

MAGNETIC PROPERTIES OF HYDROGENATED Fe₈₅B₁₅ AMORPHOUS ALLOY

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SUMMARY

Internal stresses of the Fe₈₅B₁₅ amorphous alloy during hydrogenation-dehydrogenation process are investigated by measurements of the energy of the total and stress induced anisotropy, the coercivity, the demagnetization factor, and the Barkhausen noise parameters.

Keywords: *internal stress, hydrogenation, amorphous alloy, magnetism.*

1. INTRODUCTION

Amorphous alloys prepared by rapid quenching can be characterized by excellent soft magnetic properties. Qualitative analysis of changes of the internal stresses and their fluctuations, and the presence of the clustered structure of the Fe₈₅B₁₅ amorphous alloy can be performed by the measurements of the stress-sensitive magnetic quantities, representing the magnetization curve parameters, and Barkhausen noise ones.

2. EXPERIMENTAL

The sample of the Fe₈₅B₁₅ amorphous alloy was prepared by planar flow casting technique in a form of the 10 mm wide and 20 μm thick ribbons. The 150 mm long as-cast samples were hydrogenated electrolytically at room temperature for 2 hours. The spontaneous dehydrogenation was followed by the measurements in air at room temperature. The hydrogen content was 0.1% of a sample mass. Magnetic quantities and Barkhausen noise parameters were measured in the as-cast state and after the hydrogenation. The measurement of the magnetic quantities were performed at 30 minutes interval during 20 hours of the first day of the dehydrogenation and, along with the Barkhausen noise parameters, once a day during next 29 days of the dehydrogenation [1]-[4]. Time before the hydrogenation as „negative“ is given on the time axis (Figs.1, 2).

The measured magnetic quantities are: coercivity, H_c , total and stress induced anisotropy energy, K_i and K_σ , respectively, total demagnetization factor, D , as a sum of internal and geometrical demagnetization factors, D_i and D_g , respectively. The parameters K_i and K_σ are determined from the area over the magnetization primary curve and demagnetization one, respectively, and K_σ is given by value and distribution of the internal stresses [5].

The geometrical demagnetization factor, $D_g = 8.5 \times 10^{-5}$, is calculated from the sample geometry [5].

The measured Barkhausen noise parameters are: power spectrum intensity, $S(f)$, number and total number of the Barkhausen pulses, n and N , respectively. The external magnetic field for the Barkhausen noise measurement is varied in the ± 1000 Am⁻¹ range. The parameter n is registered and increasing during the magnetization process along one branch of the magnetization curve. The parameter N represents the n value reached at 1000Am⁻¹ (Figs.1, 4) [2]-[4].

3. RESULTS AND DISCUSSION

Hydrogen atoms increase internal stresses and, consequently, caused the H_c , K_i , K_σ rapid increase (Figs.1, 2). The chemical components of the Fe₈₅B₁₅ amorphous alloy have low affinity to the hydrogen. Therefore, the desorption of H-atoms is completed during 20 hours at room temperature (Figs.1, 2), resulting in the rapid decrease of the magnetic quantities [2]-[4].

After 20 hours of the dehydrogenation, H_c reaches higher values than before the hydrogenation. This fact indicates an in-direct role of the H absorption, manifested in long-life elevated stress level and in the presence of high-level stress centres, conserved in the sample even after 20 hours of the dehydrogenation. The high-level stress centres represents high fluctuations of internal stresses. The K_i , K_σ small ir-reversible decrease after 20 hours of the dehydrogenation could be attributed to a relaxation-like effect. Due to high internal stresses around hydrogen atoms, the Fe and B atoms are pushed away into regions of lower internal stresses. This relaxation-like effect seems to be phenomenologically similar like the effect of a low-temperature annealing process [2]-[4].

The D course during the hydrogen absorption and desorption processes is shown in Fig.1. As D_g is unchanged during the hydrogenation-dehydrogenation cycle, the D change arises only from the H-induced modification of D_i . The parameter D_i is given by the demagnetization field due to magnetic inhomogeneities inside the material, e.g. non-magnetic inclusions or clusters. In the case of Fe-V-B and Fe-W-B amorphous alloys [3], [4], the immediate decrease of D during the hydrogenation indicates the presence of weakly coupled γ_1 -like antiferromagnetic clusters of the Fe atoms. The γ_1 -like antiferromagnetic clusters are transformed to the γ_2 -like ferromagnetic ones, as a consequence of the changes of distances between the Fe atoms of the clusters due to the internal stress increase. During dehydrogenation, the γ_1 -like antiferromagnetic clusters are reconstructed, as indicated by the D increase. In the case of the Fe₈₅B₁₅ amorphous alloy, the constant course of D is reflected by the presence of either the strongly coupled γ_1 -like antiferromagnetic clusters or the γ_2 -like ferromagnetic ones [6]. The magnetic quantities shown in Figs.1-3 were measured every day during 30 days of the dehydrogenation but no changes of their courses were registered [2]-[4].

The N/N_{ac} course during the dehydrogenation is shown in Fig.3, and for the as-cast sample $N_{ac}=1.33 \times 10^{13} m^{-3}$ (Fig.1). After the hydrogenation, the $\partial U/\partial x$ function barriers, represented by the fluctuations of internal stresses, increase; where $U(x)$ is energy depending on the material structure, not on the external magnetic field [5], and x indicates a domain wall position. The domain wall motion is then influenced only by them and not by the lower barriers between two high-level stress centres [2]-[4]. This fact could explain the rapid decrease of N/N_{ac} after the hydrogenation. Fig.4 shows the n courses during the magnetization process for the as-cast and hydrogenated states, and after 9 and 30 days of the sample dehydrogenation. The contribution of irreversible motion of domain wall to the total magnetization in the case of the hydrogenation-dehydrogenation process is dominant in the range to 60 Am⁻¹.

Fig.5 shows the Barkhausen noise power spectrum intensity, $S(f)$. The shift of $S(f)$ towards lower frequencies is indicated by position changes of maximum and inflexion points of the $S(f)$ courses, ω_m and ω_i (Tab.1), respectively. The dominant shift and the significantly lower slope of $S(f)$ after the hydrogenation are reflected by shorter duration of the Barkhausen pulses and by higher slope of the Barkhausen pulse increasing part, respectively [2]-[4]. The maximum and inflexion points, getting from curves to fit the $S(f)$ courses, are in a good agreement with the relation $\omega_i = \omega_m (3 + \sqrt{5})/2$ [7].

In contrast to the H_c , K_i , K_σ changes during 20 hours of the dehydrogenation, the significant time

delay of the N/N_{ac} , n , $S(f)$ reactions to the dehydrogenation is observed. It is evident that H_c , K_i , K_σ reach after 20 hours almost the same values as before the hydrogenation (Figs.1, 2). The parameters K_i , K_σ represent average value of the internal stresses over the sample. The Barkhausen noise parameters are sensitive to the presence of high fluctuations of the internal stresses, and are not influenced by the decrease of the average value of the internal stresses [5]. On the other hand, due to small amount of the high fluctuations, K_i , K_σ are not significantly influenced by their presence. Due to the relaxation of the high fluctuations, the dominant changes of N/N_{ac} , n , $S(f)$ are observed after 6-7 days of the dehydrogenation, although no dominant changes of H_c , K_i , K_σ are measured during next 29 days of the dehydrogenation. It is then evident that the changes of the magnetic properties during the dehydrogenation, caused by the decrease of the internal stress average value, were not followed by the changes of the Barkhausen noise parameters, which were consequence of changes of the internal stress fluctuations [2].

4. CONCLUSIONS

The results of H-induced changes of the magnetic quantities and the Barkhausen noise parameters can be summarized as follows:

- After the hydrogenation, expressive changes of all investigated parameters are observed, due to the internal stress increase [2]-[4];
- During the hydrogenation, a relaxation-like effect appears, being similar to that occurring during low-temperature annealing [2]-[4];

The run of changes of the magnetic quantities and the Barkhausen noise parameters during the dehydrogenation due to decreasing internal stresses, is not followed by the run of the changes of the Barkhausen noise parameters. This fact is considered to be the consequence of the changes of the internal stress fluctuations [2]-[4].

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BIOGRAPHY

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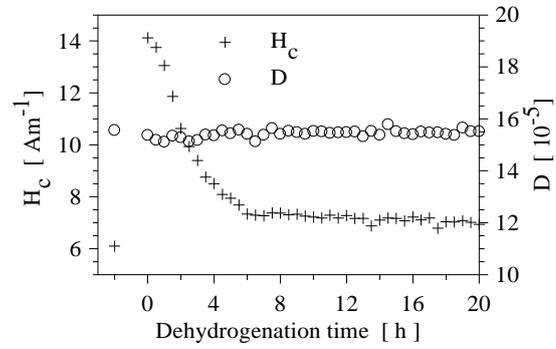


Fig.1 The coercivity, H_c , and the total demagnetization factor, D , vs. dehydrogenation time.

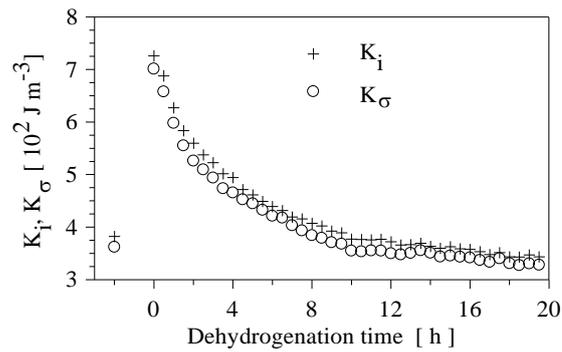


Fig.2 The total and stress induced anisotropy energy, K_i and K_σ , respectively, vs. dehydrogenation time.

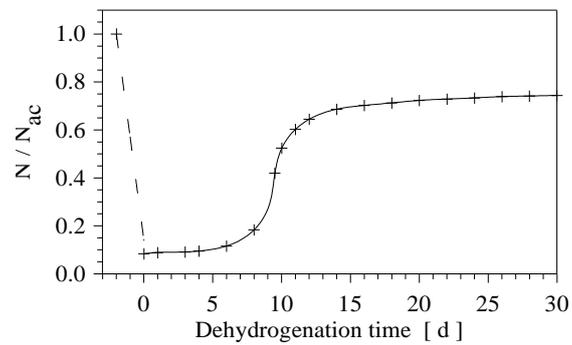


Fig.3 The parameter N/N_{ac} vs. dehydrogenation time.

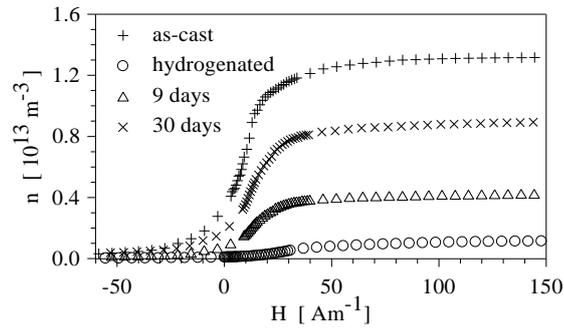


Fig.4 The number of the Barkhausen pulses per a volume unit for the as-cast and hydrogenated samples.

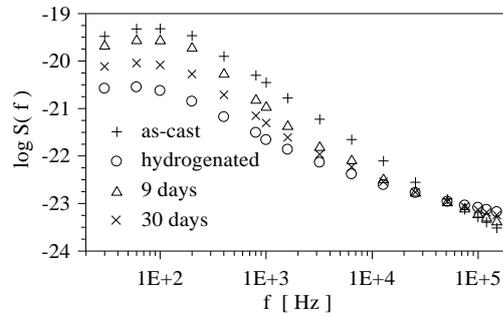


Fig.5 The Barkhausen noise power spectrum intensity, $S(f)$, for the as-cast and hydrogenated samples.

$\text{Fe}_{85}\text{B}_{15}$	As-cast	Hydrogenated	9 Days	30 Days
$\omega_m [2\pi\text{Hz}]$	496	288	378	490
$\omega_i [2\pi\text{Hz}]$	1607	1210	1396	1551

Tab.1 The maximum and inflexion points of the Barkhausen noise power spectrum intensity, ω_m and ω_i , respectively, for the as-cast and hydrogenated samples.