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THE MAGNETIC PROPERTIES AND THE BARKHAUSEN NOISE OF THE ANNEALED Fe–V–B AMORPHOUS ALLOY

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As a consequence of the annealing process, the study of structural changes which can be followed by measuring structure sensitive magnetic properties as the stress induced anisotropy, the coercive force, the demagnetizing factor, and the Barkhausen noise parameters of the as-cast and annealed $Fe_{80}V_5B_{15}$ amorphous alloys was performed. The structural changes were connected with the temperature range where the $Fe_{80}V_5B_{15}$ amorphous alloy was characterized by the soft magnetic properties.

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1. Experimental method

Samples of the $Fe_{80}V_5B_{15}$ amorphous alloy were prepared by the spinning wheel technique in a form of the 10 mm wide and 20 μm thick ribbons. The 150 mm long samples were isothermally annealed in argon protective atmosphere for 1 hour at the 5 deg/min cooling rate.

The measured magnetic parameters were [1–3]: the whole quasi-static hysteresis curve and the anhysteresis curve from which the values of the saturation and remanent magnetic polarization, J_s and J_r, respectively, the coercive force, H_c, the total and stress induced anisotropy energy, K_i and K_σ [4], respectively, the total demagnetizing factor, D, as a sum of the inner and geometrical demagnetizing factor, D_i and D_g, respectively, were evaluated. D_g was calculated from the sample geometry [4], $D_g = 14.166 \times 10^{-5}$.

The measured Barkhausen noise parameters were [5]: the number of the Barkhausen pulses (BP) per a volume unit, n, registered during the magnetization process along one branch of the hysteresis loop, the total number of the BP per a volume unit, N, which represents the n measured after the magnetization process, the power spectrum, $S(f)$, and the relative amplitude distribution of the BP, N_U/N, where the amplitude distribution, N_U, represents the number of the BP of the U size per a volume unit, $N_U = \partial N/\partial U$. Using a single-layer pick-up coil of 100 turns and 10 mm length, the BP amplifying was 15000× at which the output noise of the equipment used for the BP measurement was about 118 mV (Fig. 7).

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2. Results and discussion

The annealing process of metal alloys is connected with the relaxation process characterized by an inner stress decrease and the precipitation processes which could be generally attributed to low and high values of annealing temperature, respectively. In the case of amorphous alloys, the precipitation process is represented by the amorphous structure crystallization which could be usually preceded by forming areas whose different concentrations of atoms of elements are suitable for crystallization of individual phases [6, 7].

Figures 1–3 show H_c, K_i, K_σ, D, J_s, J_r courses as functions of annealing temperature. The relaxation process expressive influence which can be perhaps observed in the temperature range to about 250°C was a reason of the inner stress reduction causing the concave decrease in the magnetic parameters. The changes of the concave course to the convex course at about 250°C could perhaps indicate the presence of the concentration-suitable areas in the amorphous structure. The rapid increase in H_c, K_i, J_r could be connected with the crystallization process forming crystalline grains within these areas [6, 7]. The $K_i - K_\sigma$ difference in the temperature range to about 400°C is constant and small, so it could be concluded that K_i was mainly of the origin of K_σ [1]. The K_i increase above 400°C could be a consequence of the crystalline lattice anisotropy [4]. On the other hand, the

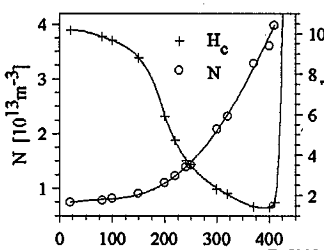


Fig. 1

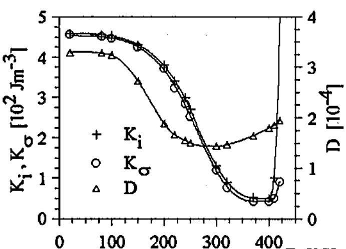


Fig. 2

Fig. 1. The coercive force, H_c, and the total number of the BP per a volume unit, N, vs. annealing temperature.

Fig. 2. The total and stress induced anisoptropy energy, K_i and K_σ, respectively, and D vs. annealing temperature.

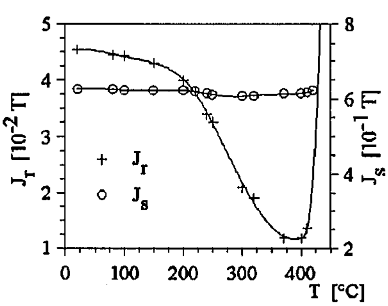
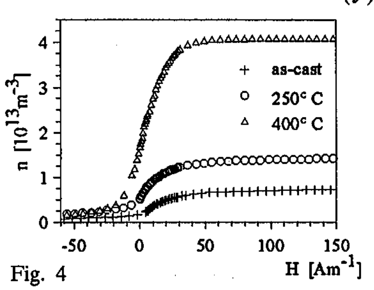


Fig. 3. The saturation and remanent magnetic polarization, J_s and J_r, respectively, vs. annealing temperature.

K_σ increase above 400°C could be probably caused by the presence of crystalline lattice defects which increase the inner stress [4]. The J_r parameter is connected with the determination of K_i, K_σ and therefore the J_r course is qualitatively similar to the courses of K_i, K_σ [1–4]. The values of H_c, K_i, K_σ, J_r at 420°C are 794 A m^{-1}, 541 J m^{-3}, 91 J m^{-3}, 0.6 T, respectively.

Modifying the Fe–V–B structure by annealing, D_g was unchanged, so the D change was only due to the D_i change [2, 3]. D_i is given by the demagnetizing field due to magnetic inhomogeneities inside the material, e.g. non-magnetic inclusions or clusters [2–4]. The D decrease in the temperature range to about 250°C could then indicate that in the Fe–V–B structure there were weakly coupled clusters of the Fe, V, B atoms [3, 8]. During the structural relaxation the weakly coupled clusters could be probably destroyed, so it could lead to a more homogeneous amorphous structure reflected by the D decrease [3, 8]. The D increase above about 250°C could be perhaps attributed to the process of forming of the concentration-suitable areas and the crystallization process.

Figure 4 shows the courses of n during the magnetization process for the as-cast and annealed states. The external magnetic field intensity, H, was the linear function of time, so n was also time-dependent which means that $dn/dt \approx dn/dH$. $S(f)$ (Fig. 5), $S(f) \approx dn/dt$ [5, 9], was always registered at the external field intensity equal to the sample coercive force. The expressionless differences of the n gradient at $H = H_c$ for the measured sample states were then responsible for the expressionless differences of the $S(f)$ intensity [5, 9].



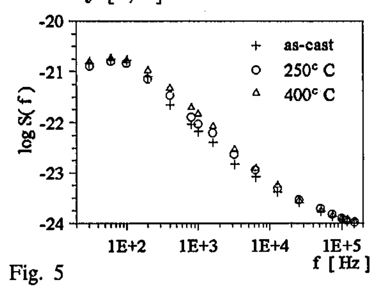
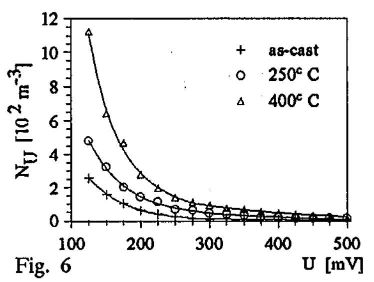


Fig. 4. The number of the Barkhausen pulses per a volume unit, n.
Fig. 5. The Barkhausen noise power spectrum, $S(f)$.



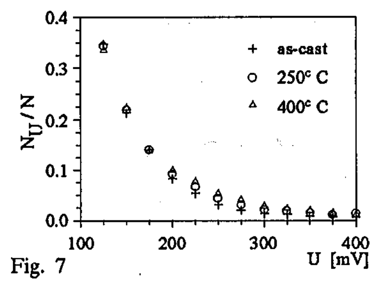


Fig. 6. The amplitude distribution of BP, N_U.
Fig. 7. The relative amplitude distribution of BP, N_U/N.

The Barkhausen noise of the annealed samples was given by the increasing total number of BP per a volume unit, N (Fig. 1), the increasing amplitude distribution of BP, N_U (Fig. 6), and the increasing rate of BP, N_U/N, in the 175–400 mV range (Fig. 7) as a consequence of the annealing temperature increase. The increasing rate could be attributed to the increasing intensity of $S(f)$ in the 0.2–25 kHz frequency range (Fig. 5) [5, 9]. BP of the size below 175 mV and above 400 mV kept their rate in the Barkhausen noise constant which could be probably connected with the $S(f)$ course in the frequency range below 0.2 kHz and above 25 kHz, respectively [5, 9].

Acknowledgments

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References

[1] L. Novák, É. Kisdi-Koszó, A. Stančáková, L. Kafková, M. Konč, *Key Eng. Mater.* **81-83**, 337 (1993).

[2] L. Novák, É. Kisdi-Koszó, P. Duhaj, *Rap. Quench. & Metast. Mat.*, suppl. 216 (1996).

[3] L. Novák, É. Kisdi-Koszó, M. Konč, M. Zatroch, *J. Magn. Magn. Mater.* **160**, 261 (1996).

[4] E. Kneller, *Ferromagnetismus*, 2nd ed., Springer-Verlag, Berlin 1962, p. 363.

[5] L. Ceniga, K. Šterbáková, L. Novák, M. Zentková, *Czech. J. Phys.* **49**; 549 (1999).

[6] L. Potocký, V. Karel, É. Kisdi-Koszó, L. Novák, S. Longauer, in: *Conf. on Metallic Glasses*, Eds. C. Hargitai, I. Bakoni T. Kemény, Vol. 2, Science and Technology, Budapest 1980, p. 319.

[7] L. Ceniga, L. Novák, E. Kisdi-Koszo, *J. Magn. Magn. Mater.* **196-197**, 154 (1999).

[8] T. Kaneko, K. Shirakawa, S. Abe, T. Masumoto, *J. Magn. Magn. Mater.* **54-57**, 305 (1986).

[9] M. Zentková, M. Datko, *Czech. J. Phys. B* **24**, 310 (1974).