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The Effect of Pressure on the Curie Points of Fe-Ni-Cu and Fe-Ni-Mn Alloys

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There is a series of papers on the effect of pressure on the Curie points T_c of Fe alloys with other transition elements. For the Fe-Ni system it is stated (1 to 4) that in the Invar concentration range T_c greatly depends on pressure P, the magnitude $|dT_c/dP|$ increases with decreasing T_c. However, in binary alloys T_c is strongly related to the concentration of both components. In ternary alloys one can vary T_c keeping the concentration of one of the components constant.

The present paper deals with the elucidation of the question whether the magnitude dT_c/dP in alloys is basically determined by the value of T_c or by the Fe concentration. For this purpose three groups of ternary alloys $Fe_{66}(Ni_{1-x}Mn_x)_{34}$, $Fe_{66}(Ni_{1-x}Cu_x)_{34}$, and $Fe_{61}(Ni_{1-x}Cu_x)_{39}$ were investigated. The Ni-Mn and Ni-Cu concentrations were changed and the iron content remained constant. The alloys were prepared from electrolytic Ni, Cu, and Mn and carbonyl Fe by melting in argon atmosphere in an induction furnace. The melts were subjected to homogeneous annealing at T = 1100 °C for 6 h and subsequent quenching in water. All the samples excepting the alloy No. 12 (Table 1) were investigated at hydrostatic pressures up to 15 kbar. The pressure was measured by a manganin wire gauge with an accuracy of ±200 bar, the temperature by a chromel-alumel thermocouple with an accuracy of ±1.5 deg. Alloy No. 12 was investigated using AgCl as the pressure transmitting medium. In this case the pressure up to 20 kbar was determined with an accuracy of ±1 kbar. The Curie points were determined by the differential transformer method (3) using the temperature dependence of the initial magnetic permeability with an accuracy of ±3 deg. The alloys Fe-Ni-Cu as well as Fe-Ni-Mn had a disordered f.c.c. structure. The obtained magnitudes of T_c and dT_c/dP are summarised in Table 1. The Curie points of all the investigated alloys decrease when substituting Ni by Mn or Cu. The dependence of the Curie points on pressure is linear. For more convenient comparison of our data with recently published results, dT_c/dP of alloys

Table 1

No.	content (at%)			T_c (^oK)	$-dT_c/dP$ (deg kbar^{-1})
	Fe	Ni	Cu		
1		34	0	467	4.35 ± 0.1
2		31	3	433	4.55 ± 0.1
3	66	28	6	425	4.40 ± 0.1
4		25	9	382	4.50 ± 0.1
5		23.5	10.5	346	4.45 ± 0.1
6		39	0	576	3.25 ± 0.1
7		33	0	438	3.25 ± 0.1
8	61	30	9	501	3.35 ± 0.1
9		27	12	445	3.45 ± 0.1
	Fe	Ni	Mn		
10		32.5	1.5	402	5.0 ± 0.1
11	66	31	3	353	4.8 ± 0.15
12		28	6	190	3.4 ± 0.4

(Fig. 1, 2) is given as a function of T_c; a similar dependence for Fe-Ni alloys (4) is shown by a dashed line.

It is seen from Fig. 1 that dT_c/dP of $Fe_{66}(Ni_{1-x}Mn_x)_{34}$ alloys increases slightly at the beginning when Ni is substituted by Mn; at further increasing of the Mn content one can observe a small drop of this value. For the investigated $Fe_{66}(Ni_{1-x}Cu_x)_{34}$ and $Fe_{61}(Ni_{1-x}Cu_x)_{34}$ alloys (Fig. 2) dT_c/dP is nearly independent of T_c.

Let us pay attention to the following point of interest. In contrast to Fe-Ni binary alloys (4), where the Curie point is varied at the expense of changing the concentration of both components, in ternary Fe-Ni-Cu and Fe-Ni-Mn alloys it is changed at the expense of the alloying component ratio, the Fe concentration being constant.

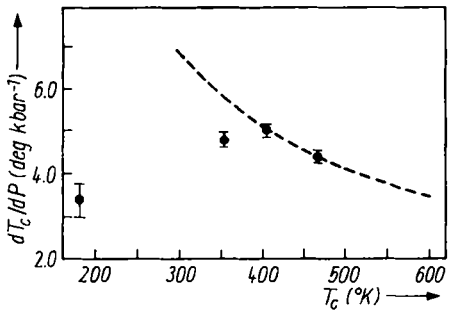

Fig. 1

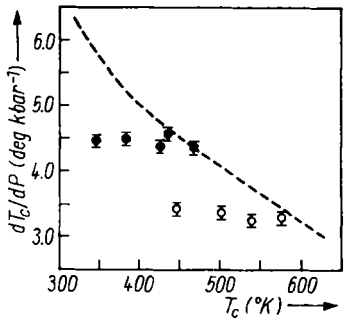

Fig. 2

Fig. 1. Dependence of dT_c/dP on T_c of $Fe_{66}(Ni_{1-x}Mn_x)_{34}$ alloys. The dashed line shows a similar dependence for Fe-Ni alloys (4)

Fig. 2. Dependence of dT_c/dP on T_c of Fe-Ni-Cu alloys; ● $Fe_{66}(Ni_{1-x}Cu_x)_{34}$, ○ $Fe_{61}(Ni_{1-x}Cu_x)_{39}$. The dashed line is for Fe-Ni alloys (4)

As it is seen in Fig. 1 and 2 in this case dT_c/dP either is nearly independent of T_c (Fe-Ni-Cu alloys) or weakly depends on T_c (Fe-Ni-Mn alloys). Thus, it is stated experimentally that the value of dT_c/dP depends basically on the iron concentration.

From the viewpoint of a collective electron ferromagnetism the Curie point and magnetization are determined by a sum curve of the electron density of states and by the value of the exchange interaction shifting sub-bands with spin directions (+) and (-). The fact that the displacement of T_c with pressure is principally controlled by the Fe concentration allows to suppose that from the summary density of states of our alloys the part concerning Fe may be separated. It is rather sensitive to the volume, depends very weakly on the Fe environment by other ions and gives rise to the observed high pressure effects.

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