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HEAT TREATMENT INFLUENCE ON MAGNETOSTRICTION CURVES OF $Fe_{78}Si_9B_{13}$ METALLIC GLASSES[1])

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Linear longitudinal and transverse magnetostriction and volume magnetostriction curves versus a magnetic field for the $Fe_{78}Si_9B_{13}$ metallic glass after various heat treatments are presented and discussed. The saturation magnetostriction changed from 28.9×10^{-6} for the as-quenched alloy to 39×10^{-6} for the annealing at 350 °C for 30 minutes.

I. INTRODUCTION

In 1842 Joule found that iron exhibits linear changes in dimensions when exposed to a magnetic field [1]. These changes of the dimensions are known as the shape magnetostriction or the longitudinal ($\Delta l/l = \lambda_l = \lambda_{\parallel}$) and transverse ($\Delta a/a$ or $\Delta d/d = \lambda_t = \lambda_{\perp}$) Joule effects. In 1882 Barrett observed a definite change in volume ($\Delta V/V$) caused by the application of a magnetic field [2]. The relative changes in volume $\Delta V/V = \omega$ are composed of three parts of differing origin, e.g. [3],

$$\omega = \omega_M + \omega_K + \omega_F, \qquad (1)$$

where the magnetization term ω_M depends only on the amount of true magnetization and can increase (positive) or decrease (negative) as the magnetization increases. In high fields where changes in the direction of the true magnetization no longer occur, ω_M in general changes linearly with the magnetic field. It means that in high fields $\partial\omega_M/\partial H$ is constant. The second term ω_K describes the dependence of the crystal volume on the crystallographic directions α_1, α_2, α_3 of

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the spontaneous magnetization at constant temperature. The form effect ω_F depends only on the schape of the sample and on the total magnetization $M(\omega_F = (1/2)NI^2/k$, where $I = \mu_0 M$ is magnetic polarization, μ_0 is magnetic permeability of vacuum and H the magnetic field, N is demagnetization factor and k is bulk modulus), e.g. [3—5].

II. EXPERIMENTAL

$Fe_{78}Si_9B_{13}$ amorphous alloys were prepared in the form of ribbons by the single-roll rapid-quenching method at Prof. Matyja's Laboratory of the Warsaw Technical University Institute of Material Science and Engineering. The samples were measured in the as-quenched state (sample no. 1) and after the various steps of the annealing programme. Five samples were annealed beforehand for 1 h at the temperature of 200 °C and slowly cooled with the furnace. Next the sample no. 2 was annealed for 1/2 h at 250 °C, sample no. 3 for 1/2 h at 300 °C and sample no. 6 for 1/2 h at 350 °C and these three samples after annealing were slowly cooled with the furnace. Sample no. 4 after annealing at 200 °C and cooling was annealed for 1/2 h at 250 °C, cooled and again annealed for 1/2 h at 300 °C and cooled. Sample no. 7, after annealing for 1/2 h at 200 °C and cooling, was annealed for 1/2 h (and next cooled) at temperatures 250°, 300° and 350° C. Sample no. 5 after production was only once annealed for 1/2 h at the temperatures of 350 °C and then slowly cooled with the furnace. The linear longitudinal $\lambda_\parallel$ and transverse $\lambda_\perp$ magnetostriction versus the magnetic field were measured using the three-terminal-capacitance method [6]. Saturation was obtained form the formula:

$$\lambda_s = \left(\frac{\Delta l}{l}\right)_s = \frac{3}{2}(\lambda_\parallel - \lambda_\perp). \tag{2}$$

The forced volume magnetostriction ω was calculated from linear magnetostriction measurements:

$$\omega = \frac{\Delta V}{V} = \lambda_\parallel + 2\lambda_\perp. \tag{3}$$

III. RESULTS AND DISCUSSION

The dependence of the linear longitudinal and transverse magnetostriction and volume magnetostriction are presented in Fig. 1. The forced volume magnetostriction $\partial\omega/\partial H$ was obtained by the slope of the ω curves beyond the technical saturation. The saturation magnetostriction of the investigated Fe—Si—B metallic glasses was changing from 28.9×10^{-6} to 39×10^{-6}, de-

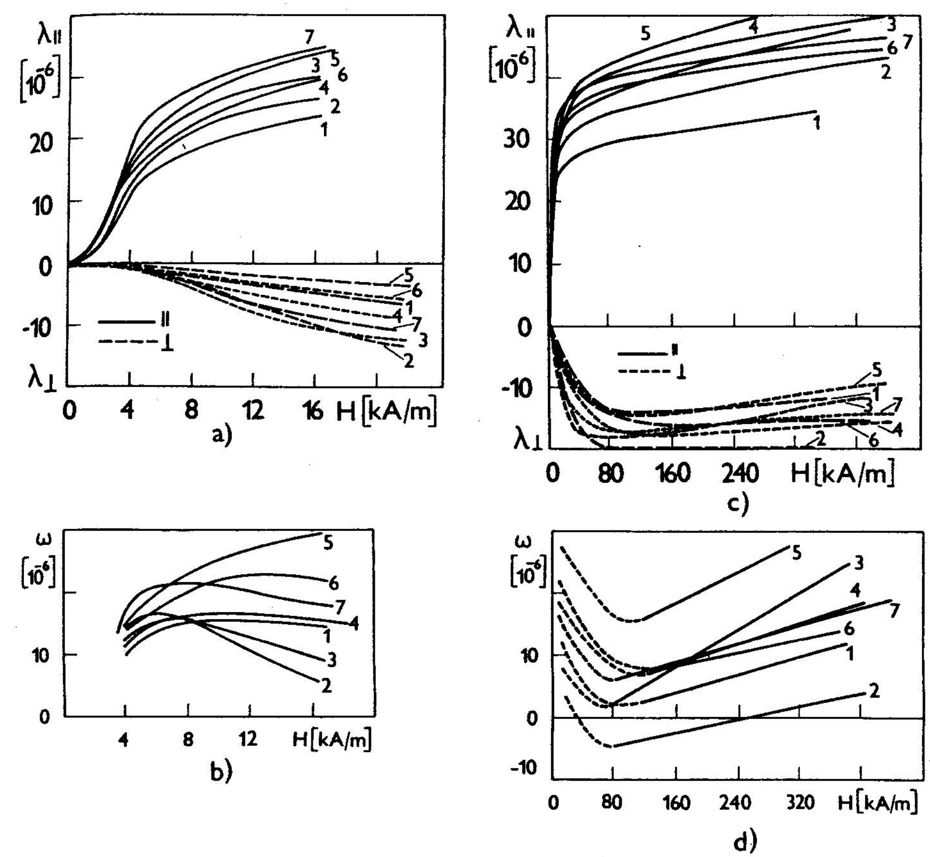

Fig. 1. Longitudinal $\lambda_\parallel$ and transverse $\lambda_\perp$ linear magnetostriction and volume magnetostriction ω versus magnetic field H for a $Fe_{78}Si_9B_{13}$ metallic glass after the various sample heat-treatment programme: 1 — as quenched, 2 — annealed for 1 h at 200 °C, cooled an annealed for 1/2 h at 250 °C and cooled, 3 — ann. for 1 h at 200 °C, cooled and ann. at 300 °C for 1/2 h and cooled, 4 — ann. for 1 h at 200 °C, cooled, ann. for 1/2 h at 300 °C and cooled, 5 — annealed for 1/2 h at 350 °C and cooled, 6 — ann. at 200 °C for 1 h, cooled, ann. for 1/2 h at 350 °C and cooled, 7 — ann. at 200 °C for 1 h and at 250, 300 and 350 °C for 1/2 h and after each annealing cooled slowly with the furnace.

pending on the mechanical and the thermal processing and 30 % changes of λ_s were observed after the annealing at the temperature of 350 °C for 30 minutes. In the strong magnetic fields the fractional changes of the length, measured in the same direction as that of H approach the limiting value, superposed on which there is a relative small length change that is known to be the volume effect-the sample expands equally in all directions [2—5]. The initial part of the

ω curves (at low fields) depends on the sample shape and total magnetization [ω_F in eq. (1)]. The forced volume magnetostriction $\partial\omega/\partial H$ was changing from 3×10^{-8} m/A to 7×10^{-8} m/A. The shapes of the magnetostriction curves are very important in the applications of the piezomagnetic materials in the ultrasonics or in the radioelectronics, e.g. [7].

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ВЛИЯНИЕ ТЕПЛОВОЙ ОБРАБОТКИ НА КРИВИЕ МАГНИТОСТРИКЦИИ В $Fe_{78}Si_9B_{13}$ МЕТАЛЛИЧЕСКИХ СТЕКЛЯХ

В работе предлагаются и обсуждаются кривые линейной (продольной и поперечной) магнитострикции, обемной магнитострикции в зависимости от магнитного поля для $F_{78}Si_9B_{13}$ металлических стекол после разных тепловых обработок.