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MAGNETIZATION OF AMORPHOUS MAGNETS

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Abstract.-The temperature dependence of the distribution of the magnetic moment in an amorphous magnet, where the exchange interactions and the magnitude of the magnetic moment at 0 K are random variables, has been investigated. In particular, we considered the two-limiting cases, the one with the fixed spin and the other with the fixed interaction. The mean magnetization is also shown in a figure. The temperature-dependence of the width of the magnetization distribution shows an opposite tendency to each other. It is to be noted that the constant width observed in the experiment can be explained by the simultaneous existence of the both effects.

The distribution of the hyperfine field determined from the Mössbauer effect in amorphous ferromagnets /1-3/ is mainly caused by the distribution of the magnetic moment of an individual atom. It is considered that the origin of the distribution of the magnetic moment is attributed to the random distribution of the exchange interaction and the distribution of the magnetic moment at 0 K. The problem is analysed in two limiting cases; the case of the random interaction and the fixed value of the spin and the case of the fixed interaction and the random distribution of the magnetic moment at 0 K. An effect of the co-existence of the both distributions is inferred from the results of the two limiting cases.

In the first case, the distribution of the mean field is approximated by

\[ R(\xi) = \frac{1}{2\pi} \int_{-\infty}^{\infty} e^{i\xi\xi'} \left[ g(k) \right]^2 dk, \tag{2} \]

and

\[ g(k) = \int_{-\infty}^{\infty} Q(2Sf(\xi))R(\xi)d\xi, \tag{4} \]

where \( f(\xi) = B_S(\xi/k_BT) \).

The equations (2) and (4) constitute the fundamental integral-equations which determine \( R(\xi) \). The equations are essentially the same as that derived by Plefka /5/ in connection with the problem of the spin glasses. It is to be pointed out that the method of the distribution function /4/ is a powerful tool in the treatment of the random spin-system, as the molecular field theory in the pure system.

For a gaussian form of the interaction distribution, i.e.

\[ P(J) = \frac{1}{(2\pi)^{1/2}(1/\Delta J)^2} \exp \left[ -\left( J - J_0 \right)^2/2(\Delta J)^2 \right], \tag{6} \]

the Fourier transform becomes

\[ Q(q) = \exp \{ iqJ_0 - (\Delta J)^2 q^2/2 \}. \tag{7} \]

Now, the equation (3) is approximated by

\[ g(k) = \exp \{ i2S\epsilon J_0 p - (\Delta \epsilon)^2 k^2 q/2 \}, \tag{8} \]

where \( p = \frac{\Delta J}{\Delta \epsilon} \) and \( q = \frac{\Delta \epsilon}{\Delta J} \).

Then we obtain a gaussian form of \( R(\xi) \), i.e.

\[ R(\xi) = \frac{1}{(2\pi)^{1/2}(1/\Delta \epsilon)^2} \exp \left[ -\left( \xi - \xi_0 \right)^2/2(\Delta \epsilon)^2 \right], \tag{10} \]

where \( \xi_0 = 2zJS_0 \) and \( \Delta \epsilon = 2zS\epsilon \Delta J \). The mean value of \( \sigma \) and the mean square deviation \( q \) are determined self-consistently from

\[ \sigma = \int f(\xi)R(\xi)d\xi, \tag{13} \]

and

\[ q = \int f^2(\xi)R(\xi)d\xi. \tag{14} \]
The temperature dependence of \( \bar{\sigma} \) is shown in Figure 1 together with one of the experimental curves /6/, and the distribution of the thermal-average of normalized spin, \( G(\sigma) \), is shown in Figure 2. It is to be emphasized that these results are effectively in agreement with the numerical solutions of the fundamental equations.

\[
G(\sigma) = \frac{1}{\sqrt{2\pi}} e^{-\frac{\sigma^2}{2}}
\]

In the second case, the mean field is given by

\[
\xi = 2J \sum \sigma_i \sigma_j.
\]

Assuming that the thermal average of \( \sigma_j \) is given by a Brillouin function of an integral spin independent of the small fluctuation of \( S_j \), the distribution of the mean field is obtained in a similar manner to the first case. The distribution of the magnetic moment at a finite temperature is given by

\[
W(m) = \int \delta(m - nS_i)G(\sigma)u_0(S)d\sigma dS , \tag{16}
\]

where \( u_0(S) \) denotes the distribution of the magnetic moment at 0 K. For a gaussian form of \( u_0(S) \) with \( S = S_0 \) and \( \Delta S = 0.15 \), the distribution \( W(m) \) at several temperatures are shown in Figure 3, together with one of the experimental curves /7/.

Finally, it can be seen from Figures 2 and 3 that each temperature-dependence of the width shows an opposite tendency to each other. It is to be noted that the co-existence of the both effect can explain the approximately constant width as observed in the temperature-dependence of the hyperfine field /8/.

References