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Optimisation of soft magnetic properties in $Fe_{83-X}Co_XNb_3B_{13}Cu_1$ (x=10, 30, 40) amorphous alloys

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Abstract: The new interesting soft magnetic alloys $Fe_{83-X}Co_XNb_3B_{13}Cu_1$ (x=10, 30, 40) were prepared by partial replacement iron by cobalt. The samples in state "as quenched" were obtained by melt-spinning techniques. After heat treatment, with the range of 473-973 K, the magnetic properties and structure of this alloy have been study. The magnetic properties (coercive force H_C, magnetic permeability μ, remanence B_R and saturation magnetisation B_S) of Fe-Co-Nb-B-Cu were carried out at room temperature. In this paper is showed how partial replacement of iron by cobalt has influence on magnetic properties.

Keywords: Soft magnetic alloys; Finemet type alloys; Magnetic properties

INTRODUCTION

Investigations on nanocrystalline materials started back in 1988 where Yoshizawa, Oguma and Jamauchi were the first researchers to obtain a nanocrystalline material from a metallic glass [1]. The nanocrystalline Finemet type alloys obtained by controlled crystallization of the amorphous samples due to their excellent softy magnetic properties are very attractive for application. Partial substitution of Fe by Co in nanocrystalline Finemet-type alloys is a way to extend their outstanding soft magnetic properties to elevated temperatures [4,6]. Their magnetic properties depend on chemical compositions and also are able to be optimised by applying a heat treatment in temperature ranges close to the crystallisation temperature [3,7]. The optimisation heat treatment depends on the atomic radius of the alloying additions. The aim of the present paper is to study the influence of alloying additions Co on magnetic properties, optimisation process of $Fe_{83-X}Co_XNb_3B_{13}Cu_1$ (x=10, 30, 40) amorphous alloys from the group of Finemet [5,8].

EXPERIMENT WORK

Experiments were carried out on following amorphous alloys – $Fe_{73}Co_{10}Nb_3B_{13}Cu_1$, $Fe_{53}Co_{30}Nb_3B_{13}Cu_1$, $Fe_{43}Co_{40}Nb_3B_{13}Cu_1$ obtained in the form of strips (thickness of about 25 μm) by the method of rapid cooling from liquid phase. In order to study the optimisation processes, all samples of the examined alloys were isothermally heat treatment within the temperature range of 473 – 793 K for 1 h in Ar protective atmosphere. The step of this treatment was of 50 K or 25 K when was expected the best magnetic permeability μ (denoted as annealing temperature T_a). Magnetic properties: coercive force H_C, magnetic permeability μ, remanence $B_{R,}$ saturation magnetisation B_S were measured at room temperature using the Maxwell – Wien bridge – working in a weak magnetic field (about 0.5 [A/m]) of frequency about 1 kHz and the VSM – Vibrating Sample Magnetometer.

DISCUSSIOMS OF RESULTS

It known that magnetic permeability is sensitive to small changes in microstructure of the magnetic material and specially on changes by partial replacement of iron by cobalt in Finemet [2]. Finemet modificated by cobalt was obtained as a samples in state "as quenched" by melt-spinning techniques. The magnetic measurements allowed defining magnetic permeability for samples of Finemet.

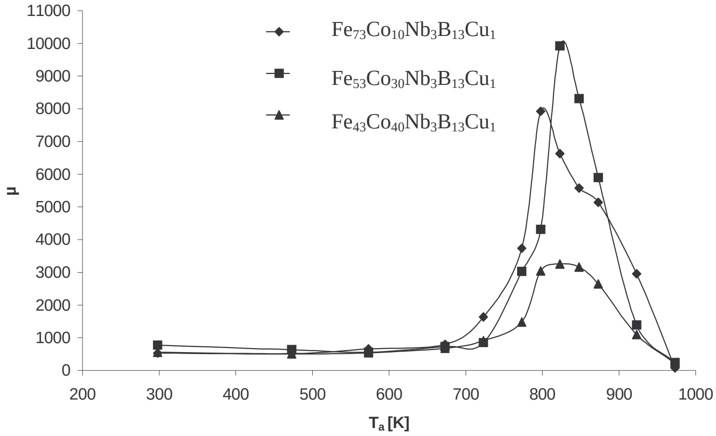

Figure 1. Magnetic permeability μ in function temperatures determined at room temperature (H=0.5 A/m) for samples after one-hour heat treatment

Table 1
Magnetic permeability for $Fe_{83-X}Co_XNb_3B_{13}Cu_1$ (x=10, 30, 40) amorphous alloy in state "as quenched" and after heat treatment

Samples in state „as quenched"	
Alloy	μ
$Fe_{73}Co_{10}Nb_3B_{13}Cu_1$	527
$Fe_{53}Co_{30}Nb_3B_{13}Cu_1$	770
$Fe_{43}Co_{40}Nb_3B_{13}Cu_1$	558
Samples after heat treatment	
Alloy	μ
$Fe_{73}Co_{10}Nb_3B_{13}Cu_1$	8000
$Fe_{53}Co_{30}Nb_3B_{13}Cu_1$	9900
$Fe_{43}Co_{40}Nb_3B_{13}Cu_1$	3250

Table 2
Relations between highest magnetic permeability μ and the optimal temperature T_{op} of heat treatment

Samples after heat treatment		
Alloy	μ	T_{op} [K]
$Fe_{73}Co_{10}Nb_3B_{13}Cu_1$	8000	798
$Fe_{53}Co_{30}Nb_3B_{13}Cu_1$	9900	823
$Fe_{43}Co_{40}Nb_3B_{13}Cu_1$	3250	823

For all examined alloys magnetic permeability passes by similar maximum. This fact indicates that application suitable one – hour heat treatment can optimised magnetic permeability of these alloys. The temperature T_{op} – the one-hour optimal temperature – corresponding to the maximum of magnetic permeability $\mu(T_a)$.

It is possible to determine the specific thermal treatment conditions causing an improvement of the magnetic properties. Generally magnetic permeability changes in third stages. In the first stage the structural relaxation takes place and the magnetic permeability μ is constant or slightly varies the annealing temperatures. For all alloys it is 300 – 700 K. In the second stage is observed high increase of the magnetic permeability and decrease of the coercivity field (H_C). As it is at in first stage so in second stage the temperatures are the same for all alloys 700 – 830 K [2,5]. In third stage the magnetic permeability decrease – initially slowly near the highest magnetic permeability and than decrease becomes very fast. The highest magnetic permeability from these three alloys is observed for $Fe_{53}Co_{30}Nb_3B_{13}Cu_1$ witch is μ at temperature T_a 823 K.

Using The VSM (Vibrating Sample Magnetometer) to investigation allows obtaining curves of hysteresis loop. Hysteresis loops for Finemet modified by cobalt defines magnetic properties as: H_C - coercive force, B_R – remanence and B_S – saturation magnetisation.

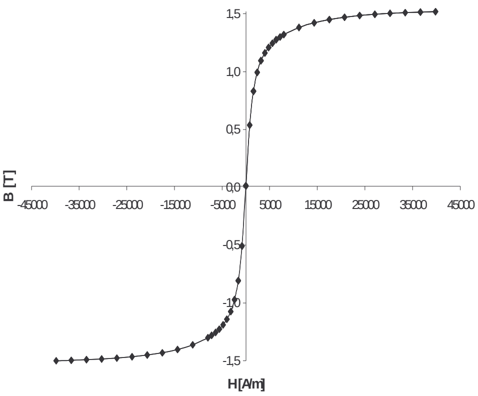

Figure 2. Hysteresis loop for $Fe_{73}Co_{10}Nb_3B_{13}Cu_1$ in temperature 798 [K]

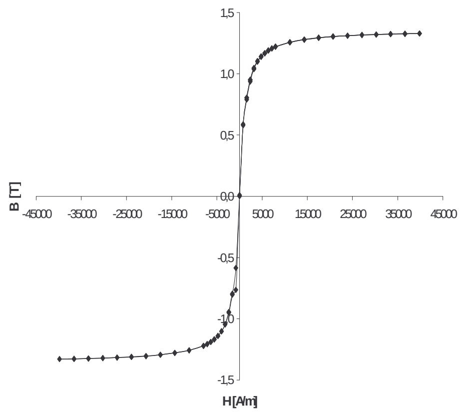

Figure 3. Hysteresis loop for $Fe_{53}Co_{30}Nb_3B_{13}Cu_1$ in temperature 823 [K]

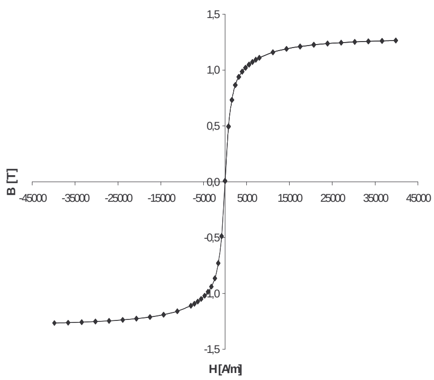

Figure 4. Hysteresis loop for $Fe_{43}Co_{40}Nb_3B_{13}Cu_1$ in temperature 823 [K]

Table 3.
Influence Co on Finemet presented by: H_C - coercive force, B_R – remanence and B_S – saturation magnetisation obtained from fig. 2 – 4

Samples in state „as quenched”				Samples after heat treatment			
Alloy	H_C [A/m]	B_R [T]	B_S [T]	Alloy	H_C [A/m]	B_R [T]	B_S [T]
$Fe_{73}Co_{10}Nb_3B_{13}Cu_1$	23.22	0.0072	1.31	$Fe_{73}Co_{10}Nb_3B_{13}Cu_1$	8.08	0.0053	1.51
$Fe_{53}Co_{30}Nb_3B_{13}Cu_1$	12.76	0.0081	1.29	$Fe_{53}Co_{30}Nb_3B_{13}Cu_1$	9.10	0.0079	1.32
$Fe_{43}Co_{40}Nb_3B_{13}Cu_1$	15.15	0.0088	1.13	$Fe_{43}Co_{40}Nb_3B_{13}Cu_1$	11.71	0.0073	1.26

Results obtained from hysteresis loops allow confirming that soft magnetic material has very good magnetic properties. Analysing the coercive force H_C of Finemet in state “as quenched” it is possible to see that $Fe_{53}Co_{30}Nb_3B_{13}Cu_1$ alloy has the most suitable value of coercive force H_C 12.76 [A/m] when B_R – remanence is 0.0081 [T] and B_S – saturation magnetisation is 1.29 [T] for this alloy. After heat treatment results of Finemet are changed and the best value of coercive force H_C 8.08 [A/m] is for $Fe_{73}Co_{10}Nb_3B_{13}Cu_1$ alloy. This alloy has also the best saturation magnetisation B_S from researched Finemet alloys. Generally $Fe_{53}Co_{30}Nb_3B_{13}Cu_1$ alloy in state “as quenched” has the best magnetic properties. The heat treatment caused improvement magnetic properties of Finemet and now the $Fe_{73}Co_{10}Nb_3B_{13}Cu_1$ alloy has the most suitable value of H_C.

CONCLUSION

This present paper explains in which way heat treatment improving magnetic properties and how partial replacement iron by cobalt in Finemet alloy has influence on magnetic properties. The optimal magnetic properties for Finemet are obtained after heat treatment and for following alloys are: $Fe_{73}Co_{10}Nb_3B_{13}Cu_1$ 798 [K], for $Fe_{53}Co_{30}Nb_3B_{13}Cu_1$ 823 [K] and for $Fe_{43}Co_{40}Nb_3B_{13}Cu_1$ 823 [K].

The main conclusions of the present study can be summarised as follows:

1. Improving soft magnetic properties for all researches alloys can be obtained by using suitable heat treatment,
2. It is observed meaningful increase magnetic permeability after heat treatment in relation to magnetic permeability in state “as quenched”,
3. Investigated alloys present very good magnetic permeability about H_C 10 [A/m] after heat treatment.

REFERENCES

1. Y. Yoshizawa, K. Yamauchi, Mater. Trans. JIM 31 (1990) 307.
2. Z. Stokłosa, J. Rasek, P. Kwapuliński, G. Haneczok, L. Pająk, Acta Physica Polonica A, (2002) 273-281.
3. Z. Stokłosa, P. Kwapuliński, G. Haneczok, J. Rasek, J. Phys. (1998) 51-54.
4. P. Kwapuliński, J. Rasek, Z. Stokłosa, G. Haneczok, Journal of Magnetism and Magnetic Materials, (2001) 218-226.
5. Z. Stokłosa, J. Rasek, P. Kwapuliński, G. Haneczok, G. Badura, J. Lelątko, Material Science of Engineering (2003), 49-53.
6. J. Zbroszczyk, J. Olszewski, W. Ciurzyński, B. Wysłocki, R. Kolano, A. Młyńczyk, M. Łukiewski, A. Kolano, J. Lelątko, Journal of Magnetism and Magnetic Materials, (2003) 513-515.
7. M. Hasiak, H. Fukunaga. W.H. Ciurzyńska, Y. Yamashiro, Scripta materials (2001) 1465-1469.
8. Kolano-Burian, J. Ference, T. Kulik, Material Science of Engineering (2004), 1078-1082.