The influence of hydrogenation and dehydrogenation on the power spectra of Barkhausen noise in amorphous alloys has been investigated. It has been shown that after hydrogenation local stress centers occur in amorphous structure. Presence of the centers leads to long-wave fluctuations of domain wall energy which cause the decrease of the number of irreversible domain wall displacements.

1 Introduction

Hydrogen absorption in metals and alloys plays an important role in modifying their electronic and topological structure which consequently changes magnetic and mechanical properties of materials [1]. The modification of magnetic properties may be extended to a level of vanishing transition metal moments in some metal hydrides, whereas appearance of ferromagnetism may also be observed in some alloys [2]. Hydrogen can be incorporated both into crystalline and amorphous alloys. Unlike crystalline materials where metal hydrides can be formed with more or less defined stoichiometric ratios (e.g. ferromagnetic UH₃), hydrogen produces interstitial solid solutions in amorphous alloys. Hydrogen atoms located in an amorphous matrix can be treated as point defects and they will impose elastic stress on material. The effect of the mechanical stress centers on the behaviour of irreversible magnetization processes, however, does not appear to have been investigated yet. In what follows we report the measurements of the influence of hydrogenation on the Barkhausen effect in some amorphous alloys.

2 Theoretical background

It is well known that the magnetization process of a ferromagnetic sample is associated within a large part of a hysteresis loop with jumps of the Bloch walls which give rise to the Barkhausen noise. The noise is a direct consequence of domain wall interactions with the microstructural defects such as impurities, dislocations and stress centers and can give detailed information on the mechanism responsible for hysteresis.

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In the previous paper [3] it has been shown that power spectrum of statistically independent Barkhausen pulses can be written in the form

$$\Phi(\omega) = 2a_0^2n|F(\omega)|^2,$$

where $a_0$ is the amplitude of elementary pulses, $n$ is the average number of pulses per time unit and $|F(\omega)|$ is the Fourier transform of an elementary pulse. Zentková and Datko [4] have derived the expression for the time dependence of the Barkhausen pulse in the case of thin ferromagnetic ribbons

$$\epsilon(t) = C(M,\gamma)t^{-2} \exp\left(-\frac{m^2}{4\gamma^2t}\right),$$

where $C(M,\gamma) = (\mu M)/(2\gamma\sqrt{\pi})$, $\gamma^2 = 1/(\mu \sigma)$, $M$ is the magnitude of the magnetic dipole that describes a Barkhausen jump, $\mu$ is the reversible permeability, $\sigma$ the electrical conductivity of the sample and $m$ is the distance of the origin of the jump from the surface of the sample. After substituting (2) into (1) we get [3]

$$\Phi(\omega) = nC^2(M,\alpha)\sqrt{4i\alpha\omega}K_1\left(\sqrt{4i\alpha\omega}\right)^2,$$

where $K_1$ is the MacDonald function and $\alpha = \mu \sigma m$ is the time constant. For higher frequencies we can use an approximative expression for the MacDonald function in the form

$$K_1(z) \approx \sqrt{\frac{\pi z}{2}} \exp(-z).$$

After substituting into (3) we have the final approximative expression for the power spectra of Barkhausen noise in thin ferromagnetic ribbons

$$\Phi(\omega) = \pi nC^2(M,\alpha)\sqrt{\alpha\omega}\exp\left(-\sqrt{8\alpha\omega}\right).$$

The function (5) has a maximum for $\omega_m = 1/(8\alpha)$ and then decreases with the inflexion point $\omega_i = (3 + \sqrt{5})/(16\alpha)$. The form of $\Phi(\omega)$ therefore depends upon the value of the time constant $\alpha$ as a function of $\mu$ and $\sigma$. These parameters have a clear physical meaning, but their values cannot be directly measured from Barkhausen noise experiments even if a rough estimate of $\alpha$ values can be made from noise observations. Their relative changes can be foreseen when a material is hydrogenated. However, it is necessary to say that already in the paper [5] clustering of elementary pulses in large Barkhausen discontinuities was described assuming a suitable distribution of time intervals separating elementary pulses. In the case of correlated impulses with the empirical Sawada's distribution, the power spectrum has the form

$$S(\omega) = \Phi(\omega)\left[1 - \frac{8s^2}{16s^2 + \omega^2}\right],$$

where $\Phi(\omega)$ is the power spectrum of the Barkhausen noise in the absence of the correlation between elementary pulses and $s$ is the average number of Barkhausen pulses in one cluster.