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Magnetic and Mössbauer Investigations of $\text{CoGa}_{2-x}\text{Fe}_x\text{O}_4$

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Abstract. The magnetic properties of system $\text{CoGa}_{2-x}\text{Fe}_x\text{O}_4$ ($x=0.1, 0.2, 0.3, 0.4, 0.5, 0.8, 1$) with spinel structure were investigated by means of dc susceptibility and dc magnetization measurements in magnetic fields 1-12kOe as well as by means of Mossbauer effect. The results of magnetic measurements show that compounds with $0.1 \leq x \leq 0.5$ exhibit features typical for spin glasses and ones with $x=0.8$ and 1 have a ferromagnetic ordering. The compounds with $x=0.8$ and 1 exhibit relaxation behaviour in their Mossbauer spectra.

It is well known that, spinels are good candidates for spin glass behaviour because of the different types of disorder and frustration that may be present in their lattices [1]. In this paper we report results of magnetic (dc susceptibility and dc magnetization) and Mossbauer measurements of polycrystalline compounds $\text{CoGa}_{2-x}\text{Fe}_x\text{O}_4$ ($x=0.1, 0.2, 0.3, 0.4, 0.5, 0.8, 1$) with spinel structure [2]. The neutron diffraction and low field susceptibility measurements showed that spinel CoGa_2O_4 exhibited spin glass behaviour due to the competing interactions between Co^{2+} ions occupying tetrahedral (A) and octahedral (B) sites [3].

DC magnetization measurements were performed in the temperature range $4.2 \text{ K} \leq T \leq 300 \text{ K}$ using a Dominicali-type pendulum magnetometer. DC susceptibility measurements in the $4.2 \text{ K} \leq T \leq 600 \text{ K}$ were carried out using a Faraday method. The applied fields used in these magnetic measurements are 1-12kOe. The Mossbauer experiment was made using a gamma-spectrometer working in a regime of constant velocity. The source used was ^{57}Co in stainless steel.

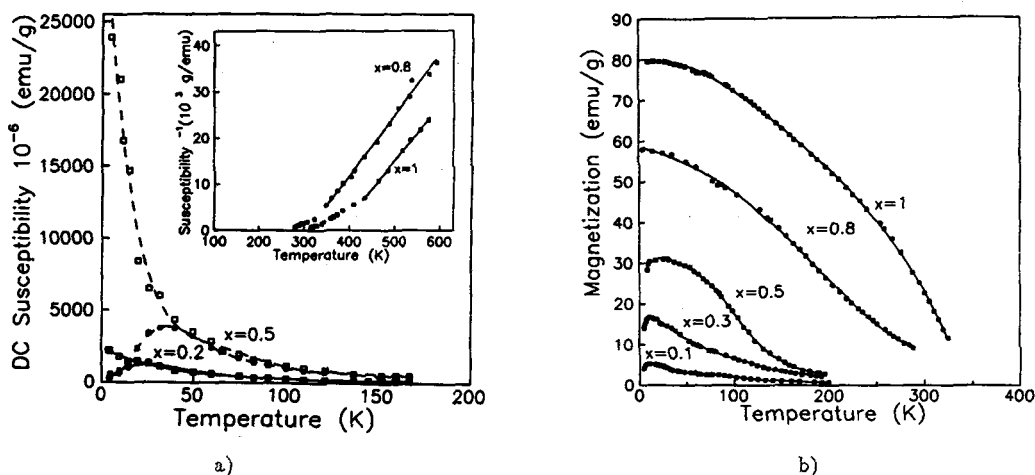


Figure 1. a) Temperature dependence of dc susceptibility (zfc-closed squares and fc-open squares) of $\text{CoGa}_{2-x}\text{Fe}_x\text{O}_4$ with $x=0.2$ and 0.5 measured in field 1kOe. The inset show temperature dependence of the inverse susceptibility for $x=0.8$ and 1. b) Temperature dependence of the dc magnetization of $\text{CoGa}_{2-x}\text{Fe}_x\text{O}_4$ with $x=0.1, 0.3, 0.5, 0.8,$ and 1 measured in field 10.8kOe.

In Figure 1(a) the temperature dependence of magnetic susceptibility of samples with concentration $x=0.2$ and 0.5 is shown. The samples were first cooled in zero field down to 4.2K. The field was applied and the measurements taken with increasing temperature (zfc curve). Then the samples were cooled again in a constant field and a new set

of measurements done with decreasing temperature (fc curve). DC susceptibility measurements made after cooling the samples in zero field (zfc) indicate the presence of anomaly at temperatures 26K and 32K in the $x=0.2$ and 0.5 respectively. The shape of zfc curve and fc curve is indicative of spin glass like behaviour for these samples. Note that the values of the paramagnetic Curie temperature are positive $\theta=102\text{K}$ and $\theta=161\text{K}$ for $x=0.2$ and $x=0.5$ respectively. Such SG-like behaviour was observed also for samples with $x=0.1, 0.3$ and 0.4. The anomaly observed on the temperature dependence of dc magnetization after cooling in zero field of samples with $0.1 \leq x \leq 0.5$ (Figure 1(b)) confirm spin glass behaviour.

The results of magnetic measurements here reported indicate two type of magnetic behaviour depending on the sample composition. The curves of temperature dependence of inverse magnetic susceptibility (the values of θ are positive $\theta=315\text{K}$, $\theta=380$ for $x=0.8$ and 1 respectively) (inset.Figure 1(a)) and magnetization (Figure.1(b)) are indicative of the presence of ferromagnetic ordering in the samples with $x=0.8$ and 1 ($T_c \sim 285\text{K}$ and $T_c \sim 335\text{K}$ for $x=0.8$ and 1). The field dependence of magnetization measured on these samples up to 12.2kOe at temperature 4.2K (Figure 2(a)) shows that the behaviour of the curves are different above and below the concentration $x=0.5$.

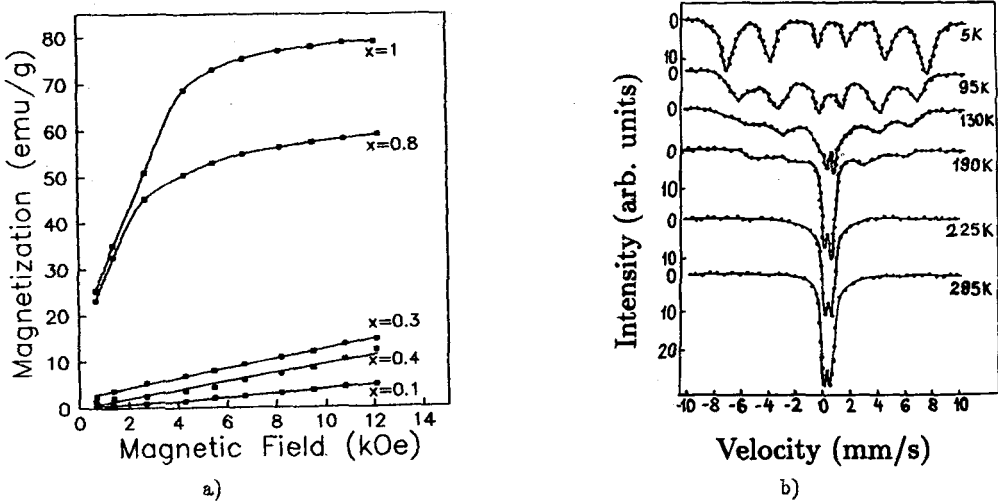


Figure 2. a)Field dependence of the magnetization of $\text{CoGa}_{1-x}\text{Fe}_x\text{O}_4$ with $x=0.1, 0.3, 0.4, 0.8$ and 1 at $T=4.2\text{K}$. b)Mossbauer spectra of $\text{CoGa}_{1.2}\text{Fe}_{0.8}\text{O}_4$ in temperature range $5\text{K} \leq T \leq 295\text{K}$.

Figure 2(b) shows the Mossbauer spectra of $\text{CoGa}_{1.2}\text{Fe}_{0.8}\text{O}_4$ and in temperature range $5\text{K} \leq T \leq 295\text{K}$. The Mossbauer spectra in this range have the features characteristic for relaxation effects [4,5]. The relaxation effects are also observed in the Mossbauer spectra sample with $x=1$ [6]. The values of isomer shift $\delta \approx 0.5 \pm 0.03\text{mm/s}$ determined from the Mossbauer spectra at room temperature are typical for Fe^{3+} . The phase transition temperature determined from the Mossbauer measurements for $x=0.8$ is 225K. There is a large difference between phase transition temperature determined by means of magnetic and Mossbauer measurements for $x=0.8$, $T_c \sim 285\text{K}$ and $T_c \sim 225\text{K}$ respectively. This large difference can be related to different time scale measurements.

Thus magnetic measurements show that samples with concentration $x \leq 0.5$ are good candidates to exhibit spin glass behaviour. The relaxation effects observed in the Mossbauer spectra of samples with $x=0.8$ and 1 indicate the presence of the spin fluctuations.

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