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MAGNETIC AFTER-EFFECT IN AMORPHOUS FeNiNbCuSiB ALLOYS*

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An influence of the partial substitution of Fe by Ni on time-temperature stability of amorphous $Fe_{73.5-x}Ni_xNb_3Cu_1Si_{13.5}B_9$ (x = 0,5, 10, 15, 20, 25 at.%) alloys was investigated. Stability of the magnetic properties was observed by the magnetic after - effect (MAE) of the reluctivity which is represented by its relative change Δr/r between two fixed times after demagnetization. The relaxation spectra $\Delta r/r(T)$ at different Ni content were studied. The heights of peaks $\Delta r/r(T)$ are increasing at $x = 5$, 10 at.% in contrary to Ni concentrations $x = 20$, 25 at.%. The most probable activation energy for MAE was found to be $Q = 1.7$ eV.

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1 Introduction

The nanocrystalline alloys are produced by annealing of amorphous materials. Therefore their properties strongly depend on properties of amorphous alloys. Magnetic after-effect of the reluctivity $1/\chi$ (MAE) is a useful method to study amorphicity and stability of magnetic alloys. In our work we are dealing with the influence of Ni on MAE in amorphous materials. This research is a continuation of the study of magnetic properties of FeNiNbCuSiB [1, 2].

2 Experimental methods

The amorphous samples of the compositions $Fe_{73.5-x}Ni_xNb_3Cu_1Si_{13.5}B_9$ (x = 0, 5, 10, 15, 20, 25 at.%) were prepared in a ribbon form by a melt-spinning technique in He-atmosphere. The relative susceptibility χ/χ_0 and reluctivity $r = 1/\chi$ were measured using a resonance LC circuit with the field amplitude $H = 0.036$ A/m at a frequency of 1100 Hz. Demagnetization of the samples was performed with an alternative field at a frequency of 50 Hz during a time of 5 s. The dependence of the relative change of the reluctivity is defined as [3]: $\Delta r(t,T)/r =$

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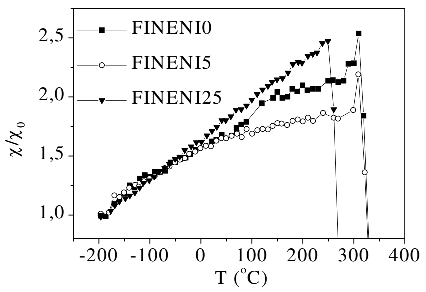

Fig.1:Dependence χ/χ_0(T) in the temperature range from -196^{o}C to T$_C$.

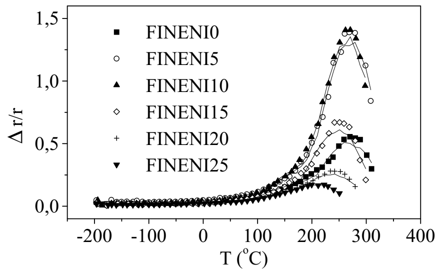

Fig.2: The relaxation spectra Δr/r(T) at Ni content x = 0, 5, 10, 15, 20, 25 at.%

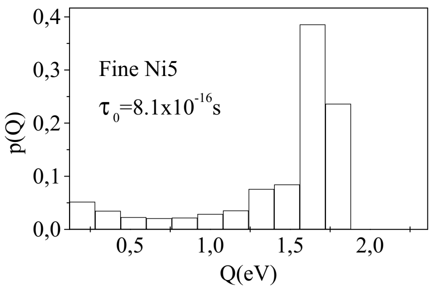

Fig.3: Example of the activation energies spectrum of amorphous $Fe_{68.5}Ni_5Nb_3Cu_1Si_{13.5}B_9$ alloy.

$[r(t_2) - r(t_1)]/r(t_1)$, where t_x are the times after demagnetization ($t_1 = 1$ s and t_2 = 180 s). The temperature dependences $\Delta r/r(T)$ were studied in the temperature range (-196°C - T_C).The values of Curie temperatures T_C change in the sequence 333°C, 337°C, 333°C, 313°C, 294°C, 263°C for x = 0, 5, 10, 15, 20 and 25 respectively. The micromagnetic model [4] was used for the computer analysis of the relaxation spectra. According to this model the dependence of the reluctivity should be expressed:

$$r(t,T) = r_0 + \Delta r. \int_0^\infty p(\tau)(1 - e^{-t/\tau}) d\tau, \tag{1}$$

where r_0 - unrelaxed reluctivity, Δr - the maximum change of the reluctivity, $p(\tau)$ - relaxation time distribution function, $\tau = \tau_0 \exp Q/kT$, τ_0 is a preexponencial factor, Q is an activation energy, k is the Boltzmann constant. Taking τ_0 as a constant, $p(Q)$ spectra were obtained by Wolfe method [5].

3 Results and discussion

Temperature dependences χ/χ_0(T) are shown in Fig. 1. Dependence $\chi/\chi_0(T)$ exhibit almost linear behavior for $x = 25$ at.%. Developments of dependences for 0 and 5 at.% are nonlinear what is due to the magnetic relaxation which consequently effects in MAE (Fig.2). Typical Hopkinson peaks were obtained for alloys with x=0, 5, 15. The Hopkinson peak was not observed for alloys with higher Ni content 20, 25 at.%.

The MAE in amorphous alloys is attributed to the reorientation of mobile atom pairs in regions of reduced mass density (so-called free volumes) [4]. In Fig.2 the relaxation spectra $\Delta r/r(T)$ at the different Ni content are compared. The peaks of dependences $\Delta r/r(T)$ which are connected with the thermal activation processes are appeared for FeNbCuSiB sample at about T_m=270^{o}C. At concentrations $x = 0$, 5, 10, 15 the positions of maxima are not varied. The Ni content $x = 20$, 25 shifts little bit these maxima to the lower values.

The presence of Ni changes magnitude of the MAE and for $x = 5$, 10 reaches the double values to the alloy without Ni. This results indicate that the substitution Fe by Ni favours the increase of the induced magnetic anisotropy in the alloy. On the other hand the high content of Ni in alloys helps magnetic stability to raise. For Ni concentration $x = 20$, 25 it was obtained that $\Delta r/r(T)$ are lower in contrary to the alloy without Ni.

The spectra of activation energies of the diffusion MAE were obtained by computer analysis. The most probable values of the activation energies was about 1.7 eV (Fig. 3). Addition of Ni doesn't influence value of Q but decrease the preexponencial factor τ_0. Ni doesn't alter the diffusion mechanism of MAE but increases the frequency at which the diffusional events take place. Since $\tau_0 = \tau_{00} \exp -S/R$, where S is an entropy and R is the universal gas constant and τ_{00} is a constant of the order of reciprocal of the Debye frequency ($\sim 10^{-13}$ s) [4], the lower τ_0 should be explained through the higher entropy of atom system when the Ni is added.

4 Conclusion

The substitution of Fe with Ni in the glassy and nanocrystalline systems FeNiNbCuSiB strongly influences theirs structural and magnetic properties.

The presence of Ni changes magnitude of the $\Delta r/r(T)$ and for $x = 5$, 10 they reach the double values to the alloy without Ni. On the other hand, for Ni concentrations $x = 20$, 25 it was obtained that values of $\Delta r/r(T)$ are lower.

The most probable value of the activation energies Q of the diffusion MAE was about 1.7 eV.

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