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THE MAGNETIC PROPERTIES AND THE BARKHAUSEN NOISE OF THE HYDROGENATED Fe-V-B AMORPHOUS ALLOY

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As a consequence of the hydrogenation-dehydrogenation process, in the present paper the study of structural changes which could 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 hydrogenated Fe₈₀V₅B₁₅ amorphous alloys is performed.

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1. Experimental method

A sample of the Fe₈₀V₅B₁₅ amorphous alloy was prepared by the spinning wheel technique in a form of the 10 mm wide and 20 μ m thick ribbon. The 150 mm long sample was hydrogenated electrolytically at room temperature for 2 hours [1, 2]. The sample dehydrogenation was effected spontaneously in air at room temperature. The first series of measurements began with a measurement of magnetic parameters [1, 2] and Barkhausen noise parameters [3] in the as-cast state and then the sample was hydrogenated. The hydrogenation time is given in Figs. 1–3 and 6 as negative time on the time axis. The magnetic parameters were then measured at the interval of 30 minutes during 20 hours.

The measured magnetic parameters were: 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 [1, 2], respectively, the total demagnetizing factor, D , as a sum of the inner and geometrical demagnetizing factor, D_i and D_g [2], respectively, were evaluated. D_g was calculated from the sample geometry [2], $D_g = 14.166 \times 10^{-5}$.

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The measured Barkhausen noise parameters were: the number of the Barkhausen pulses (BP) per a volume unit, n , which were 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, $S(f)$ [3], and the relative amplitude distribution of BP, N_U/N , where N_U represents the number of BP of the size U per a volume unit, $N_U = \partial N / \partial U$. Using a single-layer pick-up coil of 100 turns and 10 mm length, BP amplifying was $15000\times$ at which the output noise of the equipment used for the BP measurement was about 118 mV (Fig. 7) [3].

2. Results and discussion

Hydrogen atoms which occupy Bernal's holes in the amorphous matrix [1] and increase inner stress are causing the rapid increase in H_c , K_i , K_σ , J_s , J_r (Figs. 1–3) [1, 2]. The chemical components of the $\text{Fe}_{80}\text{V}_5\text{B}_{15}$ sample have not had a high affinity to the hydrogen atoms which then could move in the sample and could escape of the sample easily [1, 2]. It could be then postulated that most of the hydrogen atoms left the sample at room temperature during 20 hours (Fig. 1–3) [1, 2]. The decreasing hydrogen content was then a reason of the magnetic parameters decrease [1, 2].

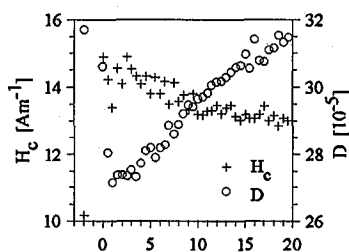


Fig. 1 Dehydrogenation time [h]

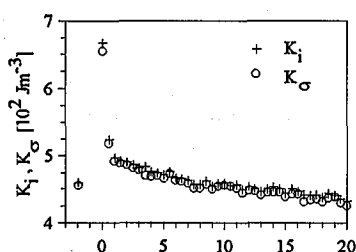


Fig. 2 Dehydrogenation time [h]

Fig. 1. The coercive force, H_c , and the total demagnetizing factor, D , vs. dehydrogenation time.

Fig. 2. The total and stress induced anisotropy energy, K_i and K_σ , respectively, vs. dehydrogenation time.

After 20 hours of dehydrogenation H_c and J_s reached higher values than before hydrogenation. This fact could indicate that either the hydrogen atoms caused some defects remained in the structure during and after dehydrogenation, e.g. microcracks [3], or the rest of the hydrogen atoms remained in the sample even after 20 hours of dehydrogenation [1, 2]. The $K_i - K_\sigma$ difference was almost constant and small, so it could be concluded that K_i was mainly of the origin of K_σ [1]. The small irreversible decrease in K_i , K_σ , J_r after 20 hours of dehydrogenation could correspond to the relaxation-like effect [1].

The course of D during the hydrogen absorption and desorption processes is shown in Fig. 1. Modifying the Fe–V–B structure by hydrogenation, D_g was unchanged, so the D change was only due to the D_i change [2]. D_i is given by

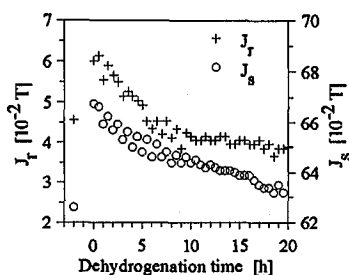


Fig. 3. The saturation and remanent magnetic polarization, J_s and J_r , respectively, vs. dehydrogenation time.

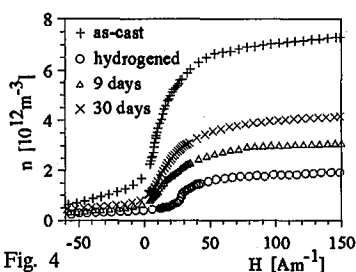


Fig. 4

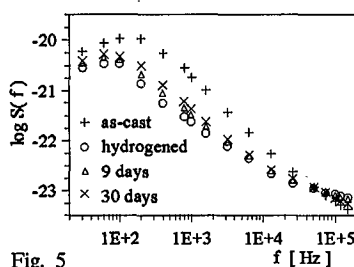


Fig. 5

Fig. 4. The number of the Barkhausen pulses per a volume unit, n .

Fig. 5. The Barkhausen noise power spectrum, $S(f)$.

the demagnetizing field due to magnetic inhomogeneities inside the material, e.g. non-magnetic inclusions or cluster [2]. The D decrease observed immediately after hydrogenation could then indicate that in the Fe–V–B structure there were weakly coupled γ_1 -like antiferromagnetic clusters of the Fe atoms [2]. The γ_1 -like antiferromagnetic clusters transformed to the γ_2 -like ferromagnetic clusters (J_s increases and D decreases) [2, 4]. This could be caused by changes of distances between the Fe atoms of the clusters as a consequence of the inner stress increase [2, 4]. During dehydrogenation the γ_1 -like antiferromagnetic clusters were probably reformed which could be indicated by the D decrease [2]. The parameters shown in Figs. 1–3 were measured every day during 30 days of dehydrogenation but no rapid changes of their courses were observed.

Figure 4 shows the courses of n during the magnetization process for the as-cast and hydrogenated states of the sample and after 9 and 30 days of dehydrogenation. 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), $S(f) \approx dn/dt$ [32], has been always registered at the external field intensity being equal to the sample coercive force. The differences of the n gradient at $H = H_c$ for the measured sample states were then responsible for the expressive differences of the $S(f)$ intensity [3].

The course of N/N_{ac} during dehydrogenation is shown in Fig. 6 for the as-cast sample $N_{ac} = 0.74 \times 10^{13} \text{ m}^{-3}$ and the course of the relative amplitude distribution

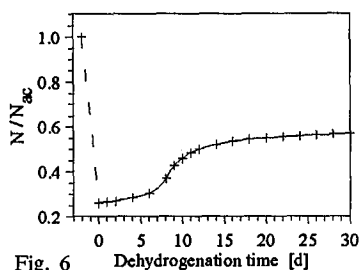


Fig. 6

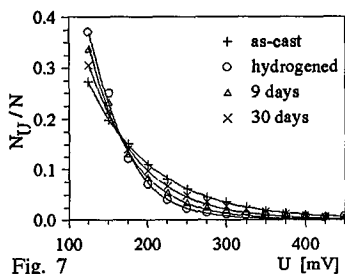


Fig. 7

Fig. 6. The N/N_{ac} parameter vs. dehydrogenation time.

Fig. 7. The relative amplitude distribution of the Barkhausen pulses, N_U/N .

of BP, N_U/N , is shown in Fig. 7. The Barkhausen noise of the hydrogenated sample was given by a higher rate and a smaller rate of low and middle BP (Fig. 7), respectively. The higher rate and the smaller rate could correspond to the more convex course of $S(f)$ in the 0.2–50 kHz frequency range and the $S(f)$ increase above 50 kHz for the hydrogenated sample (Fig. 5), respectively [3]. BP of about 175 mV kept their rate in the Barkhausen noise constant which could be probably connected with the $S(f)$ course at 50 kHz [3].

n , $S(f)$, N/N_{ac} , and N_U/N changed rapidly after hydrogenation as a consequence of the inner stress increase but the time delay of this parameters reaction to dehydrogenation is observed. After the inner stress reduction during 20 hours of dehydrogenation, the rest of the hydrogen atoms could be probably more stabilized in the amorphous matrix and in the microcracks which perhaps rose by hydrogenation [3]. This stabilization could explain almost constant course of n , $S(f)$, N/N_{ac} , N_U , and N_U/N up to 6–7 days after hydrogenation. The expressive changes of these parameters after 6–7 days could be perhaps caused by a more intensive dehydrogenation although no expressive changes of the magnetic parameters shown in Figs. 1–3 were observed. This contradiction has not been probably published so far, and then it would require a much more detailed research. The presence of the hydrogen atoms rest [1, 2] and perhaps the microcracks [3] could be responsible for the irreversible changes of n , $S(f)$, N/N_{ac} , N_U , and N_U/N observed even after 30 days of dehydrogenation.

Acknowledgments

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