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# MAGNETISM OF RANDOMLY CANTED Li-Ti FERRITE

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**Abstract.** – FC-ZFC magnetisation, hysteresis, thermoremanence and neutron diffraction measurements were performed on $Li_{1.125}Fe_{0.625}Ti_{1.25}O_4$. The results are interpreted from domain and wall properties resulting of local canted state where the spin transverse component relaxes between preferential directions.

## Introduction

The dilution problem in substituted two magnetic sublattice system has attracted considerable interest. A local canted state (LCS) was first presented by Rosencwaig [1] and refined by Patton [2]. Villain's model [3] predicted a LCS embedded within a collinear ferrimagnetic lattice. This state is expected to undergo two transitions: one at $T_N$ for the longitudinal spin component $S_z$ (collinear order) and a second one at $T_g$ for the transverse component $S_t$ (spin glass type order). Recently two transitions have been reported for the systems $Zn_xMg_{1-x}Fe_2O_4$ [4] and $Mg_{1+t}Fe_{2-2t}Ti_tO_4$ [5].

Our study on the system $Li_{0.5+0.5t}Fe_{2.5-1,5t}Ti_tO_4$ [6] has shown that, for $t = 1.25$, both Fe spins at A and B sites are canted. High magnetisation and Mössbauer results are interpreted by a thermically activated relaxation of $S_t$ between preferential directions. $S_t$ is not free to rotate; this deviates from the Villain's model. We present FC-ZFC static magnetisation, hysteresis, thermoremanence and neutron diffraction measurements.

## Results and discussion

The neutron diffraction experiment was performed between 300 and 4.2 K. The nuclear spectra ($R \sim 1.5$ %) give an atomic distribution in agreement with the X-ray and Mössbauer results. Below $T_N \approx$ 110 K, unfortunately only a very weak magnetic contribution is superimposed to the (111) peak. This can be qualitatively related to a $S_z$ ferrimagnetic order. FC-ZFC magnetisation measurements were performed with 3.4 Oe $\leq H \leq$ 138 Oe, and hysteresis loops with $H \leq$ 300 Oe and 4.2 K $\leq T \leq$ 110 K. Figure 1 shows that the FC-ZFC branching is strongly field dependent: for $H <$ 30 Oe, irreversibilities are observed until $T_N$; for $H \geq$ 30 Oe, FC-ZFC values are identical above the magnetisation maximum temperature $T_{max}$. This behavior cannot be related to (i) a spin glass regime because the sample is a perturbed ferrimagnet, (ii) a magnetic cluster model because the branching point is too sensitive to $H$. It can be rather a consequence of the hysteresis loop characteristics which depend on $T$. For a given $T$ and $H$, if the field-magnetisation $(M-H)$ curves are irreversible, FC and ZFC differ; if $M-H$ are reversible, they can be equal. The branching point depends on the hysteresis loop evolution which is related

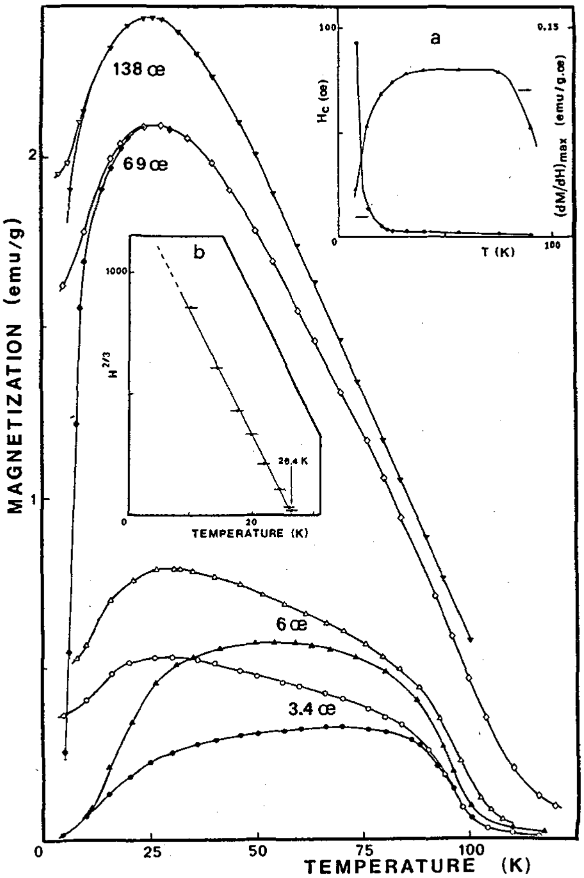


Fig. 1. – $T$ and $H$ dependence of the FC-ZFC magnetisation. Inserts; (a) $T$ dependence of the coercitive field $H_c$ and the maximum slope $(dM/dH)_{max}$ of the hysteresis loop. (b) $H$ dependence of the FC magnetisation maximum temperature.

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to the magnetic domains. But for $T \leq 20$ K, the ZFC and $(dM/dH)_{max}$ drops, like in reentrant systems, can be related to a disorder phenomenon, althought they are time dependent. These features are discussed below.

The FC maximum temperature depends on $H$ : $T_{max} = T_0 - (1.97 \times 10^{-2}) H^{2/3}$, with $T_0 = 26.4$ K and 50 Oe $\leq H \leq$ 25 kOe. This behavior is found in spin glasses and in small particles, but could also be more general if the maximum is related to an activated phenomenon as the $S_t$ relaxation.

FC values are thermic hystory dependent, just below $T_N$, in particular when the measurements are performed in decreasing $T$ with different cooling rates. Considering that $S_t$ has preferential positions [6], the system energy has probably several minima depending on $T$, $H$, cooling rate and measuring method. A magnetisation relaxation, toward a more stable state, can exist but is certainly slow.

For $T > T_{max}$ and $H \geq 20$ Oe, the hysteresis loop is closed and the FC-ZFC curves show (i) a magnetisation increase with $H$ partly due to a weak canting angle variation, (ii) a magnetisation decrease when $T$ increases which cannot be easily explained because the two sublattice existence and a possible canting variation with $T$. The presence of some $S_z$ population, with a fast relaxation, cannot be exclude, this population decreasing with $T$.

The time dependence of the thermoremanence magnetisation has been studied for applied fields $H = 3.4$, 28, 69 and 138 Oe with $4.2 \leq T \leq 90$ K. The cooling time, from 300 K to $T$, is about 25 mn, and the measuring time $\sim 10^3$ s. The phenomenological relation is observed: $\mathrm{TRM}(T,t) = C(T) \exp[-p(T) \ln t]$. $p(T)$ increases with $T$ as in spin glass regime, then decreases above $T \sim 20$ K which is not usually observed. To explain the TRM $(T,t,H)$ behavior, we have used the Khater relation [7] giving TRM $(T,t)$ from a cluster model, which permitted to determine the mean activation energy $E_a/k$. The $T$ dependence of $E_a/k$ is presented in figure 2. For $T \leq 15$ K, $E_a/k$ is constant: $(E_a/k)_0 = 280$ K. The high temperature behavior can be interpreted by adding to $(E_a/k)_0$ a supplementary term inversely proportional to the relaxation time $\tau_t$ of $S_t$. The disorder introduced by $S_t$ could explain the low temperature-TRM behavior, while at high $T$ the relaxation is fast and the order evolves toward a classical ferrimagnet.

All reported features can be explained from the domain and wall properties resulting of LCS. At low $T$, $S_t$ is frozen in an energy minimum direction and it is difficult that the walls move. Indeed, after spin rotation, $S_t$ is not again in a direction minimizing the energy and therefore the energy cost is high. Then $H_c$ is high and $(dM/dH)_{max}$ low. Nevertheless the system relaxes and an equilibrium state is reached after a certain time, then a time variation of $H_c$ and $(dM/dH)_{max}$ is observed and a decay of TRM. At high $T$, the energy barrier between the preferential directions is low, the $S_t$ relaxation is fast. Therefore the equilibrium state is rapidly reached and the properties are similar to those of a classical ferrimagnet.

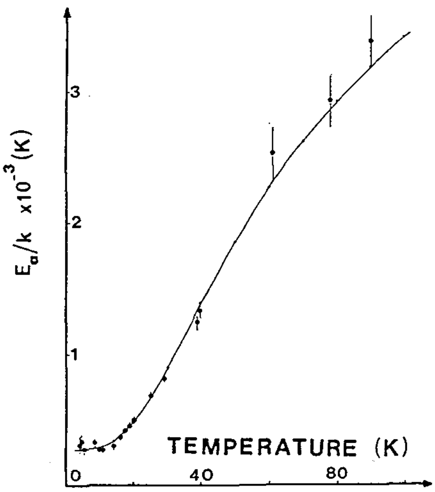


Fig. 2. – $T$ dependence of the activation energy $E_a/k$.

In conclusion, all the particular properties of this compound result of the existence of LCS where the transverse component relaxes between preferential directions.


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