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LOCAL MODEL OF MAGNETISM FOR Cu-Ni ALLOYS

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Résumé. — Pour des concentrations de Ni $c < 0,6$, la susceptibilité d'un atome de Ni dépend principalement du nombre de ses premiers voisins Ni : le nombre critique pour lequel la susceptibilité est infinie est 8 ou 9. Ce modèle permet d'expliquer la variation de l'aimantation à saturation et de la susceptibilité non magnétique avec c ; il implique l'existence de moments géants, et rend compte de la variation avec c de la constante de Curie paramagnétique.

Abstract. — For Nickel concentration $c < 0,6$, the susceptibility of a Ni atom depends mainly on the number of Ni nearest neighbours, the critical number for infinite susceptibility being 8 or 9. This model accounts for the variation with c of the saturation magnetization and of the non-magnetic susceptibility. It also explains the occurrence of giant moments, and the variation of the paramagnetic Curie constant with c .

The magnetizations of eight samples of Cu-Ni alloys (1 % to 38 % Ni) were measured in fields up to 60 kOe at 4.2 °K and 1.2 °K. The curves are interpreted as the sum of three terms : the diamagnetism of Cu, with a negative slope χ_D , the paramagnetism of non magnetic Ni atoms, with a positive slope χ_{NM} , and the magnetic of local moments carried by magnetic Ni atoms. At 1.2 °K, the high field part of the magnetization curves is linear within the experimental accuracy ; its slope is taken as $\chi_D + \chi_{NM}$, and its extrapolation to zero field gives the order of magnitude of the saturation magnetization σ_s carried by magnetic atoms.

On figure 1a $1/\chi_{NM}$ per Ni atoms is plotted versus

Ni concentration, together with earlier data deduced from low field susceptibilities [1, 2]. It can be seen that $1/\chi_{NM}$ decreases almost linearly with concentration, at least for low values of concentration. From the values of σ_s , the mean magnetic moment per atom is derived, and shown to be non vanishing (Fig. 1b) far enough in the paramagnetic range (for lower concentrations, the values are not meaningful because of the presence of some (~ 10) p. p. m. of Fe).

These phenomena can be explained in the following way : Let ρ be the local density of states on an isolated Ni atom in a copper matrix : the local susceptibility of this atom is expressed by

$$\chi_0 \simeq 2 \mu_B^2 \rho / (1 - U\rho),$$

where U is the usual effective Coulomb interaction. If one Ni atom is nearest neighbour of this atom, the overlapping of the virtual bound states increases ρ by $\Delta\rho$ and $U\rho$ by $\Delta(U\rho)$. Taking this phenomenon as additive, the local susceptibility of a Ni with n Ni nearest neighbours is given by

$$\chi_n = \chi_0 \left(1 + n \frac{\Delta\rho}{\rho} \right) / \left(1 - \frac{n \Delta(U\rho)}{1 - U\rho} \right).$$

This formula can be conveniently simplified by neglecting the term $\Delta\rho/\rho$ of the first bracket, as the main effect on χ_n is due to the denominator. Let m be the value for which this denominator vanishes. Then for $n > m$, χ_n is infinite (appearance of a local moment), and for $n < m$ the local susceptibility takes the form :

$$\chi_n \simeq \chi_0 / (1 - n/m).$$

Taking for $P(n)$ the probability for a site to be surrounded by n Ni neighbours, gives :

$$\chi_{NM} = \sum_{n < m} P(n) \chi_n.$$

On figure 1a, theoretical curves of $1/\chi_{NM}$ per Ni atom are drawn for $m = 8$ and 10 . Clearly, the fit is good with $m = 9 \pm 1$. Taking now for the appearance of a local moment a model in which the moment μ_{Ni} is

FIG. 1a. — Reciprocal susceptibilities of non-magnetic atoms compared with theoretical curves for $m = 8$ and $m = 10$.
b. — Mean moment per atom compared with theoretical curves for $m = 7, 8, 9, 10$.

either maximum or zero [3], the mean moment per site is given by :

$$\sigma_s = \mu_{Ni} \times \sum_{p \geq m} P(p).$$

On figure 1b, theoretical curves of σ_s are drawn for $m = 7, 8, 9, 10$; it is found that $m = 8$ or 9. In a previous paper [3], it was found $m = 8$. For lower concentrations, $m = 9$ fits better. A qualitative explanation can be given by assuming that nearly magnetic atoms ($n = m - 1$) can be polarized by magnetic ones, like Pd in Pd-Fe. A rough calculation shows that their contribution to σ_s , almost zero for 30 % Ni, becomes important for 50 % Ni. Then the « true » value of m could be 9, and the good fit with 8 between 40 and 60 % would be due to polarization of nearly magnetic atoms.

Thus, we find that $m = 9 \pm 1$ from two indepen-

dent measurements, which is a test of validity of the model. It has been shown previously that this model could explain the occurrence of giant moments, by the fact that the neighbourhoods of two neighbouring atoms are not independent, which leads to a correlation of their probabilities of magnetism. Then the local « true » moments are clustered in clouds, where they are strongly magnetically coupled. Moreover, the nearly magnetic atoms in the cloud are polarized by magnetic atoms, and are also involved in the giant moment. This leads to a concentration dependent size of the giant moments, in agreement with the recent measurements of Mishra et al. [4]. With our measurements of σ_s and the computed values of the giant moment, the qualitative variation of the Curie constant versus c has been computed. The agreement is good with the measurements of Kouvel and Comly [2].

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