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Investigation of the Morphological Structure of Thin Cobalt Films by AFM and TEM

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Thin obalt films, 40 nm and 100 nm in thickness, were evaporated at an incidence angle of 45° in a vacuum of about 10^{-5} mbar, simultaneously on unheated glass substrates and NaCl crystals. The magnetic microstructure of these films was investigated in a previous paper. In the present paper, to obtain an insight into relation between the magnetic microstructure and the morphological structure, we studied the latter structure with atomic force microscopy and transmission electron microscopy. For the films 40 nm as well as 100 nm thick, the presence of contribution of the shape anisotropy (related to the geometric alignment of the grains of the film) to the magnetic anisotropy of the film was found. Nevertheless, for the films investigated, we could not detect crystallographic texture.

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1. Introduction

In the previous paper [1] it was shown that the magnetic microstructure of cobalt films 40 nm and 100 nm thick, evaporated at an incidence angle of 45° in a vacuum of about 10^{-5} mbar, consists of in-plane magnetized domains running predominantly in the direction perpendicular and parallel to the incidence plane, respectively.

In the present paper, we present results of an investigation of the morphological structure of these films. The study was carried out using atomic force microscopy (AFM) and transmission electron microscopy (TEM).

2. Experimental

The specimens studied were cobalt films 40 nm and 100 nm thick. They were evaporated at an incidence angle of 45° in a vacuum of about 10^{-5} mbar.

A heater composed of two Al_2O_3 tubes threaded with tungsten wire was used. The films were deposited simultaneously on unheated glass substrates and NaCl crystals. The morphological structure of the films was investigated by AFM and TEM.

3. Results and discussion

Figure 1 shows 1 μm $\times$ 1 μm image of the surface of the cobalt film 40 nm in thickness, recorded by AFM. It is seen that the morphological structure is composed of grains elongated slightly in the direction perpendicular rather than parallel to the incidence plane. The grains are not packed very closely. The columnar structure of grains is not marked, but the alignment of columnar grains in the direction perpendicular to the incidence plane can be recognized.

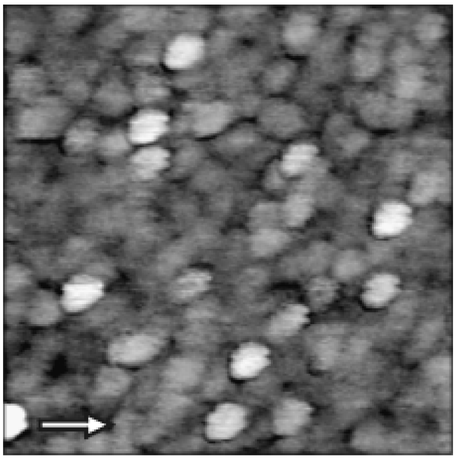

Fig. 1. 1 μm $\times$ 1 μm AFM image of the morphological structure of a cobalt film 40 nm thick; the arrow indicates the projection of the vapor beam into the film plane.

It is worth noting that the origin of columnar grain structure can be explained by the geometric shadowing mechanism. The origin of the elongation of grains in the columns can be explained, similarly as the origin of the columns themselves, by taking into account only geometric causes.

1 μm $\times$ 1 μm AFM image of the surface of the cobalt film 100 nm thick is presented in Fig. 2. The morphological structure consists of grains elongated slightly in the direction perpendicular rather than parallel to the incidence plane. In comparison with the films 40 nm thick, the grains in the films 100 nm thick are somewhat larger and the film morphology is more continuous (the grains are closer to each other). Figure 2 shows that the observation of columnar grain structure in the films 100 nm thick becomes in fact more difficult. However, in this context, it should be noted that investigations carried out on the basis of magnetic and optical measurements, reported in the literature, prove that in evaporated films

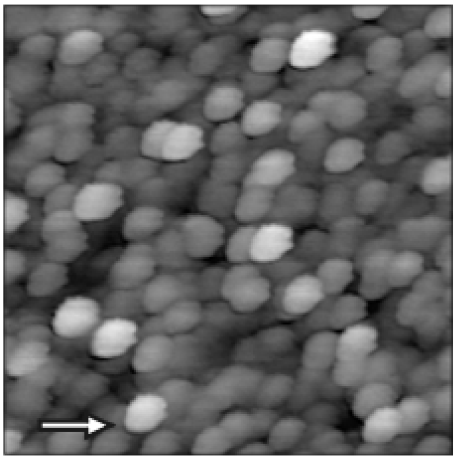

Fig. 2. 1 μm $\times$ 1 μm AFM image of the morphological structure of a cobalt film 100 nm thick; the arrow indicates the projection of the vapor beam into the film plane.

the columnar grains generally align in the direction perpendicular to the incidence plane [2].

The images of the morphological structure obtained by AFM and TEM show that for the investigated films, deposited at an incidence angle of 45°, the degree of columnar grain alignment is generally low. This is in accordance with the results reported in Refs. [3–5], where well-defined columnar grain structures were observed for large deposition angles (larger than about 70°).

In the case of polycrystalline cobalt films, the contributions to the magnetic anisotropy originate from the geometric alignment of the grains through the shape anisotropy (the anisotropy of the demagnetizing field) as well as from the crystallographic alignment (texture) of the grains through the magnetocrystalline anisotropy [2, 6].

Electron diffraction measurements in the transmission electron microscope (TEM) were made to obtain information concerning the crystallographic orientation of the films. However, the recorded diffractograms show that the films 40 nm as well as 100 nm in thickness are polycrystalline with randomly oriented grains, i.e. no crystallographic texture could be detected by the method used.

4. Conclusions

In this paper, study of the morphological structure of cobalt films 40 nm and 100 nm in thickness, evaporated at an incidence angle of 45° in a vacuum of about 10^{-5} mbar (simultaneously on unheated glass substrates and NaCl crystals), was carried out using AFM and TEM. Because of the fact that the investigated films were not deposited at large incidence angle, the shadowing effect was clearly pronounced neither for the films 40 nm thick nor for the films 100 nm thick.

For the films 40 nm thick, the alignment of columnar grains in the direction perpendicular to the incidence plane was observed in images of the film surface recorded by AFM. This finding correlates well with the magnetic microstructure of these films, composed of in-plane magnetized domains running in the mentioned direction [1]. For the films 100 nm thick, the perpendicular alignment of columnar grains can also be found, although in fact with larger difficulty. For the films 40 nm and 100 nm thick, we could detect no crystallographic texture by electron diffraction in the TEM. To obtain information on the crystallographic alignment of grains, measurements by X-ray diffraction ($\Theta - 2\Theta$ spectra) [3] or by the X-ray Schulz method [2, 6] are necessary.

Acknowledgments

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