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A. LOVAS
L. POTOCKÝ
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Hungarian Academy of Sciences

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A. Lovas, L. Potocký*, L. Novák*, É. Kisdi-Koszó,
K. Zámbó-Balla

Central Research Institute for Physics
H-1525 Budapest 114, P.O.B. 49, Hungary

*Institute of Experimental Physics, Slov. Acad. Sci, Košice,
Czechoslovakia

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АННОТАЦИЯ

Исследовались статическая коэрцитивная сила, намагниченность насыщения и температурная зависимость намагниченности в квази-эвтектических быстроохлажденных аморфных сплавах $Fe_{80}TM_3B_{17}$ /TM = 3d, 4d и 5d- переходные металлы/. Намагниченность насыщения, измеренная при комнатной температуре, показывает значительное изменение в зависимости от отношения электрон/атом. Коэрцитивная сила уменьшается под действием легирования TM, но зависит и от температуры быстроохлажденного расплава.

KIVONAT

A sztatikus koercitiv erős és a telitési mágnesezettséget, valamint a mágnesezettség hőmérséklet függését vizsgáltuk $Fe_{80}TM_3B_{17}$ kvázi-eutektikus, gyorshütéssel előállitott amorf ötvözeteken (TM = 3d, 4d és 5d átmeneti fémek). A szobahőmérsékleten mért telitési mágnesezettség jelentős változást mutat az elektron/atom arány függvényében. A koercitiv erő csökken a TM beötvözésének hatására, de függ a kvencselt olvadék hőmérsékletétől is.

ABSTRACT

The static coercive force, saturation magnetization at room temperature and the temperature dependence of magnetization have been measured on the $Fe_{80}TM_3B_{17}$ quasi-eutectic amorphous system /TM = 3d, 4d, 5d transition metals/. The influence of TM on saturation magnetization shows typical group-number effect. H_c of the as-quenched ribbons decreases with TM-additives but it also depends on the quenching temperature.

INTRODUCTION

It is thought that a small amount of another transition metal /TM/ added to iron-based amorphous alloys causes significant changes in their physical properties [1-3]. In view of this, alloying seems to be a powerful method to improve stability, corrosion resistance, as well as magnetic properties [4]. Consequently, systematic investigations in this field are highly important, particularly as far as the changes in Curie temperature /T_c^a/, coercive force /H_c/ and saturation magnetization /M_s/ are concerned. This influence can conveniently be investigated by thermomagnetic measurements [5-6].

In this paper the influence of substitution of Fe with TM /Ni, Co, Mn, Cr, V, Ti, Cu and some of the 4d and 5d elements/ on the temperature dependence of H_c, M_s, as well as on the Curie temperature and on the amorphous-crystalline transition has been studied in the eutectic alloy $Fe_{83}B_{17}$.

In all alloys the TM-content was 3 at% /disregarding the deviation caused by the alloying difficulties of reactive or volatile metals: V, T, Mn/.

EXPERIMENTAL

The preparation of alloys and ribbons have been described elsewhere [3, 5].

RESULTS AND DISCUSSION

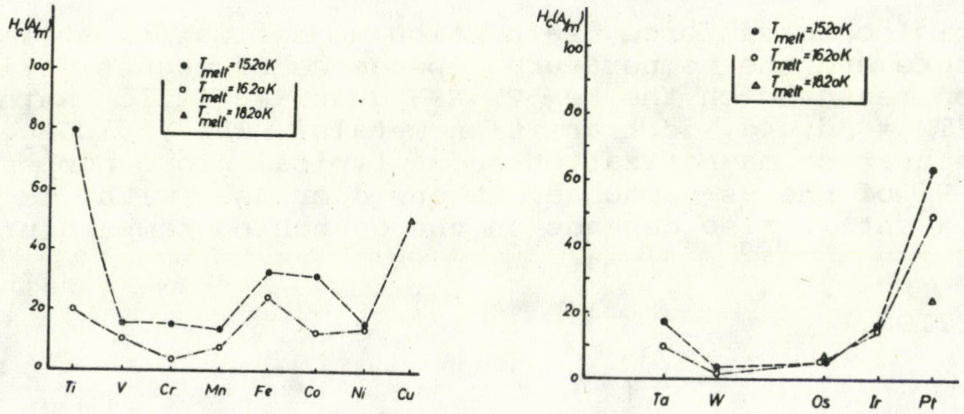

Fig. 1. The static H_c of the as-quenched $Fe_{80}TM_3B_{17}$ ribbons, quenched from different melt temperatures

<u>Coercive force of the as-quenched ribbons.</u> *Fig.1.* shows the static coercive force of the as-quenched ribbons for two different superheats of the melt /1520 and 1620 K/. H_c decreases with increasing superheat in most cases. This tendency confirms the earlier results obtained on binary $Fe_{83}B_{17}$ [7]. On the other hand, the alloying with TM-metals in most cases decreases H_c compared with the binary iron-boron alloy. With regard to the values of H_c after the quenching from 1520 K only three exceptions could be observed: Ti, Pt and Cu cause an increase /the later in spite of the high quenching temperature, 1720 K/. In the case of these alloys, the clustering or the tendency towards the two-phase nature of the melt is highly suspected. Of course, the origin of clustering in $Fe_{80}Ti_3B_{17}$ and $Fe_{80}Cu_3B_{17}$ is quite different.

The main tendencies which may lead to clustering are:

- the high affinity of TM-metal to boron /high heat of formation, ΔH of the borides/.
- Tendency of formation of intermetallic compounds.

The high ΔH of Ti-borides and the limited solubility of Ti in Fe may lead to the formation of /Ti-B/ rich clusters in the melt, forming simultaneously low boroncontent /Fe-B/ regions. The existence of clusters is confirmed by two observations: H_c falls with higher superheat of the melt. /Higher melt-temperature means more intensive miscibility between the components./ The existence of clusters with low boron-content are expected on the basis of the temperature dependence of the coercive force which indicates crystallization at low temperature /500 K/ in this alloy. The presence of the low boron content regions results in an anomalously low crystallization step in this alloy. Anomalous behaviour was found in $Fe_{80}Ti_3B_{17}$ also on measuring the saturation magnetization and with regard to the temperature coefficient of the electrical resistivity, too */Fig. 2./* [8].

As for the origin of clustering in $Fe_{80}Cu_3B_{17}$, probably the limited solubility of Cu in Fe has an important role. This alloy could not be quenched into the amorphous state from 1520 and 1620 K. at the roller-speed used. The nature of clustering in $Fe_{80}Pt_3B_{17}$ can be understood on the basis of

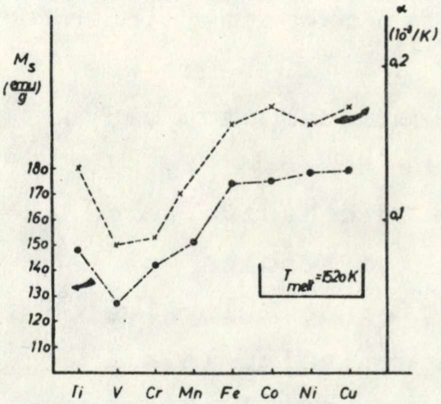

Fig. 2.
Saturation magnetization at room temperature and the temperature coefficient of resistivity as a function of the alloying 3d elements

the limited affinity of Pt to B and the good miscibility of Pt in Fe /Fe-Pt clusters with low boron content/.

Generally speaking, and supposing that coercive force is caused by the displacement of domain walls, its value can be expressed as

$$H_c = 4S\,\frac{\sqrt{A.K}}{M_s d}$$

where S is the constant taking into accout the surface roughness, and size and density of clusters. A is the exchange constant, K is the constant of the total anisotropy, M_s is the saturation magnetization and d is the sample thickness [9]. In *Fig. 3.* the $H_c dM_s$ products have been plotted for the as-quenched ribbons. The observed tendency is the same as in *Fig. 1.* This suggest that the role of strain-magnetostriction anisotropy, the change in ferromagnetic exchange and the possible clustering are highly pronounced. The strong influence

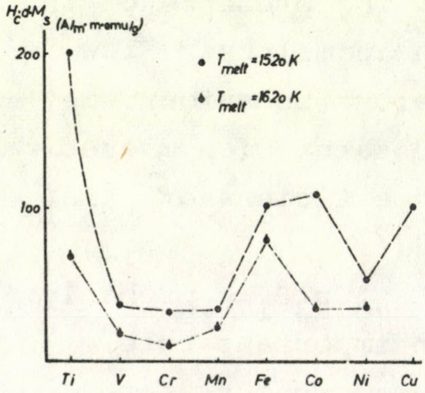

Fig. 3.
$H_c dM_s$ products for the as-quenched $Fe_{80}TM_{3/3d/}B_{17}$ metallic glasses

of ferromagnetic exchange and magnetostrictional anisotropy on the coercive force is also supported by the fact that the highest amorphous Curie-temperature was measured in $Fe_{80}Co_3B_{17}$. We also measured the saturation magnetostriction $/\lambda_s/$ of $Fe_{80}W_3B_{17}$, $Fe_{80}Co_3B_{17}$ and $Fe_{80}Pt_3B_{17}$ [10]. It was found that $\lambda_s/W/<\lambda_s/Co/<\lambda_s/Pt/$. Thus the same tendency can be obtained in the magnetostriction as in the H_c */see Fig. 1./*. The role of heat treatment on the change of coercive force has also been investigated. In *Fig. 4.* the results of isochronal annealing are plotted for two different alloys which were quenched from 1620 K and 1820 K respectively. In all cases H_c decreased showing the role of quenched-in stesses in the amorphous ribbons, however, the anomalous high value for $Fe_{80}Pt_3B_{17}$ remained high. This also supports the role of quenched-in clusters /clusters do not dissolve at such a low annealing temperature and their hindering effect to the displacement

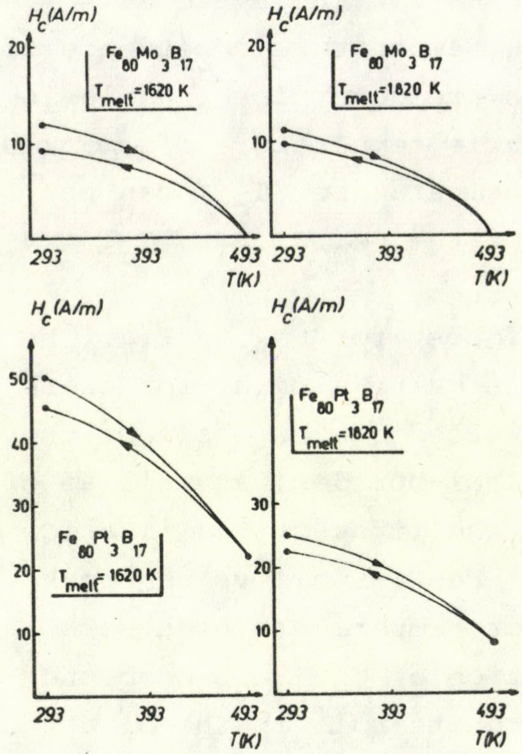

Fig. 4.
The effect of isochronal heat treatments on the H_c of $Fe_{80}Mo_3B_{17}$ and $Fe_{80}Pt_3B_{17}$ metallic glasses
(Heating rate 1.7 K/min)

of domain walls remains, while the increment coming from the quenched in stresses disappears during a low-temperature annealing/. If the anomalous high value of coercive force would arise from quenched-in stresses, the H_c of $Fe_{80}Pt_3B_{17}$ ribbons quenched from both temperatures would be nearly identical after the relaxation.

CHARACTERISTICS OF THERMOMAGNETIC CURVES

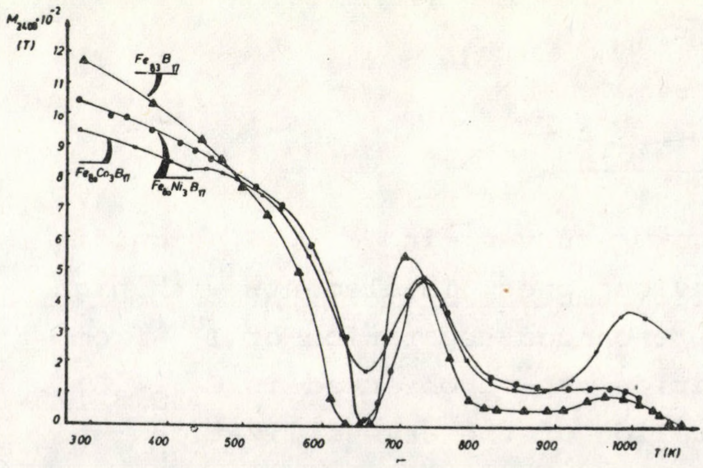

Fig. 5.
Thermomagnetic curves for $Fe_{83}B_{17}$, $Fe_{80}Co_3B_{17}$ and $Fe_{80}Ni_3B_{17}$ amorphous alloys.
Heating rate: 1.7 K/min

Fig. 5. shows the thermomagnetic curves for $Fe_{83}B_{17}$, $Fe_{80}Co_3B_{17}$ and $Fe_{80}Ni_3B_{17}$, resp. The magnetizations were measured in a constant field of 2400 A/m on the decreasing part of the hysteresis loop. From those curves and from the temperature dependence of H_c, the crystallization temperatures are determined. While in binary $Fe_{83}B_{17}$ and $Fe_{80}Ni_3B_{17}$ the Curie temperature of amorphous state /T_c^a/ and the crystallization temperature /T_{cr}/ can be clearly distinguished in the case of the $Fe_{80}Co_3B_{17}$, T_{cr} seems to be lower than T_c^a.

The Curie temperature is the highest for $Fe_{80}Co_3B_{17}$. The shape of the thermomagnetic curves is quite similar for these metallic glasses. This is well understood on the basis of the nearly equal stability of Fe, Co and Ni-borides, as well as of the nearly identic magnetization of the first crystallization products. It is interesting that for Fe-Ni-B alloys the peak on the thermomagnetic curve at higher temperature does not appear. It seems that the decomposition of the Fe_3B compound plays here a minor role as opposed to its role in the binary $Fe_{83}B_{17}$ alloys. It is possible that in this period of crystallization the precipitation of a Ni-rich phase can occur.

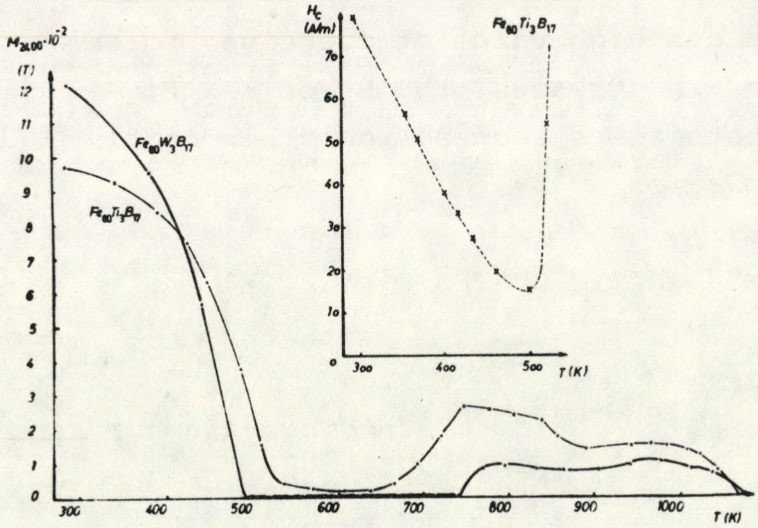

Fig. 6.
Thermomagnetic curves for $Fe_{80}W_3B_{17}$ and $Fe_{80}Ti_3B_{17}$ alloys. Insert: H_c versus the temperature.
Heating rate is the same as in Fig. 5.

The shape of the thermomagnetic curves in *Fig. 6.* significantly differs from the previous ones. TM-elements with high affinity to boron cause a pronounced separation of T_c^a from T_{cr}. Especially high separation can be observed in $Fe_{80}W_3B_{17}$. The relatively low magnetization of the crystallization products is also specific to these curves. The anomalous nature of $Fe_{80}Ti_3B_{17}$ is also obvious from the thermomagnetic curve. Although there is a significant difference between T_c^a and T_{cr}, the magnetization does not decrease to zero thereby showing that a small amount of the ferromagnetic phase is present. This ferromagnetic phase crystallizes at a very low temperature-as mentioned before.

If we compare the thermal stability and Curie temperature it can be stated in general that there is an inverse relation between the magnetic and thermal stability. Those TM-elements which raise the thermal stability lower the Curie temperature compared with the $Fe_{83}B_{17}$ eutectic alloy /*Fig. 7.*/.

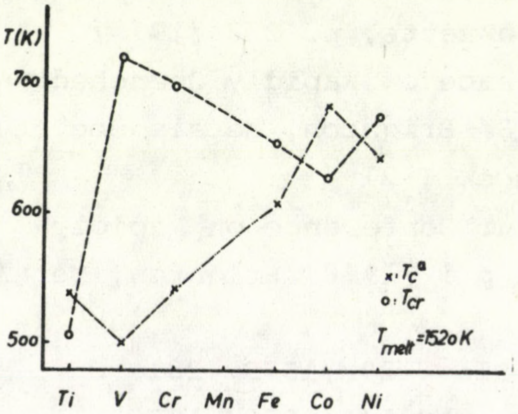

Fig. 7.
The change of Curie temperature and the temperature of crystallization due to the alloying with 3d transition metals

SUMMARY

Equiatomic /3 at%/ quantities of 3d, 4d, 5d transition metals added to the $Fe_{83}B_{17}$ eutectic amorphous alloy significantly change the magnetic porperties:

1./ The static coercive force of the as-quenched ribbons decreases except in $Fe_{80}Ti_3B_{17}$, $Fe_{80}Cu_3B_{17}$ and $Fe_{80}Pt_3B_{17}$. Saturation magnetization at room temperature is increased by those elements /Co, Ni/ which are to the right of iron in the periodic system, and decreased by Mn, Cr, V. The decrease seems to be proportional to the "relative valency" between iron and the alloying element in question. The magnetic behaviour of $Fe_{80}Ti_3B_{17}$ shows anomalies in T_{cr}, M_s and H_c. For the interpretation

of these properties the clustering tendency in the melt seems to be important, since this is connected with the affinity between the TM-element and boron.

2./ The properties are also influenced by technological parameters: H_c decreases with increasing temperature of the melt.

3./ Our results show that the influence of the alloying elements on the thermal stability and on T_c^a are opposite.

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Felelős kiadó: Tompa Kálmán
Szakmai lektor: Hargitai Csaba
Nyelvi lektor: Hargitai Csaba
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