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MAGNETISM AND ATOMIC SHORT-RANGE ORDER IN V-Fe AND Cu-Ni†

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Résumé.- Des mesures de susceptibilité magnétique sur plusieurs alliages V-Fe et Cu-Ni ont montré que la température à laquelle l'ordre magnétique est établi dépend fortement du degré d'ordre atomique à courte distance. En conséquence la concentration critique du début du ferromagnétisme dépend de l'état métallurgique de ces alliages.

Abstract.- Magnetic susceptibility measurements on several V-Fe and Cu-Ni alloys reveal that the magnetic ordering temperature varies strongly with the degree of atomic short range order or atomic clustering. The critical concentration for the onset of ferromagnetism thus depends on the metallurgical state of the alloys.

It is widely accepted that in alloys like V-Fe and Cu-Ni, where no localized magnetic moments are observed in the dilute limit, the first appearance of magnetic ordering is due to the interaction between spinclusters or polarization clouds. These spin clusters are associated with Fe-rich or Ni-rich local atomic regions. Their formation depends in a critical way on the local concentration. A small change in this local concentration, caused by varying degrees of atomic short-range order or atomic clustering, is thus expected to have a significant effect on the magnetic properties of these alloys.

It is well known that Cu-Ni alloys in general are not random but display atomic clustering of various degree depending on the temperature /1/. V-Fe alloys, on the other hand, show a tendency towards CsCℓ-type ordering /2/. Figure 1 demonstrates how the magnetic ordering temperature T_c, determined from a.c. susceptibility measurements /3/, depends on the metallurgical state of the alloys. With increasing annealing temperature both V-Fe and Ni-Cu alloys become more random. In the case of Cu-Ni this decreases the number of Ni near neighbors to a given Ni atom, thus decreasing the magnetic cluster concentration and consequently the ordering temperature. However, in V-Fe the effect of randomizing is just the opposite and T_c increases. For V-Fe alloys quenched from above 800 C, T_c depends increasingly on the quenching rate and less on the annealing temperatures. This reflects the inability to quench-in the high temperature equilibrium state.

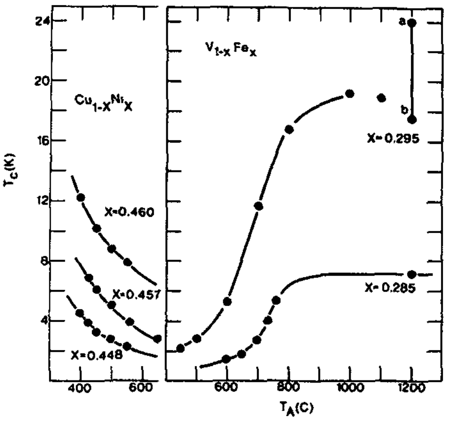

Fig. 1 : Magnetic ordering temperatures T_c of several Cu-Ni and V-Fe alloys quenched from various annealing temperatures, T_A. The two points a and b for the 29.5 at pct. Fe alloy correspond to two different quenching rates.

The variation of T_c up to a factor of ten for a given alloy in different metallurgical states may account for the large variation of the ordering temperatures reported in the literature for these alloys.

Figure 2 displays the concentration dependence of T_c for alloys in equivalent metallurgical states (quenched from the same temperature). The sudden change in slope as T_c drops below about 4 K signals a change in the type of magnetic ordering. Alloys with T_c > 4 K have previously been shown to

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be ferromagnetic /3/. For $T_c < 4$ K a spin glass or mictomagnetic freezing has been proposed /3,4/. This change in the type of ordering is also demonstrated in figure 3.

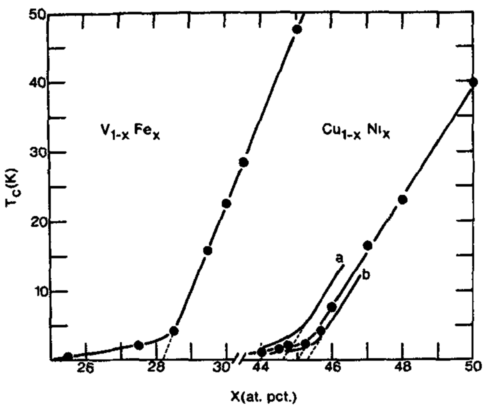

Fig. 2 : Magnetic ordering temperature T_c vs. concentration for alloys in equivalent metallurgical states, V-Fe : quenched from 750 C, Cu-Ni : quenched from 550 C data points, curve a quenched from 400 C, curve b quenched from 650 C

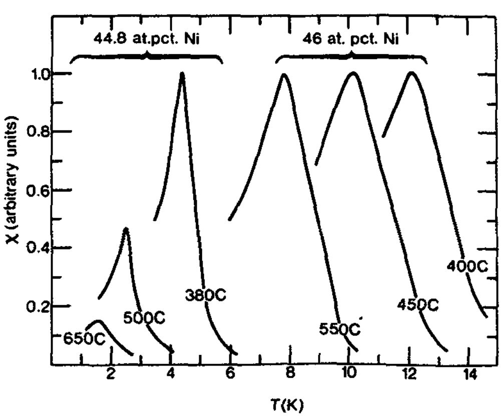

Fig. 3 : a.c. susceptibility in arbitraty units vs. temperature for two Cu-Ni alloys, numbers labeling curves are the various annealing temperatures.

For the ferromagnetic alloys with $T_c > 4$ K the height of the suceptibility maxima is independent of T_c, determined solely by the demagnetization factor of the sample /3/. For the spin glass alloys, $T_c < 4$ K, the height drops in a dramatic way as T_c is decreasing (figure 3). This behaviour is similar to that observed in more typical spin glass alloys /5/.

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