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MAGNETIC AND STRUCTURAL PROPERTIES OF Fe₇₀Al₃₀₋ₓVₓ ALLOYS

A. Bailey, R. M. Mankikar and J. G. Booth

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Abstract. - Magnetization, magnetic susceptibility, X-ray and neutron diffraction measurements have been made on Fe₇₀Al₃₀₋ₓVₓ alloys with x ≤ 0.05. The alloys have the L₂₁ structure and the Curie temperature and magnetization increase with x. The addition of vanadium inhibits the low temperature superparamagnetic behaviour seen for Fe₇₀Al₃₀.

Introduction

The alloy Fe₇₀Al₃₀ shows remarkable properties near ~ 100 K in that a re-entrant transition from a ferromagnetic state to some form of paramagnetism occurs as the temperature is lowered [1, 2]. The range of composition over which this occurs is rather small however. The partial substitution of a 3d transition metal (Cr, Mn or Co) for Al generally reduces the transition temperature [3] and the present paper gives preliminary results on the effects of vanadium substitution on the magnetic and structural properties. The series Fe₇₀₋ₓAl₃₀₋ₓVₓ has been examined for x = 1, 3, and 5 using X-ray, magnetization and neutron diffraction techniques.

Experimental techniques

Alloys having the general formula Fe₇₀Al₃₀₋ₓVₓ were fabricated with values of x equal to 1, 3 and 5 by arc melting of the components under a third of an atmosphere of argon. The powdered alloys were heat treated for 24 hours at 830 °C before being quenched into water. The alloy with x = 1 was in fact too ductile to be crushed and was heat treated and examined in solid form. X-ray diffraction studies indicated the alloys to be single phase within the limits of detection and to have the B₂ ordered CsCl structure. Neutron diffraction measurements were carried out at room temperature at AERE Harwell with the object of establishing the site occupations from a comparison of the intensities of the observed lines. The presence of the (111) family of lines however indicated that the crystallographic order was of the doubly ordered L₂₁ type rather than the B₂ indicated by X-rays. Magnetic measurements were carried out in moderate fields using a Sucksmith ring balance in the range 77 to 1 000 K. Curie temperatures were determined by conventional Arrott plots.

Results

The lattice parameter did not appear to be sensitive to vanadium substitution and a₀ = 5.78 Å for all the alloys. The structure of the alloys was discussed in terms of a double sized unit cell consisting of four interpenetrating fcc cells with their origins at the positions (000), (1 1 1) 4 4 4, (1 1 1) 2 2 2 and (3 3 3) 4 4 4.

Fig. 1. - Unit cell consisting of four interpenetrating fcc cells with origins at the positions (000), (1 1 1) 4 4 4, (1 1 1) 2 2 2 and (3 3 3) 4 4 4.

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of vanadium increases the room temperature magnetization and the Curie temperature is also increased by about 30 K per at.%. 

Discussion and conclusions

Structurally the neutron diffraction data indicated the alloys to have the $L_2_1$ structure. The site occupation models used to interpret the neutron diffraction data can be discussed with respect to the four sites A, B, C and D referred to in figure 1 assuming that for $x = 0$ the A and C sites are occupied by Fe, B sites by Al and D sites by 80% Fe and 20% Al as has previously been found for annealed alloys [4]. In model 1 vanadium is assumed to substitute for Al on D sites only. In model 2 substitution for the Al on B sites only is envisaged whereas in model 3 equal substitution on both B and D sites is proposed. Table I compares the experimental values of $\alpha$ and $\beta$ with the theoretical expectations from these three models. Since the site occupation of B and D sites (together) is identical in all models, $\beta$ has the same value in all three cases. Accordingly, only the intensity of the (111) line can be used to discriminate between the three models and unfortunately the experimental errors were such that only in the case for $x = 5$ was it possible to make a reliable comparison with the theoretical values. In this case the values of $\alpha$ and $\beta$ were consistent with model 3 in which equal substitution for Al on both B and D sites is assumed. Although further low temperature and low field data are required to complete the picture, one can say that the magnetization data revealed that only the alloy with $x = 1$ had features similar to those seen for the binary Fe$_{70}$Al$_{30}$ alloy and the occurrence of a broad maximum in these moderate field measurements suggests the presence of freezing with an increase in magnetic hardness at low temperatures. Langevin plots near 125 K suggested that any superparamagnetism occurs only over a small temperature range. The effect of vanadium substitutions therefore seems similar to those of Cr, Mn and Co where it was seen that values of $x \leq 4$ are sufficient to reduce the freezing temperature to zero and confirms the earlier conclusion that the identity of the substituting element is less important than the change in Al content [3].

Table I. - Comparison of the experimental and theoretical values of the ratios $\alpha = F^2(111)/F^2(220)$ and $\beta = F^2(200)/F^2(220)$ for the three models referred to in the text.

<table>
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<th>$\beta$</th>
<th>$\alpha$</th>
<th>$\beta$</th>
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<th>$\beta$</th>
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