IN-FIELD MÖSSBAUER STUDY OF REENTRANT FERROMAGNET Au 19 % Fe 2% Sn. MAGNETIC CLUSTER EFFECTS ?

C. Meyer, F. Hartmann-Boutron, Jean-Marc Greneche, F. Varret

► To cite this version:

C. Meyer, F. Hartmann-Boutron, Jean-Marc Greneche, F. Varret. IN-FIELD MÖSSBAUER STUDY OF REENTRANT FERROMAGNET Au 19 % Fe 2% Sn. MAGNETIC CLUSTER EFFECTS ?. Journal de Physique Colloques, 1988, 49 (C8), pp.C8-1155-C8-1156. 10.1051/jphyscol:19888530 . jpa-00228739

HAL Id: jpa-00228739

<https://hal.science/jpa-00228739>

Submitted on 1 Jan 1988

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

IN-FIELD MÖSSBAUER STUDY OF REENTRANT FERROMAGNET Au 19 % Fe 2 % Sn. MAGNETIC CLUSTER EFFECTS?

C. Meyer ⁽¹⁾, F. Hartmann-Boutron ⁽¹⁾, J. M. Greneche ⁽²⁾ and F. Varret ⁽²⁾

⁽¹⁾ Laboratoire de Spectrométrie Physique (associé au CNRS), Université Grenoble I, B.P. 87, 38402 Saint-Martin d'Hères Cedex, France

⁽²⁾ Laboratoire de Spectrométrie Mössbauer (associé au CNRS), Université du Maine, 72017 Le Mans, France

Abstract. – The dramatic effect of an external magnetic field on the ⁵⁷Fe hyperfine field in Au 19 % Fe 2 % Sn above 45 K could arise from the presence of superparamagnetic clusters.

The interpretation of the properties of $\text{Au}_{1-x}\text{Fe}_x$ ($x > 15\%$) is still controversial, as concerns both the microscopic atomic structure [1] and the exact nature of the high temperature magnetic transition [2, 3]. Following an early observation by Brand *et al.* [4], we presented in [3] preliminary in-field ⁵⁷Fe Mössbauer experiments on Au 19 % Fe 2 % Sn, which showed that a relatively modest applied field: $H_0 = 20$ kOe, had an impressive effect on the hyperfine field. This was tentatively attributed to the presence of weakly coupled superparamagnetic clusters with temperature independent sizes. In the absence of any visible relaxation effects, the temperature at which the hf field vanishes in zero applied field: $T_p = 123$ K, was tentatively assumed to characterize the cooperative ordering of these clusters, while the intracluster (= "bulk") Curie temperature was estimated to be much higher: $T_c \sim 250$ K. Spectra at 143 K ($> T_p$) in 20, 50 and 80 kOe ([3] Fig. 3-4) were used, together with an extrapolation method due to Morup, in order to get a first estimate of the cluster size: $N \sim 170 \pm 25$ atoms (intercluster exchange was neglected for simplicity). Note that this size $N \sim 170$ is small: there are more atoms on the surface of the cluster than in the inside, i.e. the cluster is not really a small piece of a "bulk" (as was assumed in this treatment).

Here we report additional results. Examples of in-field spectra at 100 K ($< T_p$) are given in figure 1. The apparent hyperfine fields $H_{\text{obs}}(T, H_0)$ deduced from such spectra for $H_0 = 20, 50, 80$ kOe are reported in figure 2 (note that fitting these spectra is not trivial). In the absence of canting, the relation between $H_{\text{obs}}(T, H_0)$ and the true hf field $H_n(T, H_0)$ is the following: when $H_n > H_0$: $|H_{\text{obs}}| = H_n - H_0$, when $H_n = H_0$: $|H_{\text{obs}}| = 0$, when $H_n < H_0$: $|H_{\text{obs}}| = H_0 - H_n$ (Fig. 2, insert). In figure 2, $|H_{\text{obs}}|$ does not vanish, therefore $H_n(T, H_0) = H_{\text{obs}}(T, H_0) + H_0$; results are reported in figure 3. Let us first assume that intercluster exchange is zero or negligible ($H_0 \gg H_{\text{ex}}(0)$, intercluster molecular field of Ref. [3]); we may use the data of figure 3 to draw "Morup's straight lines" through the points rep-

Fig. 1. – ⁵⁷Fe Mössbauer spectra at 100 K in fields: $H_0 = 0, 2, 5, 8$ Teslas.

Fig. 2. – Average apparent hf field $H_{\text{obs}}(T, H_0)$, obtained by fitting in-field spectra with a hf field distribution, versus T .

resenting $H_n(T, H_0)$ versus $1/H_0$. Their intersection with the ordinate axis yields $H_S(T)$ ("bulk" hf field at T) and their intersection with the abscissa axis, the cluster size $N(T)$. The experimental points are shown in figure 4, together with least squares straight

Fig. 3. — True average hf field: $H_n(T, H_0) = H_{obs}(T, H_0) + H_0$, versus T .

Fig. 4. — Least squares Morup's straight lines through the experimental points, $H_n(T, H_0)$ versus $1/H_0$, for various T (that for 143 K is slightly erratic).

lines. The (average) cluster sizes thus obtained are $N(T) = 184, 195, 188, 198, 171, 161, 148, 153$ atoms at $T = 200, 180, 158, 143, 118, 98, 75, 50$ K respectively. The error bar on these values is certainly large (at least ± 25 at). It appears that the cluster size does not vary appreciably with temperature.

In order to evaluate the possible effect of intercluster exchange on such determinations, we performed as in [3] a model calculation for superparamagnetic clusters having a fixed size: $N = 150$ atoms with $S = 1$, $\mu(0 \text{ K}) = 2 \mu_B$, $H_n(0 \text{ K}) = 290$ kOe, and an intra-cluster Curie temperature $T_c = 250$ K. These clusters are assumed to be exchange coupled, with a molecular field at 0 K: $H_{ex}(0) = 21.06$ kOe leading to an intercluster ordering temperature $T_p = 125$ K, and they are submitted to an external field H_0 such that

$H_0/H_{ex}(0) = 1, 2, 3, 4$ ($H_0 = 21$ to 84 kOe). We checked that with these values of H_0 , and in the temperature range $1.6 T_p$ (200 K) to $0.6 T_p$ (75 K), it is always possible to draw good straight lines through the computed points $H_n(T, H_0)$ versus $1/H_0$, as if there were no intercluster exchange. Let us consider the case $T = T_p$ (Fig. 5): with the three points at $H_{ex}(0)/H_0 = 1/2, 1/3, 1/4$ we get an apparent cluster size $N_3 = 256$, and with the four points at $1, 1/2, 1/3, 1/4$ we get: $N_4 = 322$, instead of the true value $N = 150$. The overestimate due to neglecting intercluster exchange increases when T decreases ($N_4 = 250$ at $1.6 T_p$ and 359 at $0.6 T_p$).

Fig. 5. — Effect of intercluster exchange on the cluster size determination (model calculation with $N = 150$). Plot of $H_n(T, H_0)/H_S(0)$ versus $H_{ex}(0)/H_0$ at $T = T_p$. Curve A: computed points without exchange (showing an incipient deviation from Morup's straight line B (dashed) when $H_{ex}(0)/H_0 > 1.5$). The four points with abscissas $1/4, 1/3, 1/2, 1$ lead to $N_4 = 153$. Curve C: computed points with exchange. The least square straight line through the points with abscissas $1/4, 1/3, 1/2, 1$ leads to an apparent size $N_4 = 322$.

Experimentally, however, no such increase of the apparent cluster size N is observed. This fact would be in favour of uncoupled superparamagnetic clusters, while the absence of visible relaxation effects would rather support cooperative ordering [3]. In addition the cluster size obtained here is fairly small while neutron scattering experiments [5] seem to suggest the existence of ferromagnetic order on a larger scale. Additional information would be desirable.

- [1] Cable, J. W. *et al.*, *Phys. Rev. B* **36** (1987) 8467.
- [2] Rakers, L. D. *et al.*, *Phys. Rev. B* **36** (1987) 8622.
- [3] Hartmann-Boutron, F. *et al.*, *J. Phys. France* **48** (1987) 435.
- [4] Brand, R. A. *et al.* Heidelberg Colloquium on Spin Glasses, *Lect. Notes Phys.* (Springer Verlag) **192** (1983), 79.
- [5] Murani, A. P., *Phys. Rev. B* **28** (1983) 432.