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SPIN DYNAMICS AND LOW TEMPERATURE PROPERTIES OF THE ANISOTROPIC SPIN GLASS Fe_2TiO_5

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Fe_2TiO_5 is an anisotropic spin glass with a cusp temperature T_g 50 K observed only along the "easy" magnetic axis. "Loose spins" are observed in all directions at low temperature. The frequency dependence of T_g, as determined by ac or dc susceptibility and by neutron diffraction, can be well fitted by a Vogel-Fulcher or by a power law which characterize the spin-glass transition along the easy axis.

1. Introduction

The insulator Fe_2TiO_5 exhibits strongly anisotropic magnetic properties [1-3]: A cusp is observed in the zero field cooled (zfc) magnetization around $T_g = 50$ K when the measuring field is along the easy magnetic axis (parallel to the crystal's *c* orthorhombic axis) whereas a smooth paramagnetic-like behaviour is found down to $T_1 \approx 8$ K for measuring fields along the *a* and *b* directions. Below T_1 a plateau is found for fields along the *b* direction and a broad maximum is observed along the *a* direction. The spin-glass features observed along the *c* axis resemble those of other "good" spin glasses [4]; while the weaker anomaly around 8 K could signal a cross-over to transverse freezing [3].

2. Results

We have measured the low temperature ($T > 0.1$ K) magnetization of a single crystal of Fe_2TiO_5 with a field applied along the *a*, *b* and *c* directions. The low field ($H < 3$ kOe) magnetization varies linearly with H up to 1200 Oe for temperatures down to 0.1 K. The temperature dependence of the susceptibility is described in the introductory section. A surprising *increase* in the susceptibility is found below 1 K and down to 0.1 K. This low temperature increase is observed for zfc and fc curves but not for the remanent magnetization. It is then a reversible magnetization which as in other systems ($Cd_{1-x}Mn_xTe$ [5], $ZnCr_{2x}Ga_{2-2x}O_4$ [6]...) can be attributed to "loose" or free spins which, due to the frustration, experience a null field. However, as shown in fig. 1 very different contributions of these loose spins are observed for the different crystallographic directions. The hierarchy for these paramagnetic contributions is $M_b > M_c > M_a$. This is the first evidence of a selective blocking of the degrees of freedom for the paramagnetic spins of an anisotropic spin glass.

The ac susceptibility of Fe_2TiO_5 has been measured in an ac field < 0.3 Oe and is shown in fig. 2 where the real (χ') and imaginary part (χ'') are in the same arbitrary units. As usual, χ'' goes through a maximum which corresponds to the inflexion point of χ' below T_g. The temperature, T_g, of the ac susceptibility cusp can be taken as the onset of strong irreversibility for each measuring time $t = 1/f$ ($f =$ frequency). We have also taken T_g values corresponding to the maximum of a slowly field cooled magnetization curve (in 10 Oe) or of a zero field cooled curve ($T_g = 48.1$ K for $t \approx 10^4$-10^5 s and 48.8 K for $t \approx 100$ s). Neutron scattering experiments have been carried out at constant q-energy on the same sample [4]. The observed lines have been fitted by a broad and a narrow Lorentzian components. The energy width of both Lorentzians decreases rapidly around 100-120 K. Most likely the sharp Lorentzian corresponds to longitudinal fluctuations and we have taken these characteristic spin relaxation times associated to the temperature at which they are measured ($T_g \approx 102$, 132, 200 K for $f = 3 \times 10^{10}$, 5.7×10^{10}, 9.3×10^{10} s^{-1}).

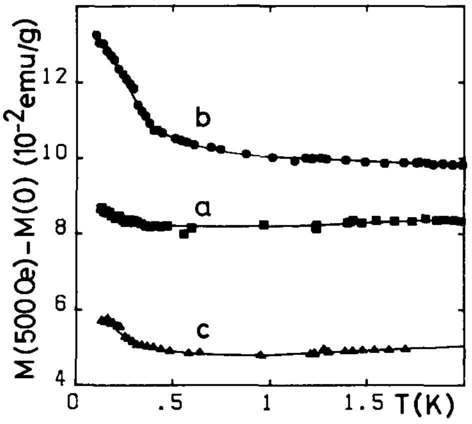

Fig. 1. The reversible part of the magnetization M(500 Oe)$-M$(0 Oe) increases at low temperature for the different crystallographic directions.

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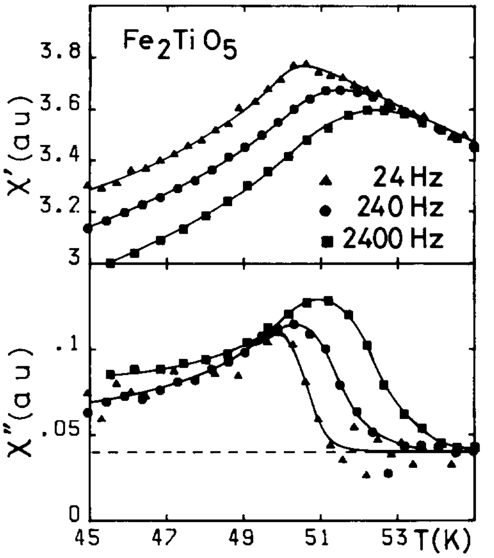

Fig. 2. The real (χ') and immaginary (χ'') susceptibilities measured along the c axis present the characteristic features of a spin glass.

We finally have T_g values over a very large frequency range. The functional dependence for $T_g(f)$ is not a simple Arrhenius law. It can be the empirical Vogel–Fulcher law:

$$\tau = \tau_0 \exp\left[E_a/k\left(T_g - T_0\right)\right]$$

which comes from the glass literature and introduces a divergence at T_0. In this case $\tau_0 = 2.5 \times 10^{-12}$ s, $E_a/k = 170$ K and $T_0 = 43.5$ K, and the frequency dependence is larger than for CuMn, AgMn …but similar to what is found for Mn aluminisilicate [7].

The most natural law expected for a critical slowing down to a transition temperature T^* is $\tau = \tau_0[(T_g - T^*)/T_g]^{-z\nu}$ [8] which should give a straight line in the diagram $\ln[(T_g - T^*)/T_g]$ versus ln, as shown in fig. 3. The best parameters for a power law are $\tau_0 = 10^{-13}$ s, $T^* = 47.4$ K and $z\nu = 9.5$. However, fig. 3 demonstrate that it is hard to choose the best fit between a Vogel–Fulcher law and the power law since one is the beginning of the series expansion of the other [10].

Finally we have also tried a generalized Arrhenius law which gives a divergent relaxation time τ only for $T = 0$ [9]

$$\tau = \tau_0 \exp(b/T^\sigma).$$

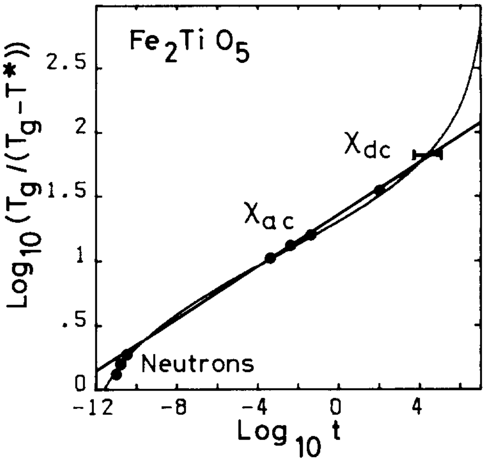

Fig. 3. Logarithmic plot of $(T_g - T^*)/T_g$ where the straight line represents the best fit by a power law, compared to the best Vogel–Fulcher plot (curve).

In that case $\sigma = 8.5$.

The $z\nu$ values obtained for Fe_2TiO_5 using a power law (transition) are similar to values obtained in some good spin glasses where σ is found to vary and to become increasingly large for decreasing temperature [10]. Here, the constant σ value found does not eliminate the possibility of the absence of a phase transition for Fe_2TiO_5 down to $T = 0$.

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