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Effect of Carbon Tailoring On Magnetic Properties of Mn_3GaC

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Abstract: We have investigated the magnetic properties of antiperovskite Mn_3GaC_x. Tailoring of carbon content affects the magnetic transition temperature of these materials. Magnetization decreases with decrease in carbon deficiency however carbon excess shows a reverse pattern. The virgin magnetization curves lie outside the hysteresis loop for x > 0.8 showing competing ferromagnetic and antiferromagnetic interactions. The pinching of magnetization loops seen especially in the case of x = 0.95 and 1.00 indicate field induced metamagnetic transitions.

Keywords: Magnetization curves and hysteresis, Antiferromagnetics, Magnetic phase boundaries
PACS: 75.60.-d, 75.50.Ee, 75.30.Kz

INTRODUCTION

Antiperovskite of type Mn_3GaC shows a series of magnetic and structural transformations with increasing temperature. The stoichiometric compound exhibiting a first-order transformation from an antiferromagnetic (AFM) to a canted ferromagnetic (CFM) phase is very interesting for magnetic refrigeration [1]. The first-order transformation AFM–CFM underlies the large Magneto-Caloric Effect (MCE) and Giant Magneto Resistance (GMR) [2] along with a second order magnetic transition at higher temperature. The poorly understood magnetic properties of these compounds seem to depend on carbon content. Carbon deficient $Mn_3GaC_{0.88}$ exhibits only a second order paramagnetic (PM) to ferromagnetic (FM) transition while the stoichiometric compound is characterised with both second order magnetic and first order magneto-structural transition. A detailed investigation of magnetic properties of Mn_3GaC as a function of carbon content is missing. In this paper we present a systematic investigation of magnetic properties as a function of carbon content of Mn_3GaC_x.

EXPERIMENTAL

Polycrystalline samples of the general formula Mn_3GaC with nominal carbon content C = 0.80, 0.90, 0.95, 1, 1.05) were prepared by solid state method. X-ray diffraction (XRD) pattern was recorded at room temperature in the range of $20° \leq 2\theta \leq 80°$ using Cu Kα radiation. The magnetization measurements were carried out as a function of temperature M (T) and magnetic field M (H) using a Quantum Design SQUID magnetometer in the temperature range of 5K to 300K.

RESULTS AND DISCUSSION

Rietveld refinement of XRD patterns reveal that the samples are formed in single phase with space group Pm3m without any major impurities especially that of carbon. Carbon doping only decreases the lattice constant *'a'* as shown in Figure 1. M(T) measured in an applied field of 1000 Oe during zero field cooled cycle is presented in Figure 2(a). Magnetization undergoes a sharp rise marking the PM to FM transition. This rise is at about T_C = 300K for x = 0.8 and about 240K for all other samples. In the case of x = 0.8, magnetization saturates to a very high value of about 14000 emu/mole which corresponds to about 0.8 μB/Mn ion. In case of x = 1.05 the Mn moment is the lowest also the FM transition is rather broad as can be seen from Figure 2(a). In all samples with x > 0.8 the magnetization drops suddenly at around 180K due to a ferromagnetic to AFM transformation. On close observation it can also be seen that with increasing carbon content, the first order phase transition temperature increase while the second order transition temperature decreases.

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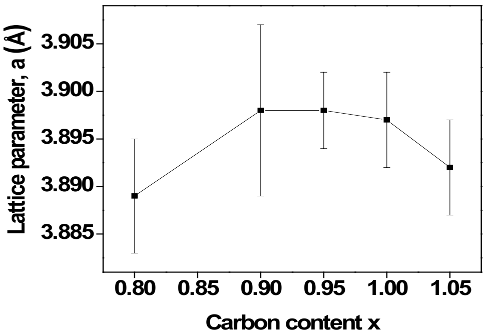


Figure 1. Variation of cell parameters with carbon concentration.

M(H) curves recorded in the range ±8Tare shown in Figure 2(b).Saturation of magnetization and hysteresis (see inset) observed in x = 0.8 compound indicates presence of ferromagnetism down to 5K.

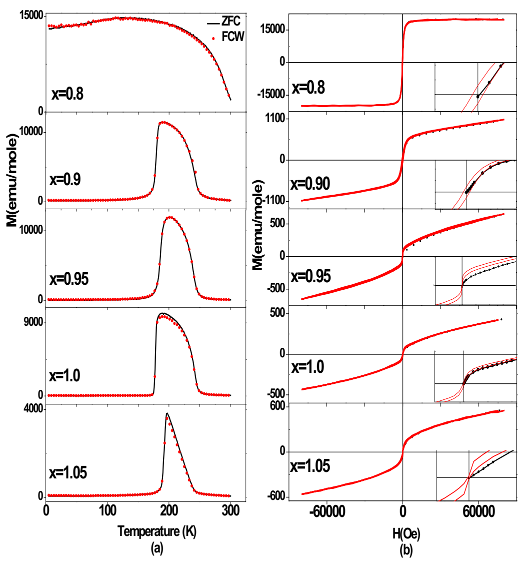
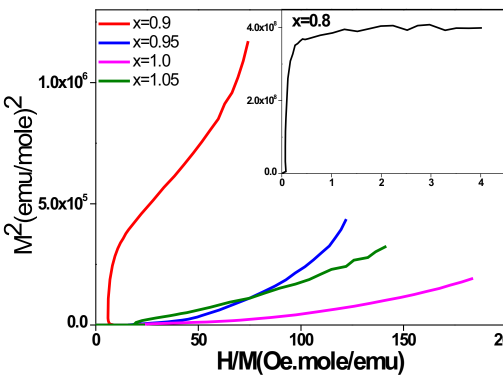


Figure 2(a). Plot of magnetization as a function of temperature during zero field cooling (ZFC) and field cooled (FCW) cycles. **(b)** Hysteresis loops recorded at 5K in the fields of ± 8T for Mn_3GaC_x.

In other compounds no saturation of magnetic moment is observed. Absence of saturation along with other features like virgin magnetization outside the hysteresis loop and zero coercivity indicate presence of competing FM and AFM interactions. The pinching of magnetization loops seen near 0 Oe applied field especially in the case of x = 0.95 and 1.00 point to field induced metamagnetic transitions.

Arrott plots (M^2 v/s H/M) plotted in Figure 3 reveal that except in the case of x = 0.8, ferromagnetism is not spontaneous but is induced by the externally applied field.It can be seen that in the case of $Mn_3GaC_{0.8}$ the abscissa is positive while in all other compounds it is either zero or negative. Interestingly Arrott plots also indicated that magnetization continuously decrease with increase in x. However, in case of x = 1.05, it shows a reversal of the trend. M(H) loop also shows presence of very small hysteresis. This leads us to infer that a small FM phase is present in this compound. It is possible that even before the PM to FM transition completes the sample undergoes a magneto-structural transition. This traps the FM phase in the AFM lattice. It may be noted that this is a carbon surplus compound. Further studies are needed to understand this phenomenon.



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igure 3. Arrott plot in case of Mn_3GaC_x

In conclusion, study of magnetic properties of Mn_3GaC_x antiperovskites indicates that with increasing carbon concentration PM to FM transition temperature decreases while FM to AFM transition temperature increases. In case of x = 1.05 sample the two transformation regions seem to overlap with FM phase being trapped in AFM matrix.

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REFERENCES

[1] J. Garcı´a, J. Bartolome´ , D. Gonza´ lez, R. Navarro, D Fruchart, J. Chem. Thermodyn. **15** (1983) 1059

[2] M.H.Yu, L.H.Lewis, A.R. Moodenbaugh, J. Appl. Phys. **93** (2003) 10128.