Structural and magnetic studies of $Fe_2MnSi_{1-x}Ga_x$ Heusler alloys for magnetic refrigeration purposes.

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Abstract: The structural and magnetic properties of $Fe_2MnSi_{1-x}Ga_x$ (x = 0, 0.02, 0.04, 0.08, 0.09, 0.12, 0.16, 0.20, 0.30 and 0.50) Heusler alloys were studied by diffraction and energy dispersive spectroscopy (EDS), X-ray diffraction and magnetic measurements, in order to investigate potential magnetocaloric properties and to optimize the possible use of these alloys for magnetic refrigeration. We found a monotonic behaviour in the structural properties with Ga content (x), but with increasing x, T_C decrease, which at first is not expected for these compounds.
Keywords: Magnetic refrigeration, Magnetocaloric effect, Heusler alloys.

Introduction

In 1881 E. Warburg measured a curious effect caused by a magnetic field on iron. He found that the temperature of the material was changed by the external field. This was called magnetocaloric effect (MCE), and the main application is the magnetic refrigeration. This phenomenon has been studied by several researchers in the world, in order to develop magnetocaloric materials, such as alloys of rare earth and metalloids (R-G), R-G-M alloys (M=transition metals), the family of manganites ($RMnO_3$-type) and intermetallic alloys M-R. In the last family can be found the Heusler alloys. These compounds are very important for the study of the magnetocaloric effect due to the coupling of the structural and magnetic transitions, increasing the possibility to use for magnetic refrigeration [1]. The samples studied in the present work are $Fe_2MnSi_{1-x}Ga_x$ alloys with x = 0, 0.02, 0.04, 0.08, 0.09, 0.12, 0.16, 0.20, 0.30 and 0.50, in order to optimized the magnetocaloric effect.

Experimental Procedure

The samples were prepared by arc furnace under argon atmosphere, with stoichiometric amounts of iron, silicon, gallium and manganese. To ensure that the samples are single phase was added an additional 3% of manganese. The samples were annealed for 3 days at 1323 K. X-ray powder diffraction data at room temperature were obtained using a Bruker AXS D8 Advance diffractometer with Cu-Ka radiation (λ = 1.54056 Å). EDS experiments were performed on a Bruker microanalysis system mounted on a SEM microscope TESCAN Vega SBU. Magnetization data was acquired as a function of temperature at 200 Oe using a commercial Superconducting Quatum Interference Device (SQUID).

Results and Discussion

The samples were refined by the Powder Cell Program, and all of them exhibit a single phase related to the Cu_2MnAl type *Fm-3m* (space group 225) with monotonic lattice parameter *a* increasing with substitution parameter *x*. This information can be seen in the Fig.1. EDS measurements were realized to make sure the composition of the samples, found differences between the nominal and experimental composition for $x = 0.08$ sample, for this it was dismissing of the series of samples. While the results of the others samples were very close to the nominal compositions.

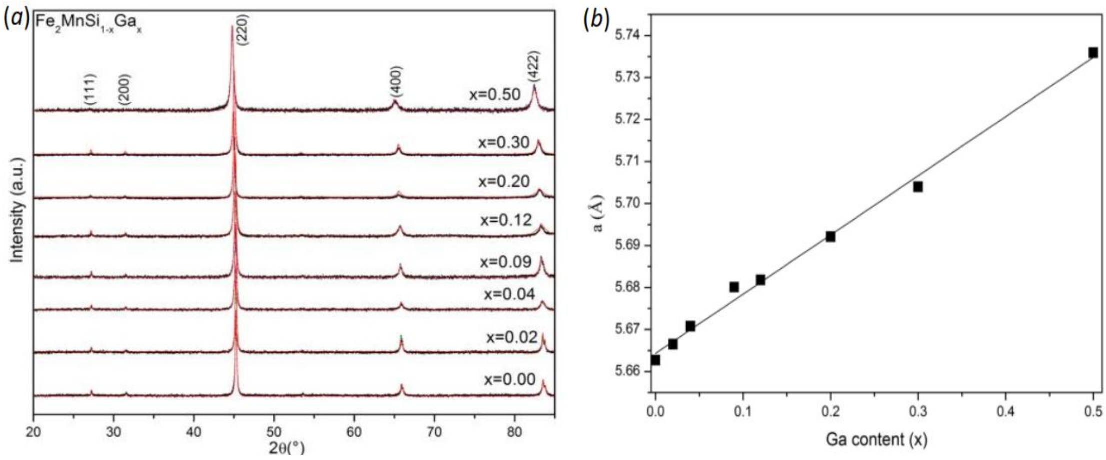

Figure 1: (*a*) X-ray diffraction of all samples. (*b*) Lattice parameter “a” increase with Ga content.

From the magnetic measurements we found the critical temperature T_C and the effective magnetic moment show a different behavior than expected for this samples. This, because we thought the temperature would increase with the Ga content from 219 K for Fe_2MnSi [2] to 750 K for Fe_2MnGa [3], however decreases with Ga content until x=0.50. The increases of Ga content in the $Fe_2MnSi_{1-x}Ga_x$ alloys increases the effective magnetic moment, which affect in the increment of the magnetocaloric behavior in the samples. The magnetic measurements are in the Fig. 2.

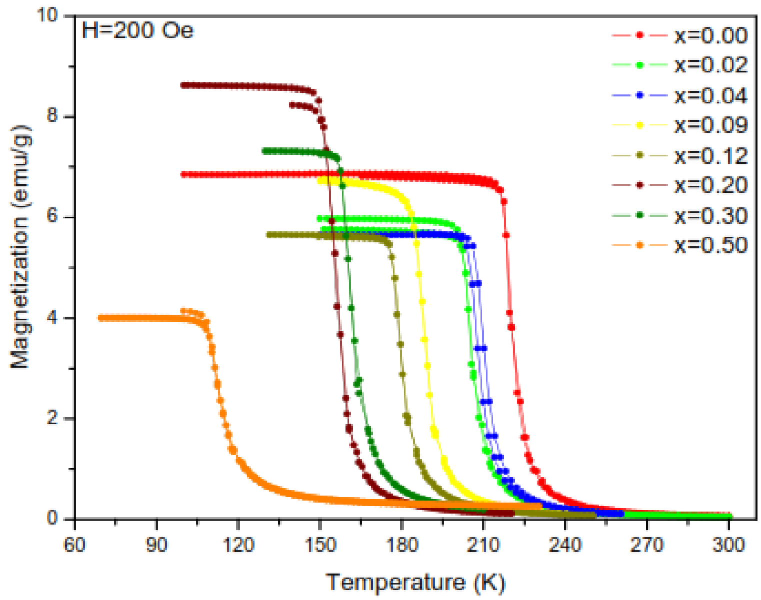

Figure 2: Magnetization of the $Fe_2MnSi_{1-x}Ga_x$ (x = 0, 0.02, 0.04, 0.09, 0.12, 0.20, 0.30 and 0.50) Heusler alloys measured at 200 Oe.

Conclusions

We synthesized the $Fe_2MnSi_{1-x}Ga_x$ Heusler alloys obtained phase crystallizes in the cubic *Fm-3m* (space group 225) and the lattice parameter increases linearly with increasing of Ga content. The Curie temperature changes significantly with Ga content the $0 < x < 0.5$ range, but the Ga doping interval chosen was not enough to bring T_C to room temperature. In this way, the present work leaves some questions opened to other futures studies to be realized with samples containing high Ga doping ($x > 0.5$) with the aim of turning T_C near room temperature. At the moment of this study are being conducted magnetocaloric effect measurements in the samples and will be presented in future work. Samples from x=0.50 to x=1 will be synthesized in order to find the amount of *x* by T_C at room temperature.

Acknowledgments

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References

[1] Thorsten Krenke et. al. Nature Materials **4**, 450 - 454 (2005).
[2] T. Nagano et. al. Journal of Magnetism and Magnetic Materials 140-144 (1995) 123-124.
[3] A. C. Jenkins et. aL Applied Physics Letters **100**, 032401 (2012)