Vol. 91 (1997) *ACTA PHYSICA POLONICA A* No. 2

Proceedings of the European Conference "Physics of Magnetism 96", Poznań 1996

PIEZOMAGNETIC DEPENDENCES ON MAGNETIC BIAS FIELD OF ANNEALED AT 450°C Fe–Cu–Nb–Si–B ALLOY

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Magnetic field dependences of the piezomagnetic dynamics, magnetomechanical coupling and elasticity moduli in the $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ alloy in an as-quenched state and annealed in vacuum for 1 h at 450°C were investigated. The maximum value of the magnetomechanical coupling coefficient was equal to 0.15 for the as-quenched state and 0.7 after annealing at 450°C. The changes of the elasticity moduli (ΔE effect) from about 60 to 180 GPa were observed after annealing at this temperature. These changes are connected with magnetostriction (equal to 25.8×10^{-6} at saturation), internal stresses, defects, mechanical, magnetic and heat treatment history.

PACS numbers: 75.80.+q, 75.60.Nt, 75.60.Ch

1. Introduction

The results of the piezomagnetic investigations of Fe–Cu–Nb–Si–B alloys with various composition after different heat treatment were previously presented, e.g. [1–5].

Now, the influence of annealing in vacuum for 1 h at 450°C on the magnetic field dependences of the piezomagnetic dynamics, magnetomechanical coupling and elasticity moduli in the Finemet type $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ strip was investigated.

2. Sample and measuring methods

The characteristics of the piezomagnetic dynamics, magnetomechanical coupling and elasticity moduli as a function of magnetic bias field were investigated.

These dependences were obtained using the resonant-antiresonant method [6] (Figs. 1 and 2). The amplitude of the exciting field was equal to about 1 A/m.

The 20 mm wide and about 23 μm thick amorphous tape was cut, using the hack-saw with the diamond blade, in three 6 mm wide ribbons and next from these ribbons the 60 mm long strips were cut out.

3. Results and discussion

The results for the sample cut out from the central ribbon for an as-quenched state and after annealing in vacuum for 1 h at the temperature of 450°C are presented in Figs. 1–3. The moduli of elasticity for the strips cut from the left ribbon were previously presented [5].

The piezomagnetic dynamics, which may be measured as a difference between maximum and minimum impedance (Figs. 1 and 2), reached a maximum two times higher after annealing than that for the as-quenched state. These maxima occurred at 50 A/m after annealing while for the as-quenched state the optimum bias field was equal 250–500 A/m (Fig. 2).

The maximum value of the magnetomechanical coupling coefficient [6–10] was equal to 0.15 for the as-quenched state and 0.7 after annealing at 450°C. The samples in the both cases were in amorphous phase. The maximum values of k coefficient received for $Fe_{73.5}Cu_1Nb_3Si_{16.5}B_6$ strips annealed in transverse

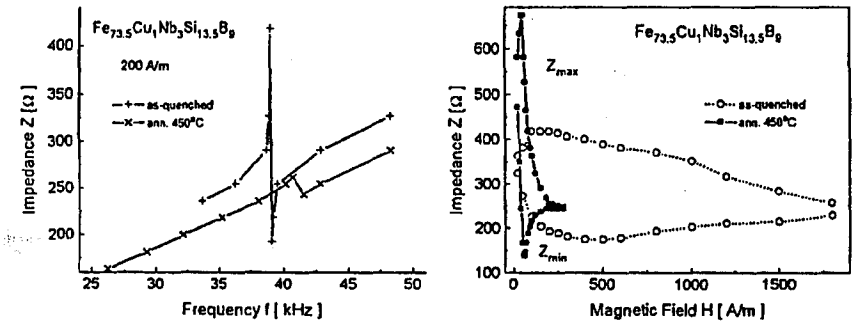

Fig. 1. Impedance (Z) vs. frequency (f) and maximum and minimum values of Z, i.e. Z_{max} and Z_{min}, vs. magnetic bias field (H) for the as-quenched sample and after annealing for 1 h in vacuum at 450°C.

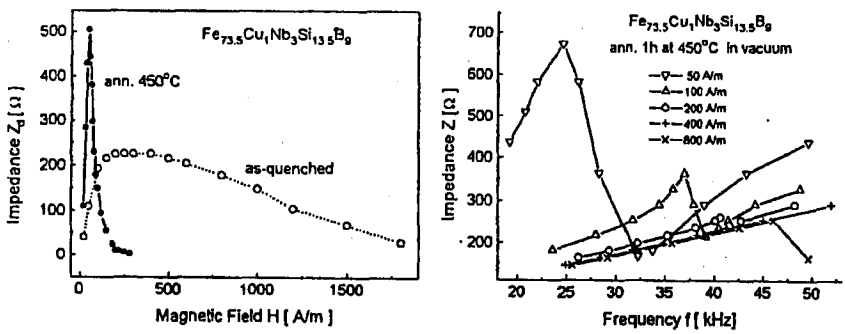

Fig. 2. Dynamical impedance $Z_d = Z_{max} - Z_{min}$ vs. magnetic bias polarization for the as-quenched sample and after annealing for 1 h in vacuum at 450°C and impedance Z vs. frequency for different magnetic bias field from 50 to 800 A/m.

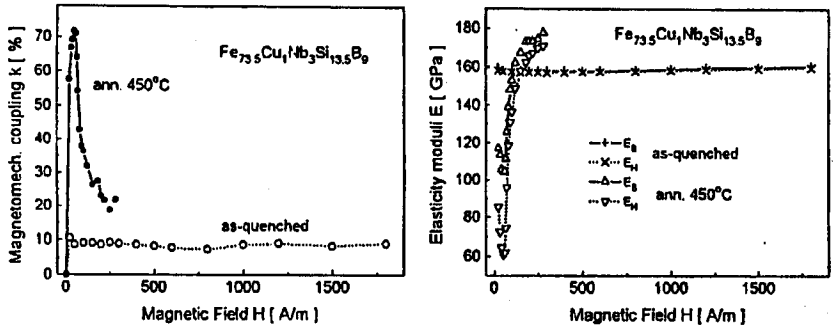

Fig. 3. Magnetomechanical coupling coefficient and elasticity moduli (E_H and E_B) vs. magnetic field (H) of the $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ as-quenched strip and annealed in vacuum for 1 h at the temperature of 450°C.

magnetic field (400 kA/m) for 1 h at 460°C in air were equal to 0.59 [2] and annealed in helium atmosphere in the temperature range from 490 to 600°C for 5 minutes were equal to 0.64 after annealing at 510°C [7].

The changes of the elasticity moduli (ΔE effect) [8–13] were observed from about 155 to 160 GPa for the as-quenched state and from 60 to 180 GPa after annealing at 450°C. The $\Delta E/E = (E_s - E_{H\min})/E_s$ was equal to 0.67 what is comparable with the value 0.65 received for ΔE in the sample cut from the left ribbon and annealed at 450°C in vacuum for one hour [5] together with the sample now investigated.

These extreme values (maximum of k coefficient and minima of E moduli at constant magnetic field, i.e. E_H, and at constant magnetic induction, i.e. E_B) were observed at the same magnetic bias fields (Fig. 3) as in the case of the piezomagnetic dynamics (Fig. 2).

The saturation magnetostriction was equal to 24×10^{-6} for the as-quenched state and 25.8×10^{-6} after annealing at 450°C.

4. Conclusions

The improvement of piezomagnetic properties is connected with reducing of the internal stresses (introduced during production and cutting) in the amorphous alloy after annealing at 450°C, i.e. above Curie temperature (about 320°C). But the defects, and the mechanical, magnetic and heat treatment histories have still an influence on the magnetic, piezomagnetic and mechanical properties of the magnetostrictive materials.

The maximum value of the magnetomechanical coupling coefficient equal to 0.7 is the record result obtained for the Finemet type alloy before nanocrystallization.

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