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Fe0.9Ti0.55Mg1.55O4
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SPIN WAVES IN REENTRANT SPIN GLASS Fe_{0.9}Ti_{0.55}Mg_{1.55}O_{4}

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Abstract. – Strong thermoremanent magnetization appears at below 25 K in low magnetic fields. At any temperature below 57 K the high field magnetization satisfies the spin wave theory but the magnetization does not follow the $T^{3/2}$ law. That suggests a mixed-phase which appears before the strong irreversibility region.

Introduction

If reentrance is usually considered as the breakdown of a ferromagnet into domains [1], one expects the long range order to be restored in sufficiently high magnetic fields, consequently a reentrant magnet should satisfy the linear spin-wave theory in high magnetic fields at low temperature. Our aim is to check that assumption on a reentrant ferrimagnet which behaves as a ferromagnet as long as optical modes are not concerned. The magnetization is given by [2]

$$M(T, H) = M(0, 0) - A(T) \times X(H/T)$$

with

$$A = g \mu_B \left( V/4n^2 \right) (kT/D)^{3/2} \Gamma(3/2)$$

and where $X(H/kT)$ may be expanded for $H/kT < 5$ as

$$X = 1 - 0.4974 (H/kT)^{1/2} + 0.07510 (H/kT)^{3/2} - 7.177 \times 10^{-4} (H/kT)^2 + 3.94 \times 10^{-6} (H/kT)^3$$

$D$ is the spin wave stiffness constant and other symbols have their usual meaning.

Experimental

The [Fe_{0.4}Mg_{0.6}]_A [Ti_{0.55}Mg_{0.55},Fe_{0.5}]_B O_4 compound was prepared by a ceramic method. It has a spinel structure in which the Fe^{3+} ions occupy both the A and B sites of the lattice. The cation distribution was determined by X-ray diffraction. The concentration of magnetic ions is above the percolation threshold for the A-B interactions [3] and a ferrimagnetic behavior is expected for an unfrustrated compound.

The magnetic measurements were carried out with a vibrating sample magnetometer operating between 4.2 and 300 K in fields ranging from 0 to 20 kOe. Low field experiments are reported in figure 1. The field cooled magnetization curve shows a strong increase of the ferrimagnetic correlations below 160 K followed by

Fig. 1. – Field cooled and zero field cooled magnetization curves in a 50 Oe magnetic field.

Fig. 2. – Plots of the magnetization in terms of the magnetic field function X at different temperatures. a: 4.2 K; b: 7 K; c: 12 K; d: 27 K; e: 47 K; f: 57 K. Only a few plots are given in order to preserve the legibility of the figure.

Fig. 3. – Plots of the bulk magnetization $M(T)$ and of $T A^{3/2} \sim D$, the spin wave stiffness constant, versus $T^{3/2}$. 

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a decrease below 25 K. Thermoremanent magnetization grows very slowly below 100 K and increases very quickly below 20 K. High field measurements have been carried out between 4.2 and 57 K. For each temperature the magnetization is recorded in fields decreasing from 20 to 5 kOe. Plots of $M(X)$ given figure 2 are linear as is expected from equation (1). The extrapolation of these plots to $X = 1$ yields the bulk magnetization $M(T)$. The spin wave stiffness constant $D$ is related to the slope of the plots as

$$D \sim T/A^{2/3}.$$  \hspace{1cm} (4)

Both $M(T)$ and $T/A^{2/3}$ are plotted figure 3 against $T^{3/2}$.

For a collinear magnetic structure one expects a linear decay of $M(T)$ with $T^{3/2}$ as long as the linear spin wave theory applies. That behavior is ruled out by the data given figure 3. $M(T)$ increases very slowly at low temperatures, shows a broad maximum at 22 K and then decreases. One may notice that the maximum is very close to 25 K, the temperature of reentrance observed in low field cooled experiments. The spin wave stiffness constant continuously increases with $T$ with a change of slope around 20 K.

Discussion

At a given temperature, the magnetic field dependence of the magnetization agrees with the linear spin wave theory of a collinear system but the thermal dependence of the magnetization does not. We suggest that the magnetic structure is not collinear at any temperature below 57 K. The coexistence of a longitudinal ferromagnetic phase and of a transverse spin-glass phase (mixed-phase) at low temperature has been theoretically proved for short range [4] as well as for long range interactions [5]. The properties of that mixed phase have been theoretically studied for long range interactions only and the results are somewhat controversial [5, 6]. Mössbauer studies on MgFeTiO4 [7] and others reentrant spin glasses [8-10] have shown a mixed phase. A similar decrease with temperature of the spin wave stiffness in reentrant spin glass, was observed by neutron studies [1, 11]. Our data suggest the existence of a mixed phase below 57 K at least. On the other hand, low magnetic field experiments show a crossover from weak to strong magnetic irreversibility at 25 K. That behavior agrees with the Cragg, Sherrington and Gabay conclusions [6].