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Variation of Magnetization M(0) and Curie Temperature T_c with Cr Concentration for the $Fe_{73.5-x}Cr_xCu_1Nb_3Si_{13.5}B_9$ with x = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12.5, 15 and 17.5 Alloys

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Abstract

There are various means of measuring magnetization of a substance. The magnetization of a substance is usually determined by measuring its magnetic moment divided by the volume or mass of the substance. Magnetic moment has been found to decrease linearly with the increase of Cr concentration. The decrease of magnetic moment is $0.055\mu_B$ for each atomic percent of Cr substitution. Compare with the Curie temperatures (T_c) is also found to depend linearly with the increasing Cr concentration.

Keywords: Magnetization, Magnetic moment, Curie temperatures, atomic percent, concentration etc.

1. INTRODUCTION

Curie temperature is a primary intrinsic property of magnetic materials. A material is ferromagnetic if it possesses regions of finite magnetization where the external magnetic field intensity H = 0. The temperature at which ferromagnetism occurs is called the Curie temperature (T_c) and depends on the strength of exchange interaction which arises from the overlapping of the electronic wave functions of the interacting magnetic atoms. It is more appropriate from the fundamental point of view to find out the T_c from the appearance of spontaneous magnetization on decreasing the temperature (cooling) than the vanishing of spontaneous magnetization as the temperature is increased (warning) because of many complexities of the co-operative phenomena, in particular domain wall motion. In general determination of T_c is not that straight forward as it seems to be from the first principle and the unique value of

T_c can be determined without ambiguity only when the material under study is perfectly homogeneous, single phase, defect free and of high purity.

It is observed that the Curie temperature decreases with increase of Cr content and may be attributed to the reduction of exchange interaction between Fe magnetic moment. A gradual decrease of permeability below T_c is a manifestation of the Hopkinson effect, according to which the initial permeability as a function of temperature increases to a maximum value just below T_c and then drops off to a small value [1]. This is attributed to the temperature dependence of intrinsic magnetic anisotropy and domain wall mobility. This is to note that the samples with $x \geq 5$ at.% Cr, the decrease of permeability below the Hopkinson peak is faster than those of low Cr content samples. This implies that the magnetic hardening occurs in those higher Cr content alloys, which increases with the Cr content as well as with the decreasing temperature originating from the increase of the magnetic anisotropy and thermal activation.

2. EXPERIMENTAL

Melt-spinning is a widely used production method for rapidly solidifying materials as well as preparing amorphous metallic ribbon [2-3]. In order to prepare amorphous of $Fe_{73.5-x}Cr_xCu_1Nb_3Si_{13.5}B_9$ alloys with x = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12.5, 15 and 17.5, a melt spinning system has been used. The arc melted master alloy was crashed into small pieces and put inside the quartz tube crucible for re-melting by induction furnace using a medium frequency generator with a maximum power of 25 kW at a nominal frequency of 10 kHz.

Fig. 1 Melt-spinning Mechine

Fig. 1 shows the pictorial view of the melt-spinning mechine. The quartz crucible has in its bottom part a rectangular nozzle tip of 8 mm length and 0.7 mm width. The position of the nozzle tip can be adjusted with respect to the copper wheel surface, so that the molten alloy was perpendicularly ejected onto the wheel surface from a distance of about 0.3 mm. The small pieces of the master alloy samples were inductively remelted inside the quartz tube crucible followed by ejecting the molten metal with an over pressure of 250 mbar of 99.9% pure Ar supplied from an external reservior through a nozzle onto a rotating copper wheel with surface velocity of 30 m/sec. The temperature was monitored by an external pyrometer from the upper surface of the molten alloy through a quartz window. The metal alloys were ejected at a temperature of about 150-250 K above the melting point of the alloy. The resulting ribbon samples had thickness of about 20-25 μm and width of ~6 mm. Processing parameters such as the thermal conductivity of the rotating quench wheel, wheel speed, ejection pressure, thermal history of the melt before ejection, distance between nozzle of quartz tube and rotating wheel, as well as processing atmosphere have influenced on the microstructure and properties of melt-spun ribbons [4-7].

3. RESULTS AND DISCUSSIONS

The saturation magnetization M(0), M(5K), M(300K) and T_c with Cr content are calculated. The magnetic moment in Bohr magneton n_B has been calculated using the formula

$$n_B = \frac{AM(0)}{N\mu_B} \qquad (1)$$

where A = molecular weight of alloy composition and M = Magnetization (emu/g) at 0 K.

The dependence of magnetic moment n_B and T_c on Cr content in the studied alloy system $Fe_{73.5-x}Cr_xCu_1Nb_3Si_{13.5}B_9$ are demonstrated in fig. 2 (a, b) respectively. The variation of the magnetic moment of the amorphous alloys can be approximated by a straight line of the form $n_B = 1.3748-0.0552x$.

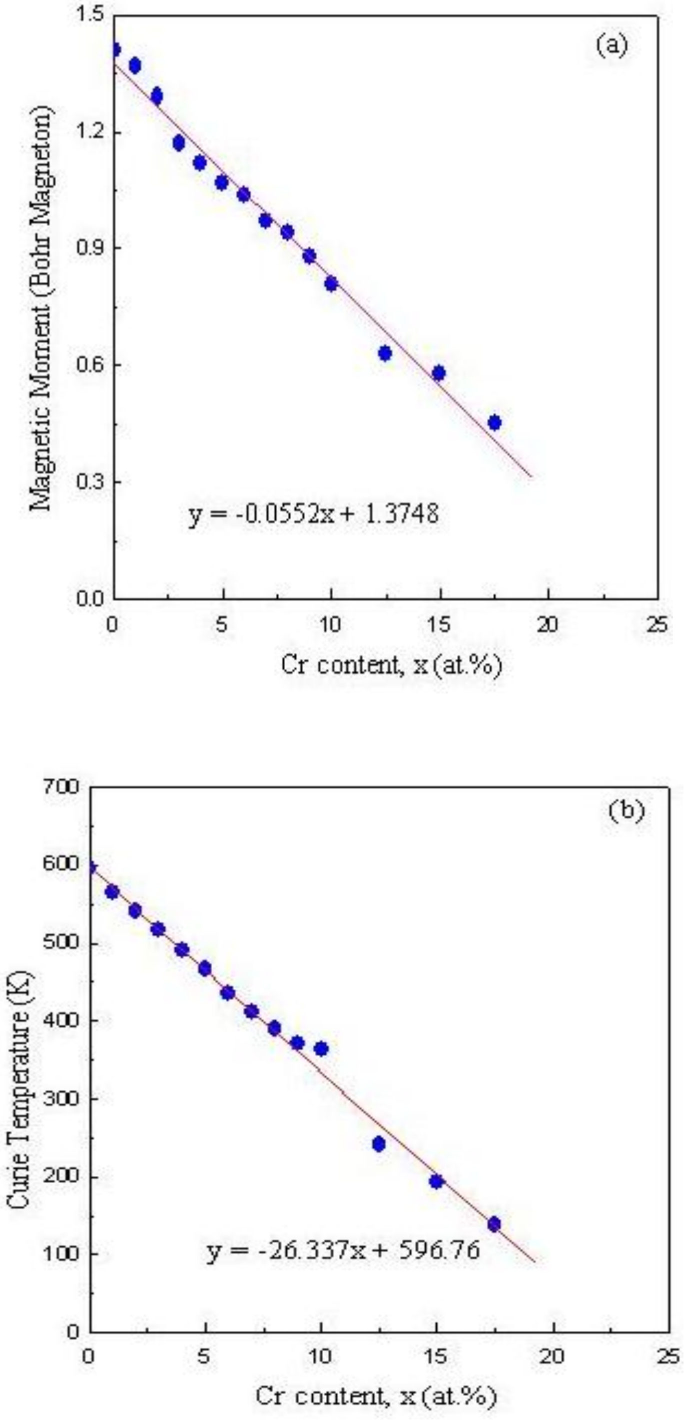

Fig. 2 Variation of (a) magnetic moment and (b) Curie temperature with the x content of amorphous $Fe_{73.5-x}Cr_xCu_1Nb_3Si_{13.5}B_9$ ribbons

A least-square fitting of the experimentally determined T_c values against Cr concentration give a linear equation of the form $T_c = 596.76 - 26.337x$ from which a decrease of T_c by about 26°C per atomic percentage of Cr substitution has been determined. Kovac *et al*. [8] studied the dependence of magnetic moment and Curie temperature of Finemet alloys where Fe has been substituted for Cr with Cr = 4, 8, 11, 14, 17, 25. The authors found a linear decrease of magnetic moment at the rate of $0.047\mu_B$ / Cr atom, while T_c decreased 25K per atomic percent of Cr.

4. CONCLUSION

All results are comparable with the result of Krishnan *et al.* [9] in their study of magnetic properties of $Fe_{40-x/2}Ni_{x/2}Cr_xSi_{10}Mo_2B_8$ alloys ($0 \leq x \leq 5$), found that decrease of magnetic moment is 0.053 μ_B / at.% Cr while that of T_c is 40K / at.% Cr. The rate of decrease of T_c is much higher than our results while compatible with results of Inomata *et al.* [10]. The critical concentration for the onset of ferromagnetism in this alloy system has been estimated to be $x_c = 24\pm1$ at % Cr by linear exploration of $n_B = 0$ and $T_c = 0$ as a function of Cr concentration. This value is in reasonable agreement with the value of $x_c = 26\pm1$ at % Cr reported by Kovac *et al*.[8].

REFERENCES

[1] S. Chikazumi, Physics of Magnetism, New work: Willey P. 273 (1964)

[2] JMD Coey and H Sun, J. Mang. Magn. Mater., 87, L251 (1991)

[3] K Schnitzke, L Schultz,J Wecker and M Katter, Appl. Phys. Lett., 57, 2853 (1990)

[4] M Endoh,M Iwata and M Tokunaga, J.Appl.Phys.Lett.,70, 6030 (1991)

[5] C N Christodoulou and T Takeshita,J.Alloys &Comp., 196, 161 (1993)

[6] PJ McGuiness, XJ Zhang, H Forsyth and IR Harris, J.Less-Common Met.,162, 379 (1990)

[7] B Gebel, M Kubis and K-H Muller, J.Magn.Magn.Mat., 174, L1-L4 (1997)

[8] J.Kovac, O.Dusa, M.Konc, T.Svec, P.Sovak., J. Magn. Magn. Mat. , 157/158, 197-198 (1996)

[9] R.Krishnan, M.Dancygier, M.Tarhouni., J.Appl.Phys.,63,7768 (1982)

[10] K.Inomata, M.Hasegawa, S.Shimanuki, IEEE. Trans.on Mag.Mag.17,3076 (1981)