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DEPENDENCES OF THE ULTRASOUND VELOCITIES IN $Fe_{40}Ni_{40}B_6P_{14}$ METALLIC GLASSES ON MAGNETIC BIAS FIELD AND HEAT TREATMENT NEAR CRYSTALLIZATION TEMPERATURE

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Abstract - The ultrasound velocities at constant magnetic field and at constant magnetic induction for as-quenched state and after heat treatment were measured in the $Fe_{40}Ni_{40}B_6P_{14}$ metallic glasses. Observed changes are connected with ΔE effect.

1 - INTRODUCTION

The magnetostrictive metallic glasses, when heat treated above Curie temperature, exhibit very high magnetomechanical coupling and ΔE effect, e. g. [1-5] Fe-Ni-B-P metallic glasses are the soft magnetic materials with very low magnetic losses [6]. The saturation induction B_s of the $Fe_{40}Ni_{40}B_6P_{14}$ alloy is equal to 0.83 T and its Curie temperature reaches 250 °C but the saturation magnetostriction ($\lambda_s = 12 \times 10^{-6}$) is not so high as in iron-rich metallic glasses, e. g. [6]. Their magnetomechanical coupling coefficient k exhibits maximum value from 0.1 for as quenched state to 0.25 after annealing at 310°C [7]. From this reason the sound velocities changes should be also higher after annealing above Curie temperature.

2 - EXPERIMENTAL

Strip-shape samples were cut from the ribbon of the $Fe_{40}Ni_{40}B_6P_{14}$ metallic glass. There were 50 mm long and 4 mm wide. Their thickness was equal to about 25 μm. The ultrasound velocities at constant magnetic field (c_H) and at constant magnetic induction (c_B) were calculated from the resonant (f_r) and antiresonant (f_a) frequencies, respectively, i. e.

$$c_H \approx 2lf_r , \tag{1}$$

$$c_B \approx 2lf_a , \tag{2}$$

where l is the legth of the half-wave resonator, i. e. l = 50 mm. Three samples were measured for as-quenches state and after annealing for 1 h at the temperatures of 200, 230, 250, 310, 330, 350 and 360 °C. The amplitude of ac magnetic field was between 1 and 3 A/m and magnetic bias field H was changed from zero to 800 A/m. Measurements were carried out at two times higher fraquencies than the lower limit of the ultrasound range, i.e. at about 44 ± 6 kHz.

3 - RESULTS

The dependences of the ultrasound velocities at the constant magnetic fields (c_H) and at the constant magnetic induction (c_B) on the magnetic bias field (H) are presented in figures 1 and 2. The annealing were carried out to the temperature of 390 °C but the samples became polycrystals and results are given up to 360°C. In fig.1a, there are presented characteristics for the all three samples at the as-quenched state. Samples no. 1 and no. 2 were together anneled at the temperatures of 200 and 230 °C (fig. 1b). Starting from the Curie temperature each sample had its indiwidual programme. Sample no.3 was measured at as-quenched state and next after annealing at the temperature of 360 °C. The crystallization temperature was equal to 365 °C. Over the crystallization temperature the magnetomechanical coupling vanishes and the magnetostrictive resonance was not observed. The ultrasound velocity was changing from 3800 m/s to 4600 m/s depending on the magnetic polarization and anneling temperature.

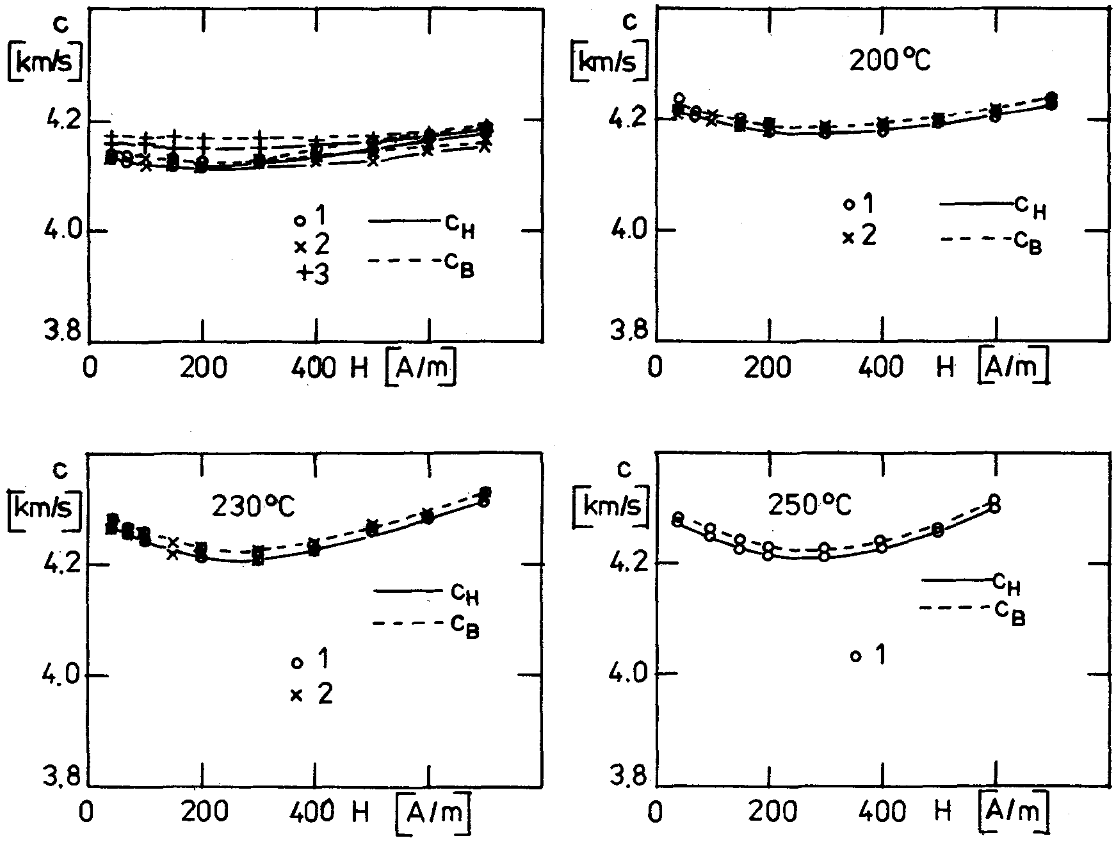

Fig. 1. Ultrasound velocities c_H and c_B versus magnetic bias field H for the as-quenched sample of metallic glass (a) and for the samples after annealing at 200 (b), 230 (c) and 250 °C (d).

4 - DISCUSSION AND CONCLUSIONS

Polycrystalline iron-nickel alloys , containing 45-50 wt. % Ni are middle-class piezomagnetic materials comparable with nickel, e.g. [8,9]. The same proportions of the iron and nickel, i.e. 1:1, used in metallic glasses give good results comparable or better than those of nickel [7-9]. The magnetomechanical coupling coefficient of this alloy after annealing at the temperatures higher than Curie temperature was higher then 0.25. But near crystallization temperature maximum value of the magnetomechanical coupling decrease and also ΔE effect, i.e. change of the Young's modulus E (or G) when material is magnetized from demagnetization state up to the magnetic saturation, is lower. That is the reason of the lower changes of the ultrasound velocities after annealing at these temperatures.

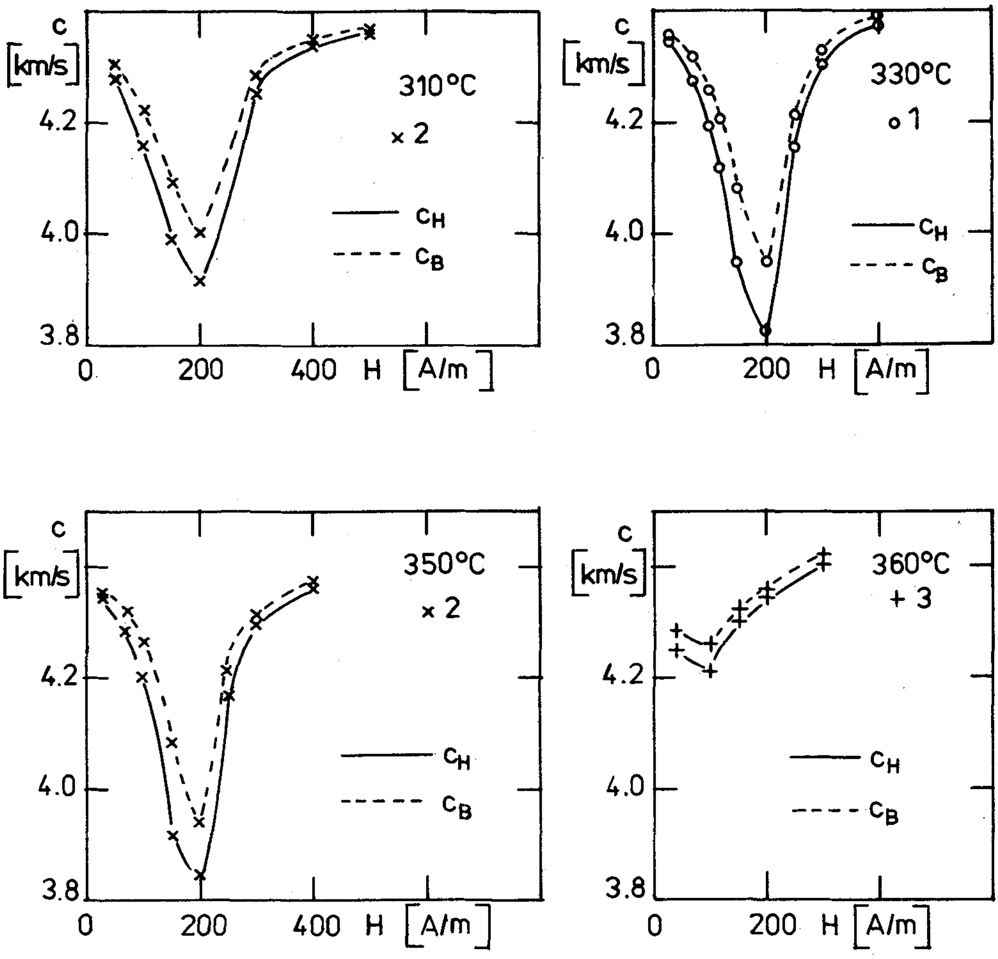

Fig. 2. Dependences of the ultrasound velocities c_H and c_B on magnetic bias field (H) for the samples annealed for 1 h at 310 (a), 330 (b), 350 (c) and 360 °C (d)

When magnetomechanical coupling vanishes ($k = 0$), sound velocities at the constant magnetic field and at the constant magnetic induction are equal each to other, i. e. for the demagnetization state $c_{Ho} = c_{Bo}$ and for the magnetic saturation $c_{Hs} = c_{Bs} = c$, where c is sound velocity calculated from the Young modulus E, i. e. $c = (E/\rho)^{1/2}$ (ρ is density and for the investigated metallic glass is equal to 7.5 Mg/m^3). When the magnetic domain structure vanishes the Hooke's law is valid. It means that strains are proportional to stresses and the proportionality constant is equal to the modulus E or to 1/E. Sound velocity is changing with magnetic field in almost all magnetic materials. Especially high variations are observed in the good piezomagnetic materials. Among them, the highest velocity changes occur in metallic glasses because these materials do not exhibit magnetocrystalline anisotropy. In the partially crystallized metallic glasses this phenomenon decreases (see results for the annealing at the temperature of 360 ^{o}C in fig. 2d).

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