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Growth of nanostructured cobalt thin film at oblique angle deposition

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Abstract. Nanocolumnar Co thin films growth by oblique angle deposition on Si substrate is experimentally studied. Formation of regular arrays of vertical Co nanocolumns has been observed at incidence angles more than 80 degrees with rotation of substrate. Such films might be perspective material for applications as a magnetic recording media for next generations of hard disks.

Keywords: Co thin films, nanocolumns, oblique angle deposition

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Материалы конференции
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Рост наноструктурированной плёнки кобальта при наклонном напылении

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Аннотация. Экспериментально исследован рост тонких пленок Co при наклонном напылении на подложку Si. Образование массивов наноколонн Co наблюдалось при углах падения более 80 градусов при вращении подложки. Такие плёнки могут быть перспективным материалом для применения в качестве носителей магнитной записи для следующих поколений жестких дисков.

Ключевые слова: тонкие плёнки из кобальта, наноколонны, напыление под углом

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Introduction

Magnetic thin films with easy axis normal to the substrate surface are of considerable interest as a promising material for ultrahigh density magnetic recording. However thin film growth at standard conditions leads to magnetization vector oriented in the plane of the surface. By controlling the texture parameters of the films during their growth, one can change their properties in a targeted manner, thereby achieving the required functional characteristics [1]. A promising method for the formation of films with special properties is their nanostructuring during growth. The formation of homogeneous and well-ordered arrays of nanostructures on the surface makes it possible to change significantly the electrophysical, magnetic, and optical properties of the films. One of the well-known technological methods allowing to ensure the growth of nanostructures is oblique angle deposition. It is a relatively inexpensive technology that can be easily implemented in conditions of mass production. This method of producing films has attracted considerable interest in recent years, and many works are devoted to it [2, 3]. It is known that this method can be used to obtain nanostructures of various shapes and sizes, from inclined nanowires and nanospirals to vertical nanocolumns [2]. It has been found that by varying the angle of incidence one can change the direction of magnetic anisotropy [4]. Besides that chiral nanostructured thin films can be produced through precise control of the angle of incidence of a vapor flux concurrent with substrate rotation [5]. It was found that the reason for nanostructuring of films under oblique deposition is the shading effect, which consists in the fact that crystallites, which received a random advantage in growth at the initial stages, further suppress the growth of neighbors, intercepting the flux of atoms incident on the surface and, thereby, forming pores. Main goal of this work was finding optimal conditions for the formation of perpendicular magnetic anisotropy in Co films using this method.

Experiment

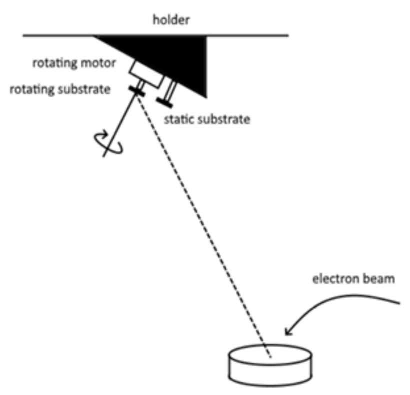

Fig. 1. Schematic of the experiment for the oblique angle deposition

Electron beam evaporation is a suitable technology for oblique angle deposition experiments. This method combines a sufficiently high working vacuum and a homogeneous flow of the evaporated material. Experiments on the deposition of Co films on an inclined substrate were carried out on an Oratoria-9 electron beam evaporation unit. The deposition conditions were as follows: base vacuum 4 10^{-6} Torr, electron beam voltage 8 kV, current 0.5 A. A standard single-crystal silicon wafer with a thermal oxide layer 300 nm thick was used as a substrate. During deposition substrate inclination angle was fixed to be equal to 85°. The distance from the evaporator to the substrate was about 1 m. This significant distance from the source of the evaporated material provided a high level of flow uniformity. Besides that the substrate was rotating around its vertical axis with variable rate. All experiments were done at room temperature. The growth rate of the film at these conditions was equal to 1 nm/s. The schematic of the experiment is shown in Figure 1. We used a collector motor to rotate the substrate at a controlled speed. The static sample was located as close as possible to the rotating one and is needed to compare with the results obtained on the rotating sample. The surface morphology of the obtained films was investigated by scanning electron microscopy (SEM) (Supra 40).

Results and Discussion

Cross-section of the film deposited at incidence angle φ = 85° and rotation rate of 30 rpm is shown at fig, 2, *a*. One can see that fibrous nanostructure is formed at these conditions. A rotation of the substrate during growth leads to vertical alignment of nanocolumns. More complete information about the morphology of the film is obtained from the analysis of top view on its surface shown at fig. 2, *b*. One can see that separate Co fibers have shape of nanocolumns extending upwards with the width less than 70 nm.

a) *b*)

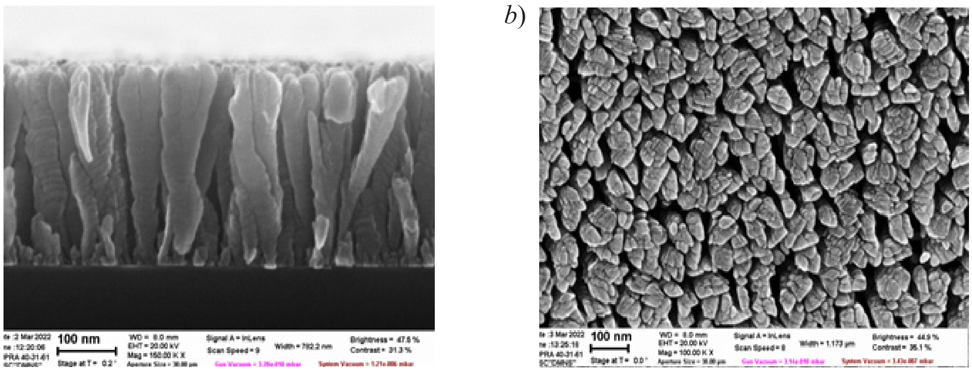

Fig.2: Cross-section of the Co film (*a*) and top view on its surface (*b*). The images were obtained using electron scanning microscopy (SUPRA-40)

The next experiment was carried out at the speed of rotation of 0.6 rpm and at incidence angle φ = 85°. Cross-section of the film is shown at fig. 3, *a*. One can see that vertical spiral nanocolumns are formed at these conditions. The analysis of the top view from fig. 3, *b* shows that separate Co fibers have shape of nanocolumns extending upwards with the width less than 100 nm. The fig. 3, *c*. and fig. 3, *d*. show the cross-section and top view of the static sample. These images confirm that spiral form of nanocolumns is the result of substrate rotation.

a) *b*) *c*) *d*)

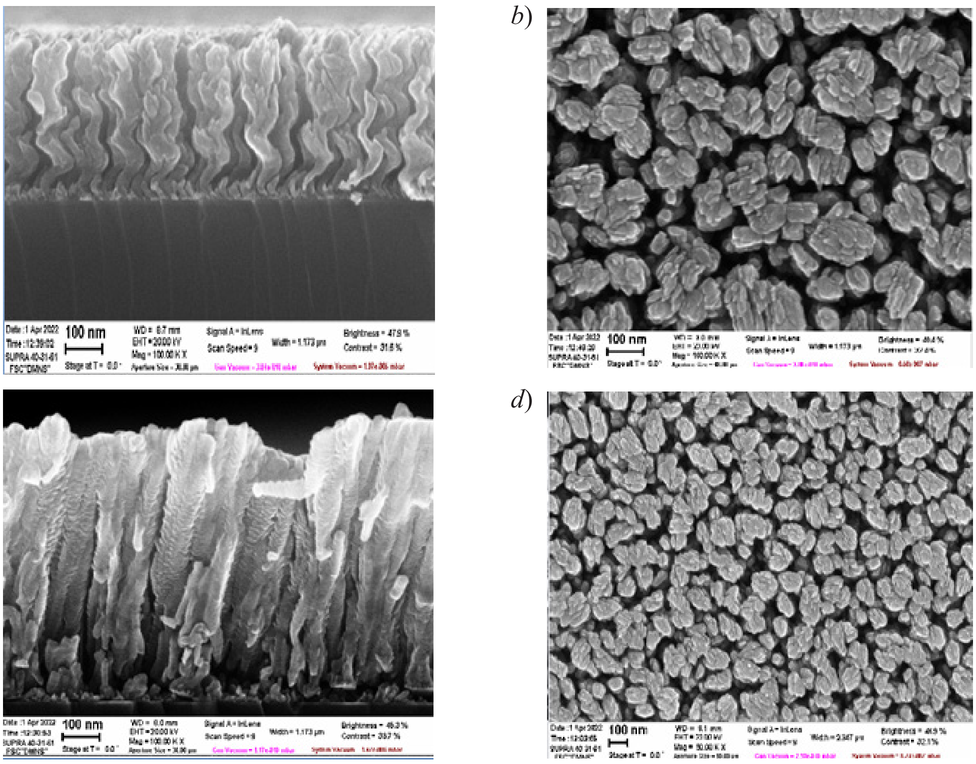

Fig. 3: Cross-section of the Co film (*a*) and top view on its surface (*b*). The images were obtained using electron scanning microscopy (SUPRA-40)

Conclusion

In summary, as the results of experimental studies of the growth of Co thin films by oblique angle deposition with rotation of substrate it was found that optimal conditions for regular arrays formation of nanocolumns and nanospirals, are achieved at the angle of 85°. By varying substrate rotation rate it is possible to change shape of nanocolumns from spiral to rod. Studies of magnetic properties of the films are currently in progress. Such films might be perspective for application in ultrahigh density magnetic recording.

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