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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_{1.250}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 $T_S$ for the transverse component $S_t$ (spin glass type order). Recently two transitions have been reported for the systems $\text{Zn}_{x}\text{Mg}_{1-x}\text{Fe}_{2}O_4$ [4] and $\text{Mg}_{x+\delta}\text{Fe}_{2-\delta}\text{Ti}_2O_4$ [5].

Our study on the system $\text{Li}_{0.5+0.5x}\text{Fe}_{2-1.5x}\text{Ti}_2O_4$ [6] has shown that, for $x = 1.25$, both Fe spins at A and B sites are canted. High magnetisation and Mössbauer results are interpreted by a thermally 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 $T_{\text{max}}$. 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

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

The FC maximum temperature depends on $H$: $T_{\text{max}} = T_0 - (1.97 \times 10^{-2}) H^{2/3}$, 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 history 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 $T > T_{\text{max}}$ 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 $S_t$ 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: $\text{TRM}(T,t) = C(T) \exp(-p(T) \ln t)$. $p(T)$ 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 $(dM/dH)_{\text{max}}$ low. Nevertheless the system relaxes and an equilibrium state is reached after a certain time, then a time variation of $H_c$ and $(dM/dH)_{\text{max}}$ 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.

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

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