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EFFECT OF PRESSURE ON THE CURIE TEMPERATURE OF Fe—Cr—B AND Fe—W—B AMORPHOUS ALLOYS[1])

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The effect of pressure (up to 0.6 GPa) on the Curie temperature T_c of $Fe_{73}Cr_{12}B_{15}$ and $Fe_{85-x}W_xB_{15}$ metallic glasses has been investigated. The large and negative shift of T_c under pressure was estimated. The absolute magnitude of the pressure shift of T_c decreases with increasing tungsten content. The obtained results are discused in terms of Wohlfarth's theory of itinerant ferromagnetism.

I. INTRODUCTION

It is well known that the Curie temperature T_c of the Fe—B amorphous alloys is very close to the crystallization temperature and also that the Curie temperature is easily affected by heating. The magnetic properties of these ferromagnetic alloys vary with the addition of a small amount of transition metals. It was concluded that the variations of the magnetic properties relate to changes in chemical short range order in these alloys. Additions of some elements (Mo, Nb, V, Cr i.e. in front of Fe in the periodic table) decrease the Curie temperature [1].

Since amorphous Fe-based alloys exhibited pronounced magneto-volume effects their magnetic properties have been studied under pressure. A large and negative pressure shift of T_c has been observed in these alloys, particularly in the alloys which exhibit the Invar-like behaviour [2, 3, 4].

In this work the pressure effect on the Curie temperature of $Fe_{73}Cr_{12}B_{15}$ and $Fe_{85-x}W_xB_{15}$ (where $x = 10, 8.1, 7$) metallic glasses is presented. Our results may be interpreted on the basis of the Wohlfarth theory of itinerant ferromagnetism. We could investigate the shift of T_c under pressure below the crystallization temperature because of the monotonic decrease of the Curie temperature with an increase of the chromium and the tungsten content.

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II. EXPERIMENTAL AND RESULTS

The amorphous $Fe_{73}Cr_{12}B_{15}$ and $Fe_{85-x}W_xB_{15}$ ribbons were prepared by the melt-spinning technique. The "as prepared" samples were used in pressure measurements. The Curie temperature was measured by the transformer method described in detail by Leger et al. [7]. The ribbons were wound into a ring and used as the cores of microtransformers. An ac current was kept constant in the primary coil and the secondary voltage, which is directly proportional to the initial permeability, was recorded as a function of temperture at various pressures. We determined the Curie temperature from the point of intersection obtained by extrapolation of the two broken lines as it can be seen in Fig. 1. The temperature was measured by a calibrated Cu-constantan thermocouple. Hydrostatic pressure (up to 0.6 GPa) was applied to the sample in the beryllium — bronze pressure cell filled with silicon oil. The pressure in the hydrostatic pressure cell was measured by a manganin sensor.

The decrease of T_c with the pressure is demonstrated by the temperature dependences of the secondary voltage of $Fe_{76.9}W_{8.1}B_{15}$ under different pressures plotted in Fig. 1. The linear decrease of T_c with the increase of the pressure was observed for all investigated glasses in the full pressure range.

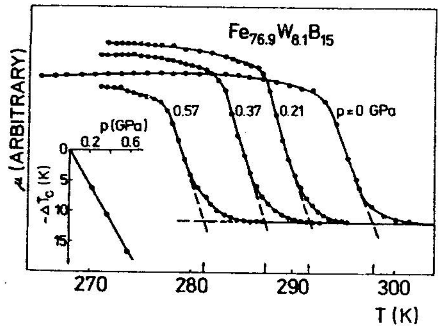

Fig. 1. Permeability vs temperature curves under various pressures for a $Fe_{76.9}W_{8.1}B_{15}$ metallic glass. The inset shows the shift of the Curie temperature as a function of the hydrostatic pressure.

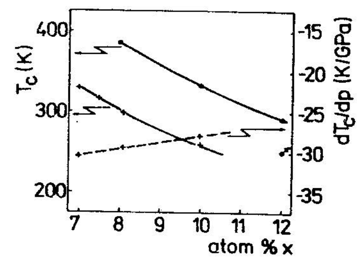

Fig. 2. The dependence of T_c and dT_c/dp on the Cr and W content for a $Fe_{73}Cr_{12}B_{15}$ glass ● and for $Fe_{85-x}W_xB_{15}$ glasses +.

The dependence of T_c and dT_c/dp on the Cr and W content in the $Fe_{85-x}M_xB_{15}$ metallic glasses (where M = Cr or W) is presented in Fig. 2 and is summarized in Table 1. The Curie temperature monotonically decreases with the increase of the M elements content. The greatest shift of T_c under pressure was observed in

Table I

$Fe_{85-x}W_xB_{15}$

x	T_c [K]	dT_c/dp [K GPa^{-1}]	α [K^2 GPa^{-1}]
7	330	−30.6	1.01×10^4
8.1	298	−29.5	0.88×10^4
10	257	−28	0.72×10^4

$Fe_{73}Cr_{12}B_{15}$

T_c [K]	dT_c/dp [K GPa^{-1}]	α [K^2 GPa^{-1}]
291	−29.7	0.87×10^4

the case of the $Fe_{78}W_7B_{15}$ glass. The absolute magnitude of the pressure shift of T_c decreases with increasing tungsten content. The parameter α exhibits the same behaviour (see Table 1).

III. DISCUSSION

A relation between the parameter dT_c/dp and the Curie temperature T_c, can be derived for the crystalline and amorphous alloys of the d-metals, by calculations within the band model of ferromagnetism. In the itinerant electron model the pressure effect on T_c, in the case of homogeneous Invar-like ferromagnets, is expressed by the following relation:

$$dT_c/dp = -\alpha/T_c, \qquad (1)$$

where α is a positive constant. For very inhomogeneous ferromagnetic alloys Wagner and Wohlfarth [5, 6] have derived the following relation:

$$dT_c/dp = -\chi_1 T_c + \chi_2 T_c^2 \qquad (2)$$

χ_1 and χ_2 are positive parameters. Such amorphous materials as Fe—B, Fe—Cr—B (high T_c) and Fe—Zr [6] obey relation (1). One the other hand such amorphous materials as Fe—Cr—B (low T_c), Fe—Ni—Zr [6] and Fe—Ni—Cr—Mo—Si—B [8] obey relation (2).

Our measurement of dT_c/dp in the $Fe_{73}Cr_{12}B_{15}$ glass is in good agreement with Fukamichi's [2] and Kamarád's [3, 4] results. A somewhat lower value of dT_c/dp may be caused by a higher boron content in our alloy. Kamarád [3] pointed out that the absolute value of dT_c/dp in these alloys decreases with an increase of the boron content.

Fig. 3 shows our results of $1/T_c\, dT_c/dp$ in the $Fe_{85-x}W_xB_{15}$ glasses. A least square fit yielded the values of χ_1 and χ_2.

Equation (2) was found to fit our $(1/T\, dT_c/dp)$ vs T_c curve quite well for the values of $\chi_1 = 0.16606$ GPa^{-1} and $\chi_2 = 2.232 \times 10^{-4}$ K^{-1} GPa^{-1}. From, this point of view these materials with a large and a negative value of dT_c/dp, can be regarded as inhomogeneous ferromagnetic materials.

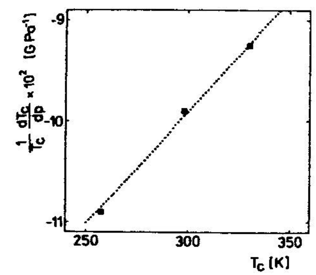

Fig. 3. $1/T_c\, dT_c/dp$ vs T_c for Fe_{85-x} glasses. The equation (2) was found to fit our $(1/T_c\, dT_c/dp)$ vs T_c curve quite well for the values $\chi = 0.166$ GPa^{-1} and $\chi_2 = 2.232 \times 10^4$ K^{-1} GPa^{-1}.

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ВЛИЯНИЕ ДАВЛЕНИЯ НА ТЕМПЕРАТУРУ КЮРИ АМОРФНЫХ СПЛАВОВ Fe—Cr—B И Fe—W—B

В работе исследуется влияние давления (вплоть до 0.6 GPa) на температуру Кюри T_c металлических стёкл $Fe_{73}Cr_{12}B_{15}$ и $Fe_{85-x}W_xB_{15}$. Был найдён большой отрицательный сдвиг T_c. Модуль величины сдвига T_c обусловленный давлением уменшается с увеличением содержания вольфрама в сплаве. Полученные результаты обсуждаются с точки зрения теории Вольфарта.