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AC SUSCEPTIBILITY AND ESR MEASUREMENTS ON THE Ag : Mn SPIN GLASS (*)

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Résumé. — On présente des mesures entre 1,2 et 4,2 K de susceptibilité en courant alternatif (AC) à des fréquences allant de 93 Hz à 109 kHz et de RPE à 1,6 et 9,1 GHz sur les verres de spin dilués Ag : Mn autour de T_G . Aux erreurs expérimentales près, la température de gel, mesurée en alternatif, est indépendante de la fréquence de mesure. Le déplacement de la raie de résonance peut être relié au champ externe statique mais la température du minimum de la largeur de raie est la même à 1,6 et 9,1 GHz.

Abstract. — We present measurements between 1.2 and 4.2 K, of the AC susceptibility from 93 Hz to 109 kHz, and of the ESR at 1.6 and 9.2 GHz on dilute Ag : Mn spin glasses around T_G . Within experimental error, the AC glass temperature is independent of the measuring frequency. The shift of the resonance line can be related to the applied static field but the temperature for a linewidth minimum is the same at both resonance frequencies.

There has been much recent theoretical interest in the correct microscopic description of a *spin glass*, this term being understood here as applying to a dilute magnetic alloy system which shows a sharp peak in the AC susceptibility, $\chi'(\omega, T)$, at some characteristic temperature, T_G , but in which no evidence of long range magnetic order can be found. Experimental verification of any one of the plethora of rival theories revolves in part around the behaviour of $\chi'(\omega, T)$ with ω . In particular, whereas theories descendent from that of Edwards and Anderson [1] predict no change in $\chi'(\omega, T)$ with ω , the approaches taken by Tholence [2], or by Binder and Stauffer [3] suggest that T_G should increase with measuring frequency.

Previous $\chi'(\omega)$ measurements on spin glasses have all been made at rather low frequencies (< 2 kHz) [4]. However, ESR data on the classic spin glass Cu : Mn has long been available [5]. It has been proposed [4] that the temperatures characterizing either the departure of the resonance g value from its high temperature (paramagnetic) value, T_{gv} , or the linewidth minimum, T_{min} , both of which are considerably higher than T_G ,

are somehow representative of $T_G(\omega)$ at the resonance frequency (previously 9 or 35 GHz).

We report here our measurements on Ag : Mn, of the AC susceptibility at frequencies up to 109 kHz, and of the ESR at 1.6 and 9.1 GHz. Five samples with Mn concentrations of 1, 2, 3, 4 and 5×10^3 atomic ppm were made by arc melting followed by a homogenizing anneal at 800 °C for 8 h. in vacuo. Grain samples for all the measurements were obtained from these master ingots. The AC measurements were made using a simple inductance bridge employing a lock-in amplifier as a null detector. Conventional reflection techniques were employed for the ESR. In all experiments the samples were immersed in a pumped ^4He bath and their temperatures determined from the vapour pressure.

Figure 1 shows $\chi'(\omega)$ versus temperature measured in the earth's field at various frequencies on the 5 000 ppm sample. We note the relatively constant shape and peak position of these curves. We have found that if the dimensions of the sample particles approach the skin depth, then the shape of these curves is drastically modified. The choice of T_G is made somewhat difficult by the rounded peak; we took T_G as the maximum value of $\chi'(\omega)$ at any frequency and obtained a mean over several (3 to 7) runs. In figure 2 we show the values of T_G thus obtained for various

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FIG. 1. — The real part of the AC susceptibility $\chi'(\omega)$ versus temperature for Ag : Mn 5 000 ppm at different frequencies.

concentrations and frequencies. Consideration of figures 1 and 2 lead us to conclude that, within our experimental error, T_G for these samples is essentially independent of frequency from 93 Hz to 109 kHz. Taking the limits of the errors in figure 2, the maximum admissible increase in T_G is 3 % of T_G over three decades in frequency. We have preliminary data from 16 to 160 Hz and from 408 kHz to 2.8 MHz which appear to support our conclusion that T_G is frequency independent.

The salient features of our ESR data are summarized

in figure 3. As expected, T_{gv} and T_{min} always lie well above T_G . Since the form of $\chi'(\omega, T)$ for a spin glass depends very strongly on external static field, we measured the AC susceptibility at 2.9 kHz in perpendicular fields of 600 G and 3 kG, the resonance fields at 1.6 and 9.1 GHz. In this manner we obtained a temperature, T_B , at which $\chi'(\omega, T)_{H \neq 0}$ deviates from Curie like behaviour.

It is interesting to note that whereas T_{gv} decreases with measuring frequency — and we argue essentially with the external static magnetic field, since T_{gv}

FIG. 2. — The mean AC glass temperature T_G versus $\log \nu$, where ν is the measurement frequency, for different concentration Ag : Mn samples.

follows T_B — the temperature for the linewidth minimum appears to be the same for both measuring frequencies. Such linewidth minima (and g shifts) at temperatures well above any magnetic ordering temperatures are characteristic of intermetallic compounds which eventually order ferro or antiferromagnetically [6]. No clear explanation of these minima has yet been advanced. This being the case, it seems premature to interpret the minima particularly as a spin glass phenomenon.

In conclusion, we find T_G for dilute Ag : Mn to be frequency independent from 93 Hz to 109 kHz. We

FIG. 3. — A summary of the various characteristic temperatures defined in the text as functions of the Mn impurity concentration. For clarity the values for $T_{\min}$ have been shifted to the left of their respective concentrations and the values for T_{gv} to the right.

further contend that there is no characteristic temperature in the ESR data which varies with the measurement frequency.

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