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HIGHLY ANISOTROPIC PHASES IN THE CoPt FILMS: SYNTHESIS, MAGNETIC PROPERTIES

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The original Co(001)/Pt(111) film structure has been obtained by consequent thermal deposition of Co layer with a cubic crystal lattice and Pt(111) from the target sprayed using a magnetron sputtering technique on a single crystal substrate of MgO(001) in the vacuum of 10^{-6} Torr. In the experiments we have used the samples with the atomic ratio: 1Co:3Pt and 1Co:1Pt; total thickness is about 300 nm. The *X-ray diffraction analysis has shown that in two-layer structures with the atomic ratio of reagents 1/3, at temperatures of annealing T = 500 and 850 ºC in the interlayer chemical interaction, phases of epitaxial cubic compounds $CoPt_3$ ($L1_2$) are formed. The annealing of the same structures with 1/1 ratio leads to the formation of the second phase CoPt ($L1_0$) with tetragonal distortion. The newly formed $L1_0$ CoPt phase grows epitaxially on the base of the presynthesized $L1_2$ $CoPt_3$ phase with the same orientation relationship. The peculiarity of the films with atomic ratio Co / Pt = 1/1 at T = 850 °C is the presence of "perpendicular" anisotropy due to the exchange interaction of two formed ordered phases CoPt (111) and $CoPt_3$ (111).*

Keywords: solid-phase synthesis, film samples, perpendicular anisotropy, magnetic properties, crystal structure.

ВЫСОКОАНИЗОТРОПНЫЕ ФАЗЫ В СИСТЕМЕ ПЛЕНОК CoPt: СИНТЕЗ, МАГНИТНЫЕ СВОЙСТВА

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Исходные плёночные структуры получены последовательным термическим осаждением слоя Co с кубической кристаллической решеткой и Pt(111) из мишени, распыляемой с использованием методики магнетронного распыления на монокристаллическую подложку MgO(001) в вакууме 10^{-6} торр. В экспериментах использовались образцы с 1Co:3Pt и 1Co:1Pt атомным отношением общей толщиной порядка 300 нм. Рентгеноструктурные исследования показали, что в двухслойных структурах с атомным соотношением реагентов 1/3, при температурах отжига при T = 500 и 850 ^oC в результате межслойного химического взаимодействия формируются фазы эпитаксиального кубического соединения $CoPt_3$ ($L1_2$). Отжиги этих же структур с соотношением 1/1 приводят к формированию второй фазы CoPt ($L1_0$) с тетрагональным искажением. Вновь сформированная $L1_0$ CoPt фаза растет эпитаксиально на базе предварительно синтезированной $L1_2$ $CoPt_3$ фазе с тем же ориентаци-

онном соотношением. Особенностями пленки с атомным соотношением Co/Pt = 1/1 при T = 850 °C является наличие «перпендикулярной» анизотропии, обусловленной обменным взаимодействием двух сформированных упорядоченных фаз CoPt(111) и $CoPt_3$(111).

Ключевые слова: твердофазный синтез, плёночные образцы, перпендикулярная анизотропия, магнитные свойства, кристаллическая структура.

Introduction. The subjects of the research of solid-phase synthesis in thin-film samples are thin two-layer films or multilayers where reaction behavior at heat treatment is possible. The search of optimum conditions of solid-phase synthesis in thin films is carried out by practical consideration; therefore, there is no concrete understanding of mechanisms of solid-phase synthesis course [3–5].

In the work we study solid-phase synthesis of various phases obtained by consecutive annealing of the two-layer structure Co (001)/Pt (111) with various atomic ratio of the elements deposited on a single-crystal substrate of MgO. We also study the processes of formation of phases in the course of solid-phase synthesis as a result of heat treatment, structural, magnetic and anisotropic properties of synthesizable phases.

Experiment. The X-ray fluorescent analysis has been used to determine the thickness of Co and Pt layers. The identification of the formed phases has been carried out on the DRON-4-07 diffractometer (CuK_α-radiation). All initial Pt(111)/Co(001)/MgO(001) samples have been exposed to thermal annealing in the temperature range from 250 to 850 ºC with a step 50 ºC holding time 40 minutes at each temperature.

The atomic ratio / Pt ≈ 1/3. Figure 1 shows the diffractogram of an initial two-layer Co/Pt sample and the diffractogram of the same sample after annealing at T = 500 °C and 850 °C.

Annealing at T = 500 and 850 ° C contributes to the formation of the epitaxial cubic $CoPt_3$ compound.

Annealing at T = 850 ° C leads to the full formation of the epitaxially ordered phase $CoPt_3$.

The atomic ratio / Pt ≈ 1/1. By way of addition of the Co layer to the synthesized film sample, atomic structure in the sample has been brought to the ratio: $CoPt_3$ (111) to Co/Pt = 1/1. The received structure of CoPt 1/1 has been annealed at T = 650 °C again.

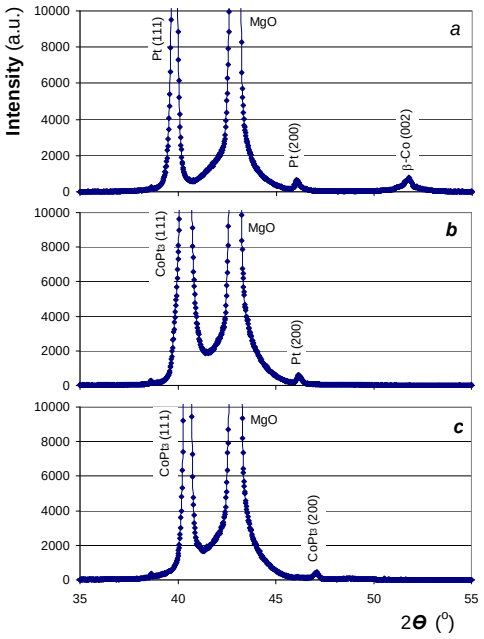

Fig. 1. Formation of the cubic phase $CoPt_3$ at heat treatment in the two-layer Co/Pt system with the atomic ratio of elements 1/3 besieged on a single-crystal substrate – MgO:
a – the layered structure of MgO(001)/So(001)/Pt (111) made at a temperature of a substrate – 250 °C;
b – temperature of annealing of layered structure at – 500 °C; *c* – temperature of annealing of structure – 850 °C

In figure 2 we can see that after annealing in the Co/$CoPt_3$ (111)/MgO system two hybridized phases are formed: $L1_2$ $CoPt_3$ (111) and $L1_o$ CoPt (111) which are most focused in the direction (111).

In figure 3 the dependence of size of coercive force on annealing temperature is shown. In this figure, it is possible to see that the value of coercive force increases, starting from the annealing temperature 450 °C. We can see that at the annealing temperature starting from 600 °C, perpendicular magnetic anisotropy appears.

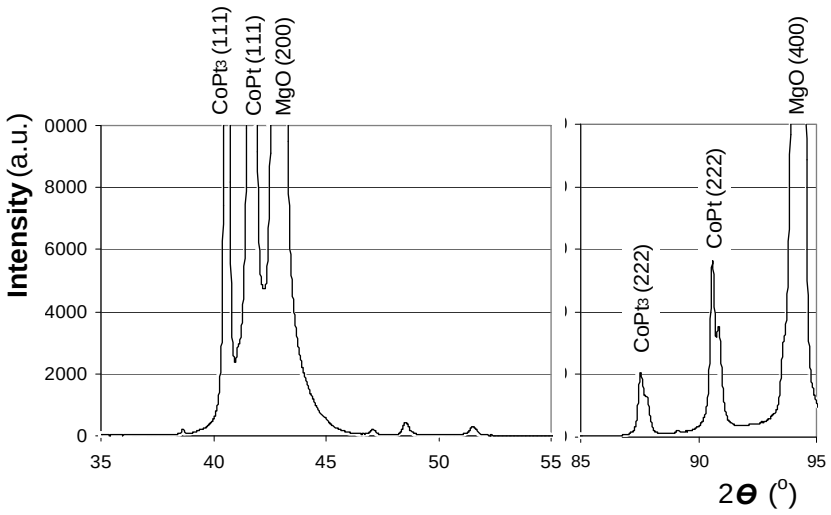

Fig. 2. Formation of cubic phases in the Co/$CoPt_3$ (111)/MgO system with the atomic ratio of elements 1/1 after annealing at T = 650 °C

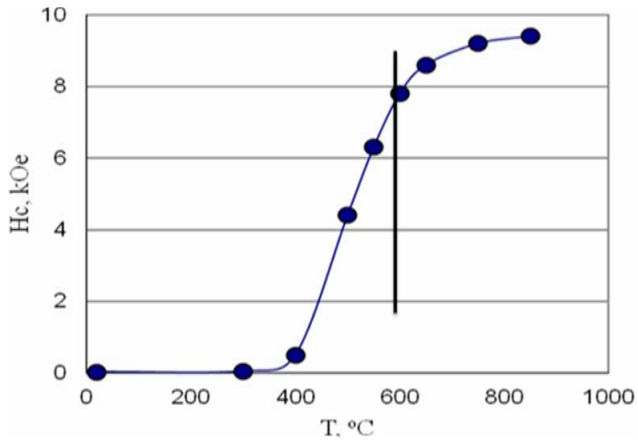

Fig. 3. Dependence of size of coercive force on annealing temperature

Conclusion. The possibility of using solid-phase reactions for formation of hybrid structure is shown: high-coercivity phase CoPt (111)-$L1_0$ and low-coercive $CoPt_3$(111)-$L1_2$ with the perpendicular magnetic anisotropy (PMA).

1. In a two-layer film Co(111)/Pt(111) with the atomic ratio of elements 1/3, MgO(001) besieged on a single-crystal substrate, at the annealing temperature T = 850 °C the cubic phase $CoPt_3$ with the plane (111) has been created.

2. By addition to the synthesized sample of $CoPt_3$ (111) of cobalt to atomic structure With / Pt = 1/1 is created hybrid structure of $CoPt_3$ (111)/CoPt (111) which at T = 650 °C shows:

– existence of perpendicular magnetic anisotropy (H_K ~ 80 кOe);

– high coercivity (H_C ~ 8 кOe);

– the nature of emergence of perpendicular magnetic anisotropy, in our opinion, consists in exchange interaction of the created magnetic phases CoPt (111)-$L1_0$ and $CoPt_3$ (111)-$L1_2$.

References

1. Hsu A. C., Lee Y. H., Wu T. H., Lee C. H. Influence of crystal structure on the perpendicular magnetic anisotropy of an epitaxial CoPt alloy // Journal of Applied Physics, 1999. Pp. 85–90.

2. Reichel L., Fahler S., Schultz L. Initial preorder as condition for $L1_0$ ordering in ultrathin CoPt films // Journal of Applied Physics, 2013. P. 114.

3. Zhigalov V. S., Myagkov V. G., Rybakova A. N. [Structural and magnetic properties of the Copts (111) films prepared using solid-phase reactions] // Vestnik SibGAU. 2015. Vol. 16, No. 1.

4. Zhigalov V. S., Mjagkov V. G. et al. Magnetic and Structural Properties of Granular Films Al_2O_3-$FePd_3$ Synthesized by Aluminothermy. Solid State Phenomenon. 2014. Pp. 215–218.

5. Barmak K., Kim J., Lewis L. H. et all. On the relationship of magnetocrystalline anisotropy and stoichiometry in epitaxial $L1_0$ CoPt (001) and FePt (001) thin films // Journal of Applied Physics, 2005. P. 98.