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GIANT MOMENTS IN PdNi ALLOYS

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Abstract. — We have studied the interaction effects in the PdNi alloys. We have shown that the isolated atoms and pairs are not magnetic. The groups of three Ni atoms are magnetic and are associated with a giant moment which is induced in the nearly magnetic PdNi host. Our results show that in the PdNi the transition toward the magnetic state is inhomogeneous.

In a number of concentrated Ni alloys [1,2] the transition from the non magnetic to the magnetic state is governed by the interactions which lead to the formation of giant moments. This paper deals with the study of the interaction effects and the occurrence of giant moments in the PdNi alloys.

We have measured the magnetization of PdNi and PdNi,Fe, alloys between 0.05 and 4 K in fields \( h \leq 75 \) kOe. These samples were melted in alumina crucibles. The analysis shows that the actual concentration of Ni is very close to the nominal one but that small amounts of iron (\( \approx 50 \) ppm) were introduced during the melting. We have also measured the susceptibility of five other PdNi samples (\( 0 < y \leq 1.3 \) %) between 4.5 and 300 K in a field \( h = 9750 \) Oe using a Faraday balance. These samples were elaborated in an induction furnace by a semi-levitation method, in order to avoid the introduction of iron impurities during the melting.

The magnetization below 1 % is approximately proportional to the field (Fig. 1). Beyond 1 % a curvature appears which increases with the concentration. For \( h > 2 \) kOe, the magnetization in the range 1-2 % is independent of the temperature. For \( h < 2 \) kOe the magnetization at 1 K is smaller than at 0.1 K (Fig. 2). This effect is due to the magnetic impurities associated with giant moments since they are saturated in a field as low as 2 kOe at 1 K. For \( y < 1 \) %, after substraction of the Palladium contribution \( \chi_{Pd} h \) and of the saturation magnetization \( \sigma_s \) due to the magnetic impurities, the excess magnetization \( \Delta M \) can be written in the form:

\[
\Delta M(h) = M_1(h) y + M_2(h) y^2
\]

where \( M_1(h) \) is attributed to the isolated Ni atoms while \( M_2(h) \) shows the effects of the Ni-Ni interactions.
\( M_1(h) \) exhibits a slight curvature beyond 50 kOe. The term \( M_2(h) \) is not saturated even in fields as high as 75 kOe. This indicates that the impurities which contribute to \( M_4(h) \) are not magnetic.

\[ M_1(h) = \frac{\Delta \chi_1}{\chi_{Ni}} (\text{emu} / \text{g}) \]

**FIG. 4.** — Diagram \( \Delta M(y) \) vs. \( y \) below 1 % at \( h = \text{Cte.} \) The numbers on the figure are the values of the field.

The excess susceptibility \( \Delta \chi(T) = \chi_{\text{alloy}}(T) - \chi_{Ni}(T) \) measured at \( h = 9.750 \text{ Oe} \) between 4 and 300 K is represented, for \( y < 1 \% \), by the law:

\[ \Delta \chi(T) = \Delta \chi_1(T) y + \Delta \chi_2(T) y^2. \]

The quantities \( \Delta \chi_1(T) \) and \( \Delta \chi_2(T) \), plotted in the diagrams \( (1 + a \chi_{Pd})^2/\Delta \chi_1, (1 + a \chi_{Pd})^2/\Delta \chi_2 \) [3, 4] as a function of the temperature, where \( a \) is a parameter determined from the experimental data, exhibit Curie-Weiss behaviours above 50 K (Fig. 4):

\[ (1 + a \chi_{Pd})^2/\Delta \chi_1 = (T - \theta_1)/C_1; \]
\[ (1 + a \chi_{Pd})^2/\Delta \chi_2 = (T - \theta_2)/C_2 \]

with

\[ \theta_1 = -25 \text{ K}, \quad \theta_2 = (-13 \pm 5) \text{ K}. \]

Within the local spin fluctuations theory [5] \( \theta_1 \) and \( \theta_2 \) can be interpreted as the fluctuation temperatures of

\[ \chi_1 = \chi_0 + C/T \]

\( \chi_0 \) is due to the non magnetic impurities and the Curie term \( C/T \) is due to the magnetic ones. Substracting
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saturation magnetization of the PdNi alloys taking the induced moments into account: We have assumed that an atom isolated, or belonging to a pair has the moment \( p_{Ni} \) when it is at a distance \( r < R_1 \) or \( r < R_2 \) from a group of three Ni atoms respectively. At distances greater than \( R_1 \) or \( R_2 \) the moment is respectively equal to \( K_1 \exp(-qr)/r \) and \( K_2 \exp(-qr)/r \). The parameters \( R_1, R_2, K_1, K_2 \) can be deduced from experimental data. The calculation gives good agreement with experiment. It will be published elsewhere.

from the Curie constant \( C \) and from \( \sigma_s \) the contribution of the parasitic iron atoms (\( x = 50 \) ppm) associated with a moment of 17.5 \( \mu_B \) [13] and from the ratio of these two corrected quantities, we deduce the spin \( S \) of the magnetic carriers:

\[
S \approx 24
\]

which confirms the existence of the giant moments.

The mechanism of the formation of those giant moments has been previously studied in the PdNiFe alloys [13]: one can assume that an atom of iron in the PdNiFe alloys plays a role similar to that of a group of three nickel atoms in the PdNi alloys. The linear increase of the saturation magnetization of the PdNiFe with the iron concentration and the linear increase of the average moment associated with each iron atoms with the Ni concentration (Fig. 6) can be explained by assuming that each Ni atom lying inside the polarization sphere of an iron atom has the saturation moment \( p_{Ni} = 2.4 \mu_B \), confirming the fact that the giant moments are due to the polarization of the PdNi host. We have done a calculation of the ratio of these two corrected quantities, we deduce the spin \( S \) of the magnetic carriers:

\[
S \approx 24
\]

Conclusion. — In the PdNi alloys the transition towards the magnetic state is governed by the interactions effects. However they are relatively small since a pair of Ni first neighbours is not magnetic. We have shown that magnetic nickel atoms exist and that they are associated with giant moments. The formation of these giant moments has been investigated in the PdNiFe alloys. These results show that in the PdNi alloys as in a number of other alloys the transition to the magnetic state is not homogeneous.

References