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INFLUENCE OF TORSION ON SOME MAGNETIC PROPERTIES OF HEAT-TREATED AMORPHOUS CYLINDRICAL LAYERS*

MICHAL KONČ**, JURAJ DANIEL-SZABÓ**, B. ZAGYI***, OTO DUŠA**, Košice

The subject of our study were non-annealed and annealed amorphous cylindrical electrodeposited layers. The influence of torsional elastic stress on the behaviour of magnetization curves of heat-treated amorphous cylindrical CoP layers and on their domain structure was investigated. The changes of the domain structure observed as result of the torsional stress may be explained by the influence of torsion on the orientation and the magnitude of the magnetic anisotropy.

ВЛИЯНИЕ КРУЧЕНИЯ НА МАГНИТНЫЕ СВОЙСТВА ТЕРМИЧЕСКИ ОБРАБОТАННЫХ АМОРФНЫХ ЦИЛИНДРИЧЕСКИХ ПЛЕНОК

В работе изучаются аморфные цилиндрические пленки гальванического покрытия, подвергнутые и не подвергнутые отжигу. Исследовано влияние напряжения при кручении ниже предела упругости на поведение кривых намагничивания термически обработанных цилиндрических пленок CoP и на их доменную структуру. Изменение доменной структуры, наблюдаемое как результат напряжения при кручении, может быть объяснено как результат влияния кручения на ориентацию и величину магнитной анизотропии.

I. INTRODUCTION

Little information has so far been available on the influence of torsion of the magnetic state of amorphous ferromagnets. The distribution of stress during the torsional stressing of cylindrical samples may — according to [1] — significantly influence the local orientation of the vector of magnetic polarization of the individual domains. The domain structure of cylindrical CoP layers in a thickness range from 16 μm to 90 μm is similar to that of plane amorphous CoP electrodepo-

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** Dept. od experimental Physics, Faculty of Science P. J. Šafarik University, nábr. Febr. víťazstva 9, CS-041 54 KOŠICE.

*** Dept. of Physics Electrotechnical Faculty, Technical University, Park Komenského 2, CS-040 01 KOŠICE.

sited layers with a weak magnetic anisotropy with the easy axis of magnetization perpendicular to the surface of amples.

II. EXPERIMENTAL DETAILS

The amorphous cylindrical $Co_{76}P_{24}$ layers were prepared by electrodeposition [2, 3] onto the rotating cylindrical copper substrates ($\varnothing = 2$ mm, $l = 120$ mm), or thin-walled copper tubes ($\varnothing = 3$ mm, $l = 120$ mm), which were prior to deposition thoroughly cleaned and both mechanically and chemically polished. After the deposition of layers the copper tubes were removed by chemical etching. The amorphousness of layers was checked by the X-ray method and their composition by purely chemical methods. The thickness of the investigated cylindical layers was determined on the transversal section by an optical microscope and was found to be in the range between 16 μm and 90 μm. The mechanical torsional stressing was realized by twisting the free end of the cylindrical sample. As a measure of torsional deformation caused by twisting the relative displacement $\gamma = \varphi r / l$, where

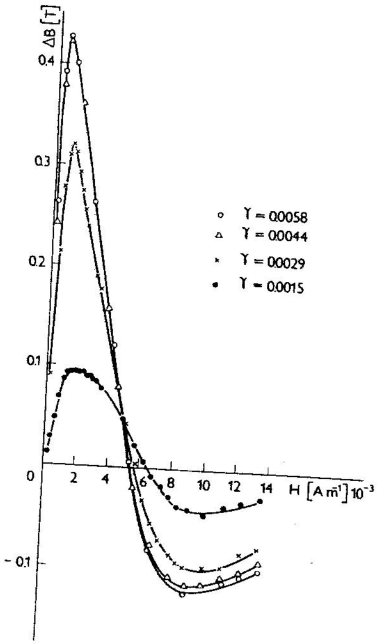

Fig. 1. Changes of the magnetic induction $\Delta B(H)_{\gamma=const}$ caused by the torsion in the amorphous cylindrical CoP lay-er which was not heat-treated (thickness ~40 μm).

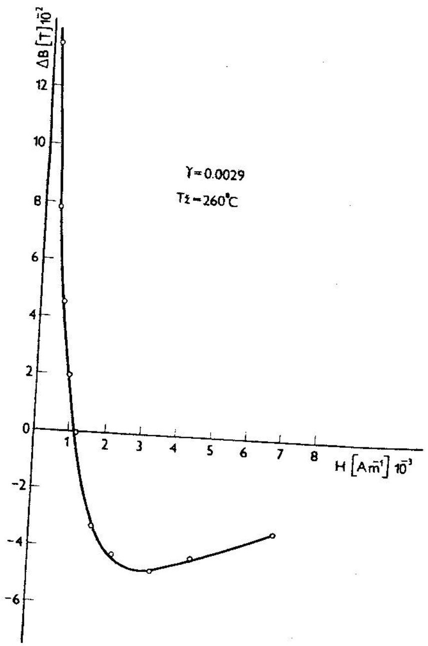

Fig. 2. Changes of the magnetic induction $\Delta B(H)_{\gamma=const}$ of the amorphous CoP layer (thickness ~30μm) after isothermal annealing at a temperature of 260 °C. Annealing time 1 hour.

φ is the angular twisting of the sample free end, r is the mean radius and l is the sample length.

III. RESULTS AND DISCUSSION

Magnetostriction of investigated CoP cylindrical layers is negative and the average value of the magnetostriction constant in the saturated state of the samples is $\lambda_s = -1.5 \times 10^{-6}$.

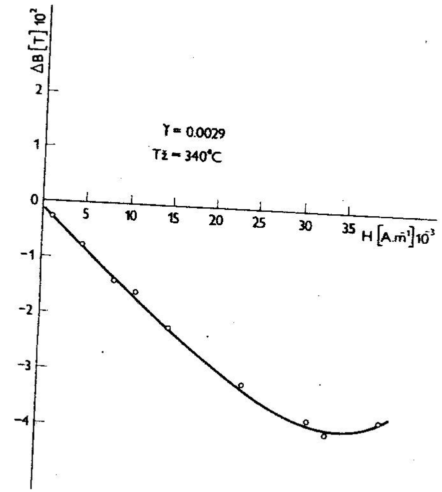

Fig. 3. Change of the magnetic induction $\Delta B(H)_{\gamma=const}$ of the CoP layer (thickness ~ 30 μm) after isothermal annealing at a temperature of 340 °C. Annealing time 1 hour.

Fig. 1 shows the dependence of the changes of the magnetic induction ΔB upon the external magnetic field H at constant γ for the non-annealed CoP layer (~40 μm thick), obtained from the comparison of the magnetization curve of the non-stressed ($\gamma = 0$) sample to that of the torsionally stressed sample ($\gamma \neq 0$). The sample was magnetized in the longitudinal (axial) direction. It is evident that with the increasing torsion also the changes of induction B increases. As was shown in [3], the torsional elastic stress leads to the improved rectangularity of the hysteresis loop and to the decrease of the coercive force of cylindrical CoP layers.

Fig 2 shows the same dependence $\Delta B(H)_{\gamma=const}$ of the CoP amorphous cylindrical layer heat-treated isothermally at a temperature of 260 °C during 1 hour. This temperature is below the crystallization temperature of the sample [2]. Such an annealing leads to the relieve of internal stresses, which are quite high in the electrodeposited layers [4] and is reflected also in the characteristic of the dependence $\Delta B(H)_{\gamma=const}$. The powder method revealded no domain structure on

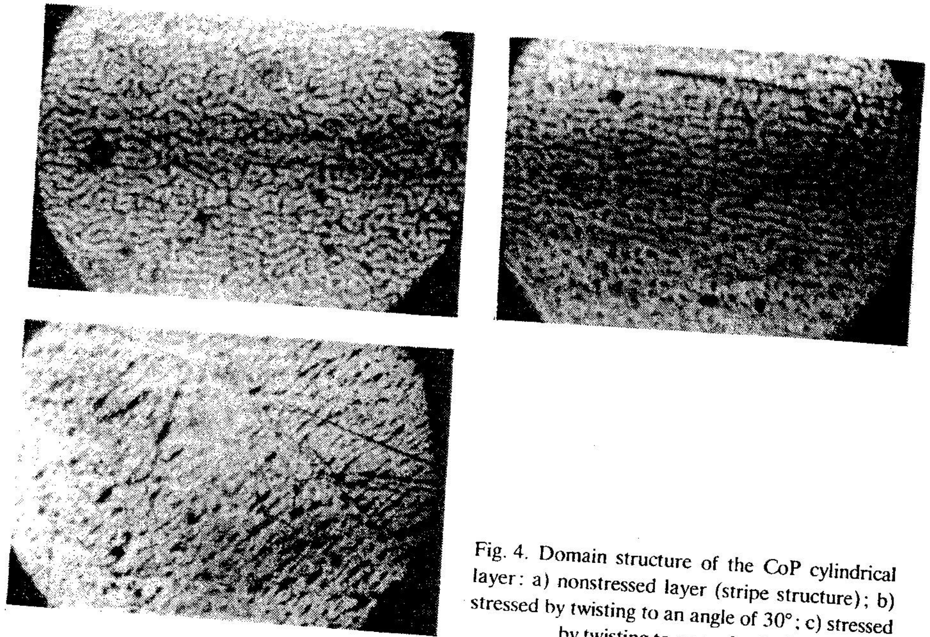

Fig. 4. Domain structure of the CoP cylindrical layer: a) nonstressed layer (stripe structure); b) stressed by twisting to an angle of 30°; c) stressed by twisting to an angle of 40°.

the surface of the layer after this annealing, which may be — we believe — the result of the decrease, resp. disappearance of the weak perpendicular anisotropy.

Fig. 3 shows the dependence $\Delta B(H)_{\gamma=const}$ of the CoP layer subjected to isothermal annealing at a temperature of 340 °C for 1 hour; this temperature lies above the crystallization temperature of the sample. Annealing in this region of temperatures produces phase changes connected with the formation of α—Co and Co_2P phases [5]. With respect to the different specific volumes of these phases additional internal stresses may be produced in the samples. This also results in a simultaneous decrease of the rectangularity degree of the hysteresis loops and in an increase of the coercive force of the samples. The observed changes of the induction are only negative. This fact may be connected with the changes in the magnitude and in the direction of the magnetic anisotropy and according to [6] also with the changes of the elastic and magnetostrictive characteristics of the sample.

Fig. 4 shows photographs of the domain structure obtained by the powder method on the surface of the cylindrical amorphous CoP layer 30 μm thick; in the non-stressed state (Fig. 4a), while stressing the sample by twisting its free end to an angle of 30° (Fig. 4b) and to an angle of 40° (Fig. 4c). The complex labyrinth structure of the „stripe" type is — according to [7] — a consequence of the presence of the weak perpendicular magnetic anisotropy in the radial direction of the cylindrical layer. The kind of the domain structure of the sample twisted to an

angle of 40° (Fig. 4c) indicates the change of the orientation of the direction of the easy axis of magnetization, caused by the torsional elastic stress, which leads to the appearance of the circular component of the magnetic polarization. When this mechanism is used, the observed changes of induction at torsional stressing of the amorphous cylindrical layers may be explained.

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