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Multilayer Magnetic Films for Hard Disks

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Abstract

The research paper covers production of multilayer magnetic films for hard disks. The authors considered ways of acquisition of multilayer magnetic films as data carriers for hard disks. The authors generalized practical experience of manufacturing, and also give the analysis of magnetic properties of experimental samples.

Keywords: multilayer magnetic film, coercitive force, scanning electron microscopy, hard disk.

INTRODUCTION

In development of devices with a high–density data recording the essential role is played by researches of data storage item.

Multilayer magnetic films are widely used at manufacturing of microwave electronic devices. One of the basic directions of development of microwave devices componental base is connected with designing of the ferrite devices constructions that meet technical and operational requirements of the systems.

The leading place among computer external memory devices is occupied with storage devices on hard disks, since the volume of the information that is stored on them is continuously increasing. A data carrier in storage devices on hard disks is the thin magnetic film. The thin-film technology [1] is mainly used for production of magnetic films.

Use of thin magnetic films in production of hard disks allows increasing data recording density, and it also has a number of advantages:

– allow to receive homogeneous coatings;

– posess high coercive force up to 120 kA/m and a residual induction up to 1.5 T at very small thickness of a working layer, that makes possible to increase considerably data recording density preserving sufficiently large value of a playback signal;

– allows to increase signal-to-noise ratio.

At use of thin-film technology, there are technological and other negative factors which have caused change in development to multilayer magnetic films in hard disks.

For manufacturing of data storage devices multilayer magnetic films possess a number of advantages over the single-layer ones: the additional degrees of freedom that appear in multilayer systems open new ways of the approach to problems which are difficult for solving in a separate thin film.

In multilayer structures the important role is played by the interaction between films of multilayer structures during a hard disk development. Owing to an exchange or dipole interaction between separate parts of the whole system the magnetic condition of one layer can influence a condition of another layer or several layers. Thus, the behaviour of various films appears interconnected.

METHODS

There are different structures of magnetically connected films, but the greatest interest is represented by the structure presented (Figure 1, a).

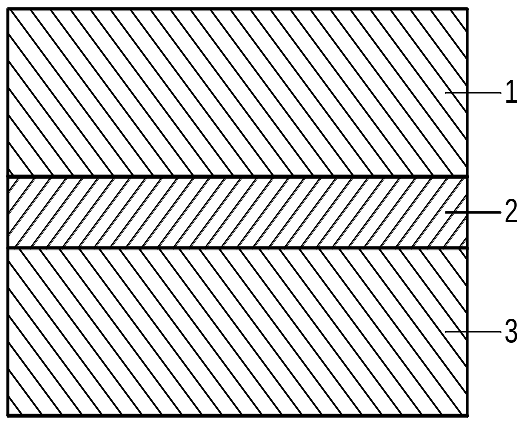

Figure 1 a: Structure in which two films are connected through a weakly–ferromagnetic layer (non–magnetic layer);

1, 3 – strongly–ferromagnetic layers;

2 – weakly–ferromagnetic layer

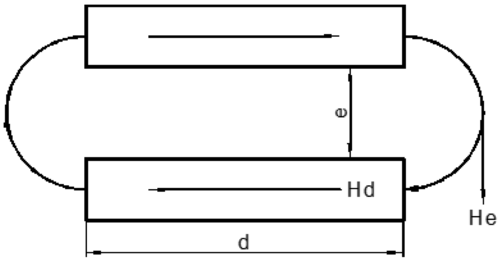

Figure 1, b: Model of connection through a scattered field for the structure represented in Figure 1, a.

Hd – demagnetizing field;

He – middle external field at the films' edges;

e – thickness of the intermediate layer;

d – diameter of the films

A structure in which two films are connected through a weakly–ferromagnetic layer (Figure 1, a). Two ferromagnetic films are connected through an intermediate weakly–ferromagnetic film. It is discovered, that, for example, for layers of an alloy 81 Ni - 19 Fe, separated by a palladium layer, the bottom and the top ferromagnetic films interact, when a thickness of intermediate palladium film is below some value (about 30 nm).

It should be noted that, that energy of connection between the top and the bottom layers is proportional to cosine of a corner θ between their magnetizability. The magnetizability of one layer operates like an effective field on the magnetizability of another layer [2].

The variant of production of multilayer magnetic films on the structure represented in figure 1a is the most perspective and applied now.

Two films represented (Figure 1, b) will tend to arrange their magnetizations antiparallel, to close a flow, i.e. the connection is negative.

If we consider two films with identical thickness, magnetizability and uniaxial anisotropy, which axes of easy magnetization are mutually perpendicular we will find out, that interaction of a pair of films with different anisotropy has the major practical interest. Using such structure it is possible to produce memory systems with reading without information destruction. Reading occurs with a "soft" (fast) film, and "rigid" (slow film) is practically not disturbed. Then, when the reading field is taken away, the magnetizability of the soft film is restored due to coupling.

Essentially important problem of platters manufacturing is the choice of a method of layering of thin magnetic films on a basis of a magnetic disk, as parametres of samples to a large degree depend on it.

Various methods of production of films are applied at manufacturing of multilayer magnetic films:

– cathode sputtering;

– magnetron sputtering;

– vacuum evaporation;

– chemical deposition.

Magnetron sputtering systems have a number of advantages in comparison with systems of electron-beam evaporation and high-frequency sputtering as shown in Table 1; they also find wide application in various areas of technics and industrial production [3].

Table 1: Comparative characteristics of methods of film coating layering

Ref. No	**Characteristics**	**Method of film coating layering**		
		Electron-beam evaporation	**High-frequency sputtering**	**Magnetron sputtering**
1.	Maximum specific power, W/cm^2	10	10^2	$5*10^2$-10^3
2.	Average current density, A/cm^2	(0.5-2)*10^{-1}	3*10^{-3}	3*10^{-1}
3.	Specific evaporation (sputtering) rate, g cm/s	(2-20)*10^{-3}	(2-20)*10^{-7}	$(4\text{-}40)^{-5}$
4.	Deposition rate, nm/s	10-60	0.3-3	10-60
5.	Substrate heating during deposition, K	up to 770	up to 670	up to 370

The method of magnetron sputtering provides more flexibility in alteration of coercive force, thickness of a film and use of light nonmetallic substrates that is of great importance as recording density increases. The technology of magnetron sputtering allows to apply a method of vertical recording that increases data recording density.

For the reasons stated above, the method of magnetron sputtering of thin magnetic films is the most perspective regarding increase of data recording density.

RESULTS

At present there is a large quantity of various designs of hard disks [4], but the basic part of a design is the multilayer magnetic film.

A variant of multilayer magnetic structure (a substrate - a sublayer - a magnetic material layer - a weak-magnetic material layer - a protective layer) was chosen.

Some versions of multilayer magnetic structure (table 2) were chosen for research in which composition of layers № 3 and № 5 vary.

Table 2: Structure and compositions of experimental samples of platters

№	Structure	Version №1	Version №2	Version №3
1.	Substrate compositional/diameter, mm	alloy Al-Mg1541/133	alloy Al-Mg1541/133	alloy Al-Mg1541/133
2.	Sublayer compositional/thickness, nm	Cr/500	Cr/500	Cr/500
3.	The layer of magnetic material compositional /thickness, nm	Co77Cr23/15-40	Co80Cr20/15-40	Co80Ni20/15-40
4.	Feebly magnetic material layer composition/thickness, nm	Cr/40	Cr/40	Cr/40
5.	Magnetic material layer composition /thickness, nm	Co77Cr23/15-40	Co80Cr20/15-40	Co80Ni20/15-40
6.	Protective layer composition /thickness, nm	TiN/100	TiN/100	TiN/100

General thickness of the layers applied on a substrate has made about 680 nm.

Table 3: Magnetic properties of experimental samples of platters

№	Hc, Oe	S_{Co}	U, mV	$\tau_{0,5}$, ns	A_{100}, mV	d, ns
$Co_{80}Cr_{20}$						
1.	420		48	280/240	140/110	51
2.	400		48	300/240	120/110	61
3.	420		96	240/400	160/300	42
$Co_{77}Cr_{23}$						
1.	83	0,59	58	200	400	85
2.	250	0,73	71	250	510	55
3.	130	0,65	33	300	600	48
4.	200	0,42	560	800	700	70
5.	290		40	300	60	59
6.	190		56	240	100	63
7.	200		48	300	110	59
$Co_{80}Ni_{20}$						
1.	608	0,76	70	400	200	48
2.	553	0,68	95	200	250	50
3.	563	0,71	75	300	200	40

As is obvious from table 3 samples of disks with coercive force H_c from 130 to 608 Oe and saturation magnetization I from 510 to 700 Gs were received. The squareness ratio of the films decreases with increase of H_c that conforms to existing conceptions.

The best parametres were achieved in samples with working layer $Co_{80}Ni_{20}$ (two layers $Co_{80}Ni_{20}$ with an interval between layers Cr), received by angular deposition in uniform technological process without opening the coating chamber. Following values of magnetic characteristics are received: the coercive force Hc is 600 Oe, the rectangularity of hysteresis loop S is 0.76.

The microstructure of the samples was studied with a method of raster electronic microscopy. The increase from 1000 to 10 000 was used. Samples with a working layer $Co_{80}Ni_{20}$ and sublayer Cr have a smooth perfect microstructure with chemically pure crystals. The size of crystals is less than 0.05 microns. The films have partically no defects.

The efficiency factor of the received samples and reliability of adherence film to a substrate is defined through review of adhesive properties.

For the purpose of increase of adhesive properties the substrates of magnetic disks were cleared by ion impact in the argon environment during 15 minutes (Figure 2).

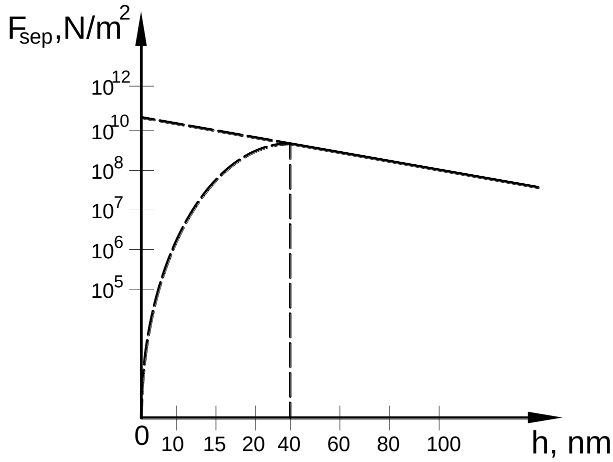

Figure 2: The dependence of adhesion *Fsep* from the film thickness h

The optimum thickness of a magnetic layer of 40 nm corresponds to force of separation 10^{10} N/m^2.

The dependences of coercive force from films thickness (Figure 3, 4) were investigated.

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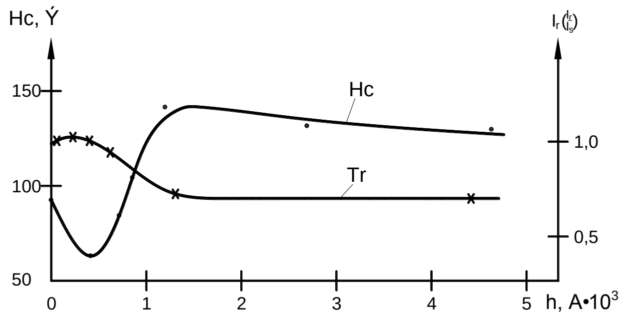

Figure 3: The dependence of the coercive force *Hc* and relative remanent magnetic induction $j\left(\frac{I_r}{I_S}\right)$ from films thickness *Co – Cr*. The density of *Cr* is 10%

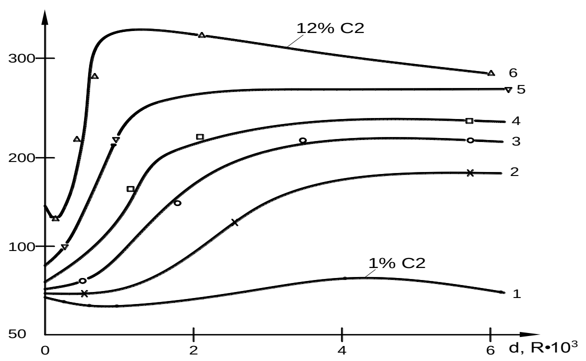

Figure 4: The dependence of the coercive force from films thickness *Co – Cr*.

Concentration of chromium, weight: 1 – 1%; 2 – 4%; 3 – 5%; 4 – 7%; 5 – 9%; 6 – 12%.

CONCLUSION

The experimental samples of the platter with data–storage medium from alloy films Co80Cr20, Co77Cr23, Co80Ni20 and a passivating thin-film coating from TiN are made and tested. The coercive force of the magnetic carrier is 200-500 Oe. The intensity of magnetization is up to 1000 Gs. The maximum recording density is 400-800 bits/mm. Use of the multilayer magnetic films received by a method of magnetron sputtering, consisting of working layers Co80Ni20 - Cr - Co80Ni20 has shown efficiency factor of application and has allowed to increase by 10-12 % data recording density.

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