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The Induced Anisotropy and its Influence on Domain Structure of Amorphous Co-P and Co-Ni-P Films

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The results of experimental research of the induced anisotropy in amorphous Co-P and Co-Ni-P films received by chemical sedimentation are presented. The features of formation of domain structures, magnetization processes and coercive force change are established at presence and absence of the induced anisotropy.

Keywords: amorphous magnetic films, induced anisotropy, domain structure, coercive force.

The amorphous ferromagnetic have found wide technical application due to the unique properties, in particular, they possess record-breaking big magnetic permeability and low coercive force. The uniqueness of such ferromagnetic is also reflected in the fact that they allow easy forming uniaxial anisotropy that is reached by variations of the external magnetic field during annealing or in the course of samples reception. The influence of artificially induced anisotropy on magnetic properties of amorphous ferromagnetic is not absolutely unequivocal. In some cases it leads to improvement of magnetic characteristics, in others, on the contrary, to their deterioration [1]. The reasons for such changes as well as the creation mechanisms of the induced anisotropy in amorphous magnetic are not clear in many cases. In the present work the results of research of induced anisotropy influence on the magnetization processes and domain structure of amorphous Co-P and Co-Ni-P films received by chemical sedimentation are presented. A specificity of the magnetization process and domain structures formation is shown at presence and absence of induced anisotropy. Also it is shown that the changes of coercive forces H_c from a thickness of films in the presence of the induced anisotropy are similar to the coercive forces changes in polycrystalline samples in many cases.

1. Explored Samples

The explored samples were gained by chemical sedimentation on glass substrates. The two types of samples were investigated. The samples of the first type were received in the small residual magnetic field which did not exceed 0,001Qe [2]. The samples of the second type had

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uniaxial anisotropy which was induced in a magnetic field by intensity of 3 kQe. For reception of Co-Ni–P films the solution with acidity pH = 8,0 was used. This solution contained (in g/l): nickel sulphate 5, cobalt sulphate 30, gipofosfit sodium 10, citric acid sodium 80, acetic sodium 100, sulphate ammonium 40 and ammonia of 20 ml/l. The sedimentation was yielded at temperature 80°C during 10min. The Co-P samples have been made from a solution with pH = 9,0 and composition: cobalt sulphate 30, gipofosfita sodium 30, citric acid sodium 80 and ammonia of 30 ml/l. Sedimentation of films was made at temperature 90°C within 7 minutes. The chemical compound of samples was determinate by X-ray spectral method. The Co-P films contained Co — 94,5; P — 5,5. In conformity with the phase diagram the compositions of samples were in area of existence of an amorphous phase.

2. Experimental Results and Discussion

The films which were created in the absence of the magnetic field were isotropic. The demagnetization of films along some direction leads to occurrence of the domain structure which is presented on Fig. 1.

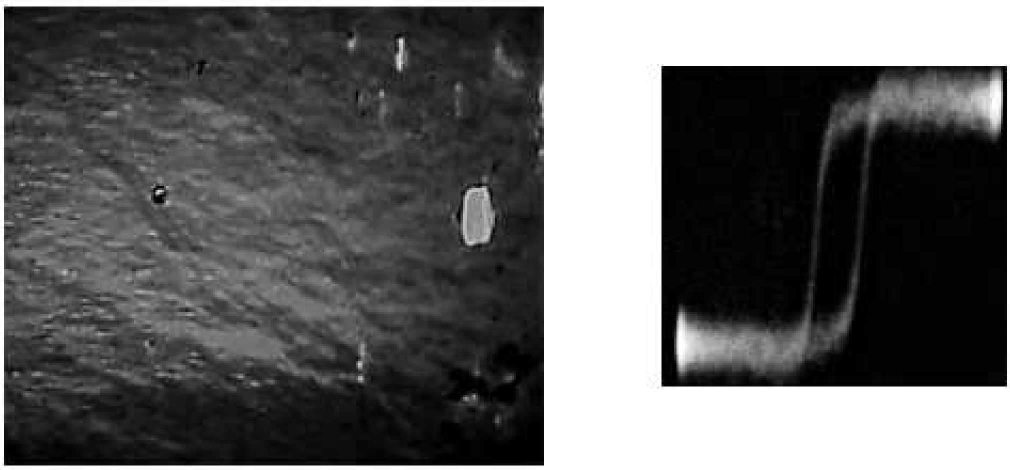

Fig. 1. Domain structure and hysteresis loop of isotropic films

The typical hysteresis loop of such samples is presented here. It arises on all areas of a film and has a chaotic shape. Obviously such a character of the domain structure formation is caused by the films isotropy and local inhomogeneity which occurred as centers of domains germs.

Superimposition of an external magnetic field in the course of sedimentation of films leads to development of a uniaxial anisotropy. The easy axis of magnetization directs along this field. The value of an induced anisotropy field H_k depends on the film structure. At Ni concentration $x = 30$ (in weight %), $H_k = 24$Qe for Ni-Co-P films, at $x = 15$, $H_k = 20$Qe and at $x = 0$, H_k=15Qe. The occurrence of uniaxial anisotropy leads to the change of the domain structure which gets a strip form with almost identical period on the area of a film (Fig. 2).

The form of hysteresis loops reflects a uniaxial anisotropy of the films. At magnetization reversal of a film along an easy axis the hysteresis loop looks like a step, that reflects a small

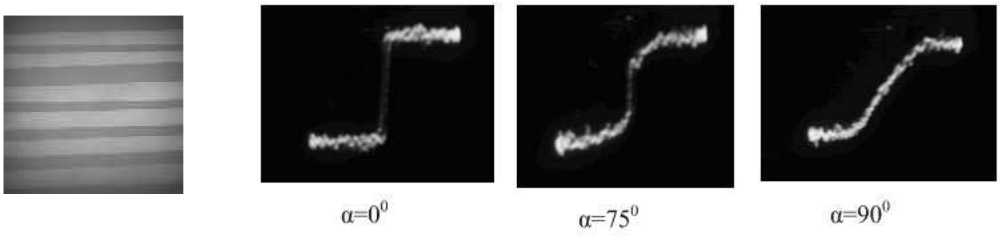

Fig. 2. Domain structure and hysteresis loops form of anisotropic film at various orientation of magnetic field to easy axis

angular dispersion of magnetization.

The unusual form of the hysteresis loops between difficult and easy directions reflects the complication of magnetization reversal process. Visual supervision establishes that at such orientation of magnetic field the magnetization at initial stage is carried out by parallel displacement of domain walls up to saturation of film along an easy axis. It is caused by small value of H_c in comparison with H_k. The subsequent magnetization (a flat part of a loop) occurs by magnetization turn in a field direction. The coercive force of isotropic films varies with thickness of a film slightly (Fig.3): at $h = 400$Å, the H_c = 4,3Qe and it varies to 2,9Qe at $h = 1200$Å.

In amorphous films with a uniaxial anisotropy the value of Hc sharply decreases with increase of thickness (Fig. 3): at $h = 800$Å, H_c = 34Qe, at $h = 5000$Å, H_c =3 Qe and at $h = 15000$Å, the $H_c \sim$ 0,15Qe. The minimum of coercive forces which was observed by authors [3] in the field of thickness 10000Å is not found out in investigated films.

A coercive force of amorphous films substantially depends on their structure, namely, of the dispersion value of an energy exchange, anisotropy and a magnetostriction which is caused by the elastic pressure [4]. In isotropic samples the crystallographic anisotropy is absent or it is very small, therefore the defining factor of the coercive force change is magnitostriction. Basically the magnitostriction of investigated samples is connected with the pressure on the film-substrate boundary, the increase of a film thickness will provide a smaller influence on domain walls pinning and lead to the observable coercive force change from a thickness of the film.

The basic difference in a magnetization reversal of amorphous films in the presence of the induced anisotropy, most likely, is connected with change of walls domain structure, their energy and width. It is known that the density of such walls energy will be in inverse proportion to a thickness of a film h [5] (in the assumption, that they were a Bloch type). In the case of polycrystalline films it leads to the known dependence ($H_c\ h^{-4/3}$). If we assume such dependence for our samples the change of Hc from h will look like Fig. 3. For calculations, we assume that the value of H_c = 33Qe at $h = 800$Å. It is possible to conclude that the used model is in the qualitative agreement with experimental dependence of change of H_c from h.

As well as in case of polycrystalline films the observable deviations of calculated and experimental values can be connected with presence of other type of the walls which are distinct from Bloch walls in considered area of thickness. It was not considered at calculation of the wall energy. Thus, it is possible to make the following conclusion: in many cases magnetic properties of

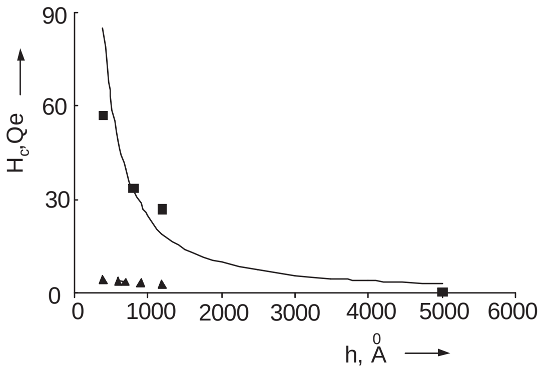

Fig. 3. Change of coercive forces from a thickness for: — anisotropic, — isotropic films. The continuous line corresponds to calculation dependence

amorphous ferromagnetic films are defined by presence of the induced anisotropy. In spite of the fact that such anisotropy does not change amorphous structure of films, it leads to qualitative change of magnetic properties. Most likely such changes are connected with distinction of walls domain structure in isotropic and anisotropic of amorphous films.

References

[1] Amorphous metallic alloys. Edited by F.E. Luborsky. *J. Metallurgy*, Moscow, 1987, (in Russian).

[2] S.J. Kiparisov, The testimony authoring, Patent no. 1157132 (1985), (SU).

[3] S.S. Grabchikov, O.I. Koncevich, In the collection of international conference reports *Actual problems of solid state physics PhSS-2005*, Minsk, 2005, 129–132.

[4] Li Zhao-Hua, Domain walls and a wall-pinnig effect in amorphous magnetics, *IEEE Trans. on Magn.*, MAG-23(1987), 2990–2992.

[5] R.F. Soohoo, Magnetic thin films, Moscow, Mir, 1987, (in Russian).

Индуцированная анизотропность и влияние на структурную область аморфных Co-P и Co-Ni-P пленок

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Представлены результаты экспериментального исследования индуцированной анизотропности в аморфных Co-P и Co-Ni-P пленках, полученные химической семидентацией.

Ключевые слова: аморфные магнитные пленки, индуцированная анизотропность, структура области, коэрцитивная сила.