_d}{d\epsilon^2} = \left(\frac{dN_d}{dc}\right)^2 + N_d\frac{d^2N_d}{dc^2}\ , \tag{15}$$

we finally obtain

$$\frac{\Delta\rho(H)}{\rho_0} = -\frac{1}{\mu^2}\left[\left(\frac{d\chi}{dc}\right)^2 - \frac{\chi}{2}\,\frac{d^2\chi}{dc^2}\right]H^2\,. \tag{16}$$

We assume that $\mu = \mu_B$ the Bohr magneton, and choose the units such that χ is in g^{-1}, H is in Oe, and c is the fractional concentration of solute; then we have

$$\frac{\Delta\rho(H)}{\rho_0 H^2} = -3.65\times 10^{-4}\left[\left(\frac{d\chi}{dc}\right)^2 - \frac{\chi}{2}\,\frac{d^2\chi}{dc^2}\right]. \tag{17}$$

The differential dc is positive when the electron/atom ratio *increases*.

DISCUSSION

When s-d scattering constitutes an important contribution to the residual resistance of a metal, an unusual temperature dependence, such as has been observed for the *Pd*-Rh alloys,[1] may be expected in the electrical resistance at low temperatures if the energy dependence of the density of the d states is substantial. Measurements on dilute *Pd*-Ag alloys, on the other hand, where the energy dependence is little different from that in dilute *Pd*-Rh, support the theoretical argument[16] that s-s scattering determines ρ_0 in these alloys. Indeed, the composition of the present *Pd*-Ag alloys was carefully chosen using data from Dugdale and Guenault[5] so that s-s scattering should be dominant and, since the density of states in the s band is not a strong function of energy, $\Delta\rho_B$ should then be zero in these alloys.

The magnetoresistance results for the *Pd*-Ag alloys which are shown in Fig. 1 together with the results for pure Pd, do not follow a general Kohler function. However the concentration dependence of the magnetoresistance may be interpreted in terms of a residual scattering mechanism with one value of anisotropy in the pure metal that is gradually dominated by the characteristic Ag scattering as the alloy concentration is increased toward *Pd*-1% Ag. In noble-metal alloys evidence from the Hall effect[17] and thermoelectric power[18] indicates that a similar behavior occurs except that a much smaller solute concentration is required to dominate the residual scattering mechanisms in the pure metals. Thermoelectric power measurements[19] support the conclusion that the scattering anisotropy is concentration dependent at these surprisingly large concentrations in *Pd*-Ag alloys. The similarity of the magnetoresistance of the 1 and 2% Ag alloys leads us to conclude that the magnetoresistance of pure palladium follows one Kohler function, whereas it follows another Kohler function in palladium in which s-s scattering at Ag ions dominates the resistance.

Turning to the *Pd*-Rh alloys, it is immediately obvious that they are extraordinary as the magnetoresistance changes sign when the concentration is increased above 2% Rh. However the results for the two most dilute alloys lie very close to a single Kohler curve that is not greatly different from the curve for pure palladium. This observation combined with the knowledge that Rh is a much more effective electron scatterer than Ag (as measured by the ρ_0 values of the alloys) indicates that Rh scattering is dominant even in the most dilute alloy. Since $\Delta\rho_B$ is known from Eq. (17) to increase with ρ_0, we assume that it is negligible in very dilute alloys and therefore $\Delta\rho = \Delta\rho_A$ in the *Pd*-$\frac{1}{5}$% Rh alloy. The $\Delta\rho/\rho_0$ values shown in Table II for the other *Pd*-Rh alloys were then estimated by simple application of Kohler's rule. Since $\Delta\rho_A/\rho_0$ decreases with alloy concentration, the $\Delta\rho_B/\rho_0$ values for the more concentrated alloys, which were obtained by subtracting $\Delta\rho_A/\rho_0$ from the measured values of $\Delta\rho/\rho_0$, are obtained with reasonable accuracy. The similarity of the $\Delta\rho_B/\rho_0$ values for all the *Pd*-Rh alloys except the most concentrated one lends us further assurance in this method of analysis.

In order to make a more quantitative comparison of the experimental results with theoretical estimates, we form the band magnetoresistance parameter $\Delta\rho_B/\rho_0 H^2$ shown in Table II. Using Eq. (17) and values of χ as a function of Rh concentration from Manuel and St. Quinton,[20] and graphically estimating the first and second derivatives of χ, the theoretical estimates of $\Delta\rho_B/\rho_0 H^2$, shown in the final column of Table II, are obtained. These estimates parallel the experimental results in their concentration dependence, including the decrease in the value for the *Pd*-7% Rh alloy, although they are a factor of about

TABLE II. Separation of magnetoresistance components.

Alloy (at. %)	$10^3 \Delta\rho/\rho_0$ (at 28 kOe)	$10^3 \Delta\rho_A/\rho_0$ (calc.)	$10^3 \Delta\rho_B/\rho_0 = 10^3 (\Delta\rho/\rho_0 - \Delta\rho_A/\rho_0)$	$10^{12} \Delta\rho_B/\rho_0 H^2$ (expt.) (Oe^{-2})	$10^{12} \Delta\rho_B/\rho_0 H^2$ [from Eq. (17)] (Oe^{-2})
Pd-$\frac{1}{5}$% Rh	7.60	7.60	0		
Pd-$\frac{1}{2}$% Rh	2.70	3.00	−0.30	−3.8	−15
Pd-1% Rh	0.52	1.00	−0.48	−6.1	−15
Pd-2% Rh	~0	0.42	−0.42	−5.4	−15
Pd-4% Rh	−0.198	0.16	−0.36	−4.6	−16
Pd-7% Rh	−0.065	0.070	-0.13_5	−1.7	−4
Pd-$\frac{1}{10}$% Ru	10.35	10.35	0		
Pd-$\frac{1}{2}$% Ru	1.37	1.65	−0.28	−3.6	
Pd-$\frac{1}{2}$% Pt	5.30	5.30	0		
Pd-43% Pt	0.02	0.014	+0.008	+0.1	

three larger. This is tolerable agreement when it is borne in mind that magnetoresistance cannot be accurately predicted even in simple metals.

It would be possible instead of using Eq. (13) to use an equation relating the electronic specific heat parameter γ to N_d. Indeed, this has been done to estimate the size of the resistance minimum phenomena in these alloys.[1,7] Whether magnetic susceptibility or specific heat is used, the many-body enhancement effects present in palladium and its alloys are being empirically included in the estimates of the transport phenomena. It has long been realized that the many-body enhancement effects in these metals affect specific heat and susceptibility by quite different amounts,[20] and therefore estimates of the transport phenomena based on the two measurements are different by more than an order of magnitude. Satisfactory agreement with experiment is obtained when estimates are made using χ values for magnetic-field-dependent effects and γ values for temperature-dependent effects. This analysis in its present form does nothing to differentiate between the different models of the many-body effects.

In Fig. 4 the magnetoresistance of three other dilute alloys of Pd is shown. The results for the *Pd*-Ru alloys are of interest because of the resistance minimum observed in the zero-field resistivity of the more concentrated alloy.[7] We believe that this minimum also arises from the energy dependence of the density of states, and if that is the case this alloy should also exhibit some band magnetoresistance. If it is assumed that the anisotropy magnetoresistance due to the presence of Ru is fully developed in the more dilute alloy, and then $\Delta\rho_A$ and $\Delta\rho_B$ are separated just as they were for the *Pd*-Rh alloys, the results shown in Table II are obtained. The value of $\Delta\rho_B/\rho_0 H^2$ obtained in this way is remarkably similar to those for the *Pd*-Rh alloys, and the magnetoresistance of more concentrated *Pd*-Ru alloys should, therefore, be negative.

It is to be noted that the results for the *Pd*-$\frac{1}{2}$% Pt alloy are only slightly offset from the extension of the line for pure Pd, a result that is consistent with Pt being the residual scatterer in "pure" Pd. It is thought[1,7,21] that Pt is an *s*-*s* scatterer in Pd so that $\Delta\rho_B/\rho_0 H^2$ should be small for *Pd*-Pt alloys. This leads us to assume that $\Delta\rho = \Delta\rho_A$ for this alloy. The *Pd*-43% Pt alloy entered in Tables I and II is far too concentrated to properly belong in the present discussion, but its magnetoresistance was measured because it showed a resistance minimum at 3.5 K in the zero-field resistivity. It is interesting to note that the very small, positive $\Delta\rho_B$ that is obtained from magnetoresistance data for this alloy is, within experimental error, equal to the small negative value that would be expected on the basis of the small resistance minimum.

Further examination of Table I shows that those alloys where we earlier noted that the field dependence of $\Delta\rho$ is less than quadratic are just those in which it turns out that $\Delta\rho_A$ is the dominant contribution, whereas x is increased by the presence of $\Delta\rho_B$. Indeed, for the *Pd*-4% Rh and *Pd*-7% Rh alloys, where the magnetoresistance is negative and almost entirely due to $\Delta\rho_B$, $\Delta\rho \propto H^{2.3}$ approximately. Although simple one-dimensional theory predicts a quadratic dependence on magnetic field for both band and anisotropy magnetoresistance, the situation obviously becomes more complicated in real polycrystalline metals.

TABLE III. Anisotropy magnetoresistance parameters.

Kind of alloy	$10^3 k_A$ [a]
Pd-Rh	0.78
Pd-Ag	1.60
Pd-Ru	1.27
Pd-Pt	0.44
"Pure" Pd	0.48

[a] Data taken from graphs where units of H and ρ_0 are, respectively, kOe and $\mu\Omega$ cm.

The arguments presented in this section have enabled us to obtain $\Delta\rho_A$ for several different solutes in Pd. In Table III we have collected the values of $\Delta\rho_A$, and for convenience expressed them in terms of the Kohler's rule parameter k_A. The values of k_A vary by a factor of four, which is to be compared with variations of about ten in noble-metal alloys.[8] The most surprising result is that Pt and Ag impurities, both of which are thought to be s-s scatterers, produce the extreme values. We believe that the observed sensitivity of k_A to the subtleties of the scattering anisotropy makes it interesting to perform more systematic studies of magnetoresistivity in single crystals.

CONCLUSION

The longitudinal magnetoresistance of several dilute, nonmagnetic, polycrystalline, palladium alloys has been measured at liquid-helium temperatures. A remarkable variety of behavior is observed ranging in *Pd*-Rh alloys from positive to negative values as the Rh concentration is increased. These results have been analyzed in terms of an anisotropy magnetoresistance, which is positive and follows a different characteristic Kohler rule for each solute, and a negative band magnetoresistance that arises from the energy dependence of Mott s-d scattering in these alloys. This scattering has previously been used to account for the peculiar zero-field resistivities of these and other palladium alloys. It is observed that magnetic-susceptibility measurements may be used to estimate the band magnetoresistivity satisfactorily, whereas electronic specific heat results more accurately reflect the temperature dependence of the resistivity. The variation of the anisotropy magnetoresistance with the kind of solute is remarkable and may be useful in further studies of the anisotropy of electron scattering in transition metals.

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[2] In the notation used here the host or solvent metal is always named first; the impurity or solute is second. When an alloy of specific composition is referred to, the concentration of the solute is given in at.%.

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