acta physica slovaca vol. 54 No. 5, 459 – 463 **October 2004**

DISAPPEARANCE OF THE REENTRANT SPIN GLASS PHASE IN $Fe_{0.7\text{-}x}R_xAl_{0.3}$ (R = Mn OR V)

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Received 21 May 2003, accepted 13 July 2004

A reentrant spin glass phase is revealed in the $Fe_{0.7}Al_{0.3}$ alloy as the temperature is lowered. Our measurements of the DC magnetization in zero field cooled and field cooled of $Fe_{0.7-x}R_xAl_{0.3}$ alloys (with R=Mn or V) showed critical concentrations x_c of Mn and V atoms. Above these critical concentrations the alloys no longer exhibit reentrant spin glass behavior. We found for Mn-atoms x_c = 0.04 and for V-atoms x_c = 0.02. This behavior is attributed to the magnetic nature of these atoms. Also, compared to the V and Mn free alloy ($Fe_{0.7}Al_{0.3}$) the spin glass temperature T_f is more influenced by the V-atoms.

PACS: 75.50Bb

1 Introduction

Considerable attention has recently been paid to alloys like $Fe_{0.7}Al_{0.3}$ that exhibit reentrant magnetic phase transitions (RSG) [1–4]. On lowering the temperature, the $Fe_{0.7}Al_{0.3}$ alloy goes from paramagnetic (PM) state to ferromagnetic (FM) state at around 430 K and then from FM state to PM state at around 170 K. Finally it goes to spin glass state at around 70 K [5,6]. The phase between 170 K and 70 K is attributed as to the existence of ferromagnetic clusters.

In a previous work, we studied the effect of concentration of R = Mn, V and Co atoms in the $Fe_{0.7-x}R_xAl_{0.3}$ alloys on the freezing temperature T_f, where we found that T_f decreases with increase in the concentration x of all these elements [7,8]. In the present work we focus our attention to the RSG state and determine the critical concentration values x_c of the elements R = Mn and V, above which the RSG phase disappears and the materials exhibit the usual PM to SG magnetic phase transition on lowering of temperature.

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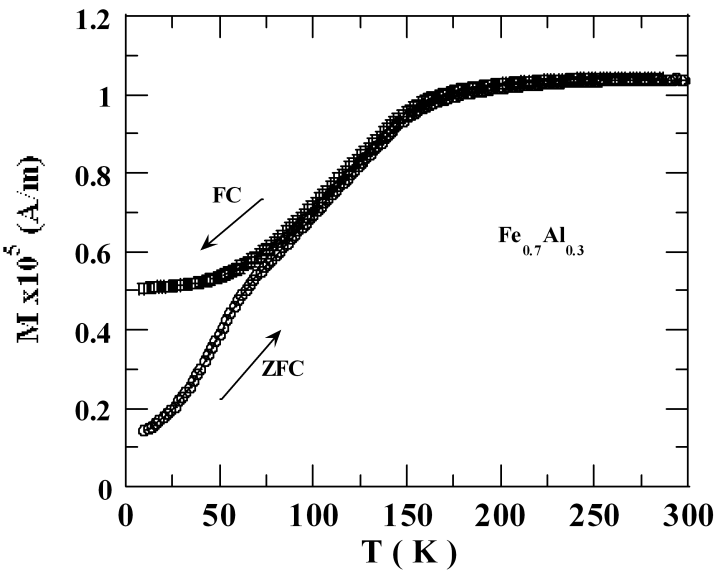

Fig. 1. Magnetization M versus temperature T for $Fe_{0.7}Al_{0.3}$ alloy.

2 Experimental

The $Fe_{0.7-x}R_xAl_{0.3}$ (R = Mn, V) alloy samples are prepared using arc melting technique as described in our earlier papers [7,8]. Samples of nearly 0.5mm $\times$ 0.5mm $\times$ 3.5mm dimensions are used for the measurements. The magnetization measurements are carried out using commercial superconducting quantum interference magnetometer (Quantum Design) SQUID. The samples are zero field cooled (ZFC) to 10 K and then a constant magnetic field of 0.01 T is applied parallel to the length of the sample. The magnetization M versus the temperature T is recorded as the temperature is raised in steps of 2 K up to 300 K. The corresponding plot represents the zero field cooled (ZFC) branch of the magnetization curve. Keeping the magnetic field at 0.01 T, the temperature is then lowered in the same manner from 300 K to 10 K; the resulting plot of M versus T gives the field cooled (FC) branch of the magnetization curve.

3 Results and Discussion

Figure 1 is the plot of M versus T for the $Fe_{0.7}Al_{0.3}$ alloy. This shows that ferromagnetic phase exists for $T > 170$ K. As the temperature is lowered below 170 K, the compound goes to the mixed state of SG–PM phases with ferromagnetic clusters up to $T_{\mathrm{f}} = 70$ K, below which the well defined spin glass state is established [5]. The temperature $T_{\mathrm{L}} = 170$ K represents the value above which the mixed phase no longer exists. These observations made in the present work are in good agreement with those reported earlier [5,6]. The behavior observed here is not an expected one since the usual behavior of a material is to go from PM phase to SG phase on lowering the temperature. This peculiar behavior has been attributed as due to the existence

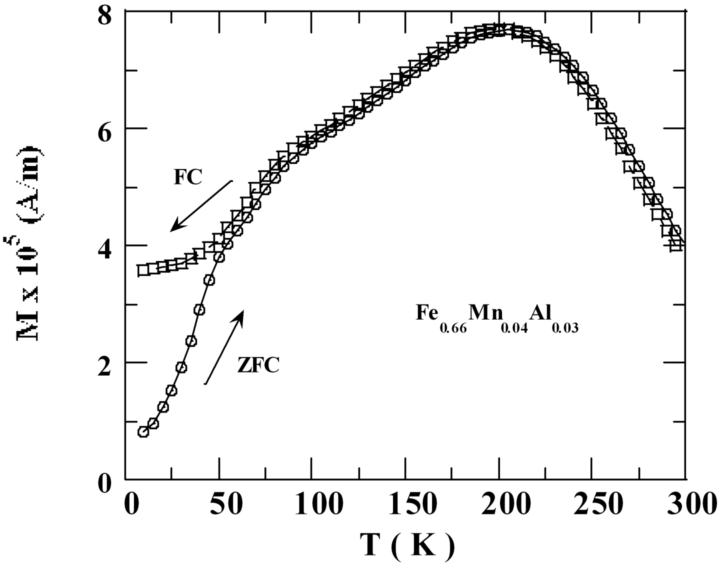

Fig. 2. Magnetization M versus temperature T for $Fe_{0.7-x}Mn_xAl_{0.3}$ alloy.

of the spin clusters in the temperature range 10 K $< T <$ 500 K [5,6]. The results of our ZFC and FC magnetization measurements on the $Fe_{0.7-x}R_xAl_{0.3}$ (R=Mn,V) alloys for different concentrations of $0 \leq x \leq 0.10$ in steps of $x = 0.02$ have led us to determine the critical concentration x_c of R atoms, above which the FM phase completely disappears and the material is no longer classified as RSG.

Figure 2 shows the results of M versus T for $Fe_{0.7-x}Mn_xAl_{0.3}$ for $x_c = 0.04$. The figure shows that the material goes to spin glass state at T_f = 65 K and, as T increases, the mixed phase exists up to T_L = 200 K. The regime in this temperature range 65 K $< T <$ 200 K consists of spin clusters [7]. As the temperature T is increased above 200 K the material enters the PM phase. Therefore $x_c = 0.04$ represents the critical value of Mn concentration. The corresponding critical concentration of V atoms in the $Fe_{0.7-x}V_xAl_{0.3}$ alloys is found to occur at $x_c = 0.02$. From Fig. 3 giving the M vs. T plot for this alloy we get T_f = 55 K and T_L = 230 K; the mixed state existing in the temperature range 55 K $< T <$ 230 K. The results for all the alloys are also tabulated in Table 1.

Tab. 1. T_f the transition SG temperature, T_L the temperature above which the FM phase disappears, x_c is the critical concentration.

Alloy	x_c	T_f	T_L
$Fe_{0.7}Al_{0.3}$	—	70 K	170 K
$Fe_{0.7-x}Mn_xAl_{0.3}$	0.04	65 K	200 K
$Fe_{0.7-x}V_xAl_{0.3}$	0.02	55 K	230 K

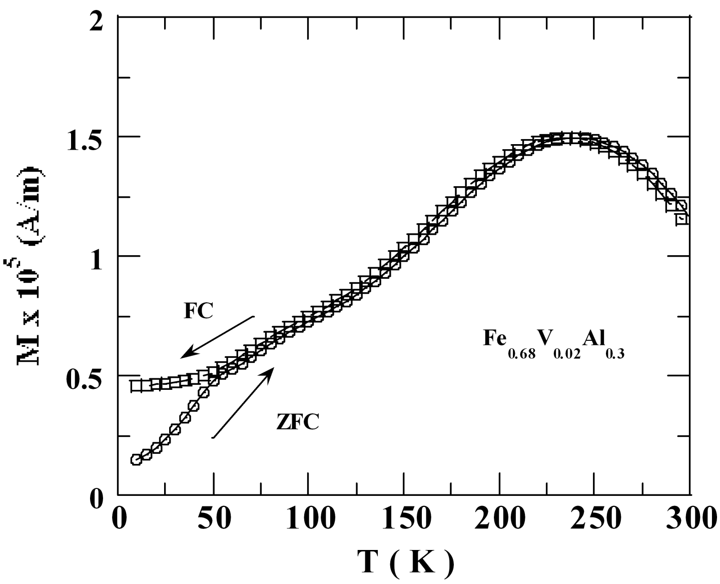

Fig. 3. Magnetization M versus temperature T for $Fe_{0.7-x}$ $V_xAl_{0.3}$ alloy.

A comparison of the results from the figures and the table between the $Fe_{0.7-x}R_xAl_{0.3}$ alloys and the R-free alloy $Fe_{0.7}Al_{0.3}$ shows that a small amount of V-atoms has more influence on the T_f and T_L values. The temperature range for the existence of the mixed phase is wider in the case of V-atoms. On the other hand, the coexistence of the mixed phase is survived to a higher concentration in the case of Mn-atoms the x_c value for Mn is double that of the V-atoms. This means that replacing the Fe-atoms by a small amount of V-atoms results in a faster disappearance of the FM phase. The significant difference between Fig. 1 and the other two figures is that the ferromagnetic state in $Fe_{0.7}Al_{0.3}$ survive over a wide temperature range from $T_L = 170$ K up to $T_c = 430$ K [5,6], while there is no sign for the existence of PM phase at these critical concentrations for the other two alloys. The fast disappearance of FM phase in the case of V atoms at low concentration demonstrates the strong paramagnetic behavior of the V atoms in this case. It is worth mentioning that our Mössbauer spectral studies on these alloys have shown the presence of magnetic ordering at these concentrations [9].

4 Conclusions

In this work, we have studied the ZFC and FC magnetization as a function of temperature for the $Fe_{0.7-x}R_xAl_{0.3}$ (R = Mn, V) alloys. A comparison with the results on the R-free alloy $Fe_{0.7}Al_{0.3}$ (which is the $x = 0$ case of the former alloys) shows the existence of certain critical concentration values of the Mn and V atoms above which the FM phase disappears. The critical concentration values observed are $x_c = 0.02$ and 0.04 for the V and Mn cases respectively. This shows that doubling the concentration of Mn atoms with respect to V-atoms leads to the same effect of V atoms in the disappearance of the FM phase, i.e., V has double the influence of Mn on the T_f and the T_L values. The mixed phase survives over a wide temperature range in the case of replacement of Fe atoms by V-atoms. This sort of behavior is attributed as due to the difference in the magnetic nature between V-atoms and Mn-atoms. Above the critical concentrations of the R-atoms, both the alloys $Fe_{0.7-x}Mn_xAl_{0.3}$ and $Fe_{0.7-x}V_xAl_{0.3}$ exhibit the usual PM to SG transition as T is lowered, and they are no longer classified as RSG alloys.

Acknowledgement: One of us (K.A. Azez) would like to thank M. McElfresh, Lawrence Livermore National Laboratory, CA, USA for providing lab. facilities. We would like to thank W. Oliver from the Department of Physics at University of Arkansas. We are grateful to Jordan University of Science and Technology for financial support.

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