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MAGNETIZATION AND SUSCEPTIBILITY AT LOW TEMPERATURE IN METGLAS

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Abstract. – We have assembled an experimental apparatus suitable for measuring magnetization at low temperature (down to 1.5 K). Samples of amorphous metal (Fe₄₀Ni₄₀P₁₄B₆) were investigated. The most interesting results concern the initial susceptibility, which shows a maximum as a function of temperature. The observed behaviour suggests a transition from ferromagnetic to cluster glass properties.

1. Experimental

Figure 1 shows the scheme of the experimental arrangement utilized to measure magnetization at low temperature on ferromagnetic ribbon samples. In a thermostatic cell there are: a Cu substratum B (which unifies the temperature of sample and thermic sensor), the sample S and a carbon-glass temperature sensor T. A non-magnetic rod props the cell into a Dewar vase (with cavity walls) in which the liquid helium can be transferred. The pumping system RP makes vacuum (<0.5 torr) inside the vase as well as in its hollow walls. The outer thermos-bottle is used for precooling the system by means of liquid nitrogen. The temperature in the cell was stabilized by: i) the control of the vacuum level in its inside by the diffusion pump IP; ii) an helium gas flow; iii) an heating coil in the Cu base. Two coils C, distant 20 cm each-other, are wound around the cell. The sample is sited in one of these coils, while the other coil counterbalances the flux of the external magnetizing field without experiencing the field produced by the magnetized material itself. Owing to the ribbon sample dimensions (100 x 1.7 x 0.05 mm³) demagnetizing effects were negligible. The induced e.m.f. was analysed by the flux-meter FM that digitalizes the peak value of the longitudinal magnetization $M_{L}$.

The long solenoid F, supplied by the a.c. low frequency generator PS, produces the magnetizing field $H_{E}$ (10 Hz) for the measurements of $M_{L}$. It is also possible to produce both a static field and a little overlapped a.c. field (10 Hz) for the differential susceptibility measurements. The ribbon sample is just placed along the solenoid axis in a region of high uniformity in $H_{E}$. Field changes so little as 1 A/m could be produced and the pick-up apparatus was sensitive to induction field variation of $10^{-4}$ T. The component of earth’s field was compensated. The amorphous samples (Fe₄₀Ni₄₀P₁₄B₆) were pre-annealed at 590 K for 2 hours, in inert atmosphere, in order to produce the well-known relaxation effects [1, 2]. The flux-meter response was adjusted by having the experience of the sample properties at room temperature [3, 4].

2. Results and discussion

Figure 2 represents the magnetization curves at 285 K (room temperature), 77 K (liquid nitrogen),

![Fig. 1. Experimental apparatus for magnetization measurements at low temperature (see description in Sect. 1).](http://dx.doi.org/10.1051/jphyscol:19888601)
4.2 K (liquid helium) and 2 K (liquid helium at low pressure). The saturation magnetization $M_s$ increases with decreasing temperature $T$; but when $H_t$ is lower than 30 A/m the magnetization doesn’t monotonically increases with cooling. This fact was emphasized if $M_t$ measurements are taken for decreasing $T$ at a fixed value of the magnetizing field $H_t$ (Fig. 3). A maximum of $M_t$ is observed at a temperature $T_m$; which decreases with increasing the field $H_t$. This fact signifies that the cooling, whereas increases $M_s$, on the other hand freezes the coupling among the magnetic moments with a facility which increases so much as the pre-established magnetization level decreases. The results are also supported by the temperature dependence of the initial differential susceptibility

$$\chi_0 = \lim_{H_t \to 0} \frac{\Delta M_t}{\Delta H_t}$$

and the maximum differential susceptibility $\chi_{\text{max}} = (\Delta M_t / \Delta H_t)_{\text{max}}$ (Fig. 4). $\chi_{\text{max}}$ behaviour, measured for decreasing $T$, agrees with literature data [5, 6] which indicates that, even in the absence of crystalline structure, the reduction in temperature causes few spin waves excitations. This is why the Bloch $T^{3/2}$ law is found for an amorphous ferromagnet. On the other hand, the $\chi_0$ maximum (Fig. 4) suggests a transition from an effective ferromagnetic state to a weak ferromagnetic one (transition to reentrant state). A similar behaviour, due to spin glass transition, is observed in delute metallic alloys containing Fe [7, 8]. In our case, referring to the coexistence of finite and infinite clusters above the percolation threshold (as postulated by Coles et al. [9]), we believe that the reentrant transition is probably caused by a cluster glass state coexistent with the ferromagnetic one.

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