Magnetic after-effect in the bulk amorphous alloy Tb52Ag48

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Résumé. — On a fait des mesures de traînage magnétique à différentes températures et sous différents champs. L'aimantation décroît comme ln t. On donne la loi de variation du champ coercitif avec la température et le temps. L'expression reliant le temps à la température et au champ a la forme d'une loi d'activation. L'énergie correspondante varie comme H^{-1} et $T^{-2,1}$. On donne une valeur estimée du volume dans lequel l'aimantation se retourne sous l'influence du champ et de *l'activation.*

Abstract. — Magnetic after-effect measurements have been carried out at various temperatures and under different values of applied field. The magnetization decreases as ln t. The temperature and time dependence of the measured coercive field have been determined. The relation between the time, the temperature and the field is similar to an activation law. The corresponding energy varies as H^{-1} and $T^{-2,1}$. The volume in which the magnetization is inverted under the simultaneous influence of applied field and activation is estimated.

The magnetic properties of $Tb_{52}Ag_{48}$ have been found to exhibit, at low temperature, a high coercive field and an after-effect (Fig. 1) [1]. The after-effect measurements have been done with the apparatus and sample described in reference [1]. The variation of the magnetization as a function of time t has been measured for given values of the temperature T and the field H.

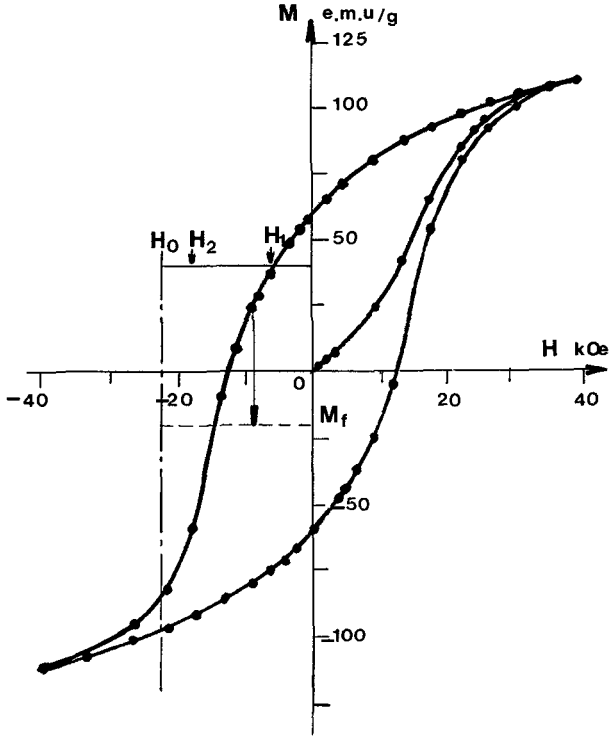

Fig. 1. — Hysteresis loop at 5.6 K after ref. [1]

At a given temperature, the hysteresis loop was saturated ; then the applied field was reduced to zero and then inverted. The reverse field was increased up to the value for which the measurement of $M(t)$ was done. Between each measurement at different temperatures, the sample was heated above the magnetic ordering temperature.

For given values of T and H, the measurements were carried out from time t_i, which is about the time used by the field for increasing from zero to H. The after-effect was measured during 30 or 40 min. Beyond this time, the variation of the magnetization was very small in every case. Thus, with this time scale, we have no information for t small ($t < t_i$) and t large ; with these conditions, an after-effect has been observed only for $H_1 < H < H_2$. H_1 is dependent on T (table I) and H_2 is about 18 kOe at 5.6 K (Fig. 1). The after-effect has been measured for $5.6 \leqslant T \leqslant 14$ K.

1. **Experimental results.** — 1.1 For given values of T and H, we find :

$$M_{T,H}(t) = M^{i}_{T,H} + \alpha_{T,H} \ln t \qquad (1)$$

where $M_{T,H}(t)$ is the measured magnetization, $M^{i}_{T,H}$

Table I

T K	H_1 (kOe)	H_1' (kOe)	H_c (kOe) Exp. ref. [1]	Calc. Eq. (3) $\Delta t \sim 60$ s
—	—	—	—	—
5.6	− 6.3	− 5.5	11.5	11.1
8.0	− 2.5	− 2.6	7.0	7.0
10	− 1.5	− 1.2	5.0	5.0
12	~ 0	− 0.3	3.5	3.7
14	~ 0	+ 0.3	2.75	2.8

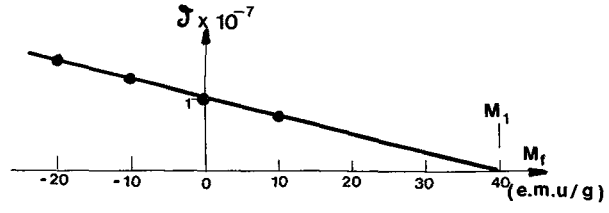

Fig. 3. — Variation of δ as a function of M^f.

the magnetization at t_i, that is to say the magnetization connected to the hysteresis loop and $\alpha_{T,H}$ a negative coefficient.

1.2 As in references [2, 3], a time t_f is defined as the time for which $M(t) = M^f$, M^f being a chosen final magnetization state (e.g. $M^f = 0$). One can write : $\Delta t = t_f - t_i$ ($\Delta t \neq t_f$ if M^f is small or negative (Fig. 1)). Δt is dependent on H and M^f. These experiments show that (Fig. 2) :

$$\ln \Delta t/t_0 = \frac{\delta}{T^{2.1}} \left(\frac{1}{H} - \frac{1}{H_0} \right) \qquad (2)$$

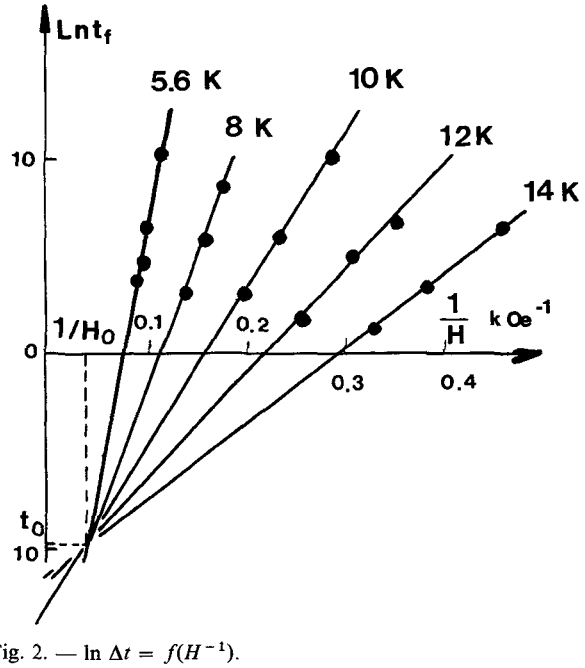

Fig. 2. — $\ln \Delta t = f(H^{-1})$.

where t_0 and H_0 are constants ; ($H_0 = 22.7$ kOe, $t_0 = 6 \times 10^{-5}$ s) and δ is a parameter independent of T and H, but dependent on M^f (Fig. 3). We point out :

— that no after-effect exists, for the time scale used, if $M > M_1 = 40$ emu/g regardless of T. The values H_1' of the field, for which M_1 is obtained from the hysteresis loop at different T values, are in agreement with the values of H_1 (table I).

— that the slope of the straight line representative of $\ln \Delta t = f(1/H)$ varies linearly with M^f,

— that, whatever the value M^f chosen, the line converges at the point $1/H_0$, t_0.

1.3 For given values of T and H, the final magnetization state $M^f = 0$ is reached after time Δt. At this time the sign of the magnetization changes and H is equal to the coercive field H_c. From (2) :

$$\frac{1}{H_c} = \frac{1}{H_0} + \frac{T^{2.1}}{\delta_{M^f=0}} \ln \Delta t/t_0 . \qquad (3)$$

Using (3), the values of H_c given in reference [1], are obtained, if one takes $\Delta t \sim 60$ s (table I). This value of Δt is in good agreement with the experimental conditions described in reference [1].

2. **Interprétation.** — 2.1 Relation (1) shows that the characteristic time τ for reversal of the moments has a large distribution [4].

2.2 From relation (3), H_0 is the value of the coercive field at $T = 0$ K. But it is also the limiting value of the coercive field for all T, when Δt tends to t_0. It is not possible to measure this value directly, Because one is not able to obtain a variation in the field from zero to H in a time as short as t_0. When $H > H_0$, no after-effect is possible.

2.3 From (2), t_0 is the shortest time necessary for magnetization reversal. The value of t_0 is large in comparison with the values observed in crystallized alloys (10^{-11} s) [2].

2.4 From (1), we have :

$$\frac{1}{t} = \frac{1}{t_0} \exp - \frac{E}{kT} \qquad (4)$$

with

$$E = kT \ln \Delta t/t_0 = kT \frac{\delta}{T^{2.1}} \left(\frac{1}{H} - \frac{1}{H_0} \right). \qquad (5)$$

The relation (4) is formally an activation law.

According to relation (5), the energy E :

a) varies as $1/H$ as has been observed for crystallized alloys [5] ;

b) is dependent on the initial (M^i) and final (M^f) magnetization states, but in a first approximation is dependent only on the final state. That is to say that E is dependent on the time at which the measurement is done ;

c) varies like $T^{-1.1}$;

d) has an average value of about 10^{-14} erg (with the time scale chosen).

2.5 If the E value is compared to the energy spent for magnetization reversal ($\sim 6 \times 10^{-6}$ erg/at [1]), it is possible to estimate the size of the volume v in which the magnetization has been inverted under the simultaneous influence of the field and the *activation*. v is about 10^3 Å^3 or 20 to 25 magnetic atoms. v would be larger if the measurements were extended for longer times. When T increases, the energy connected to the hysteresis loop varies as T^{-2} [1], E being proportional to $T^{-1.1}$, v varies approximation linearly with T.

References

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