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HIGH-COERCIVITY, LOW-NOISE SPUTTERED MAGNETIC DISKS

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1. INTRODUCTION

Recently, the high recording density of hard disk drives has maintained the speed of increase of recording density of 10 times in 10 years conformed to by the rule of memory capacity evolution from the beginning. As we entered the 1980's, the magnetic disk used with these equipment shifted from the particle coated disk to the continuous thin film disk and the magnetic head also shifted from the bulk head to the thin film head and were improved technologically.

To achieve still higher recording density in the future, high coercivity, low noise disks are essential. High recording density technology based on data recently obtained by Fuji Electric is described.

2. MATERIAL OF SPUTTERED MAGNETIC DISK AND HIGH RECORDING DENSITY

The layer structure of sputtered magnetic disk is described.

Al-alloy with electroless plated Ni-P is usually used as the substrate. The surface of this substrate is given a consistently rough profile by a texturing process. This process is effective in obtaining a desirable magnetic anisotropy. A Cr underlayer is sputtered on the substrate before the magnetic layer. Coercivity increase with Cr layer thickness as shown in *Fig. 1*. This probably occurs because making the Cr layer thicker makes the crystallographic orientation of the Cr (110) stronger and keeps the C-axis (axis of easy magnetization) of the Co alloy within the film plane so that it fits this orientation.

Let's observe the effect of these preparation conditions by taking a CoCrTa magnetic layer as an example. The conditions which effect coercivity are the substrate heating temperature, Ar gas pressure, and substrate biasing effect. The effect of these conditions is shown in *Fig. 2*. As can be seen from this figure, higher substrate heating temperature, lower Ar gas pressure, and higher bias voltage are effective in realizing high coercivity. Substrate heating accelerates compositional segregation of the CoCrTa magnetic layer and low Ar gas pressure accelerates the decrease of the grain size and the substrate bias promotes improvement of the crystallographic orientation of the magnetic layer by keeping the interface between the Cr underlayer and the magnetic layer clean, as well as the same effect as substrate heating. However, because these conditions are also used similarly during Cr underlayer sputtering, attention must be given their effect on the underlayer sputtering process.

Fig. 1 Coercivity (H_c) dependence on Cr underlayer

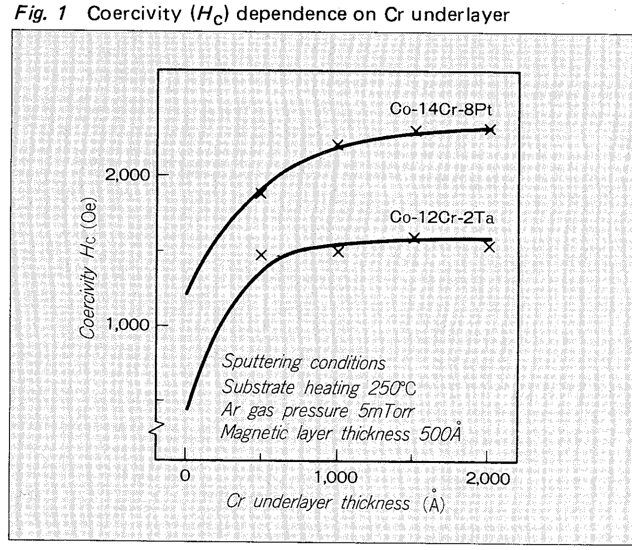


Fig. 2 Effects of sputtering parameters for coercivity of CoCrTa disk

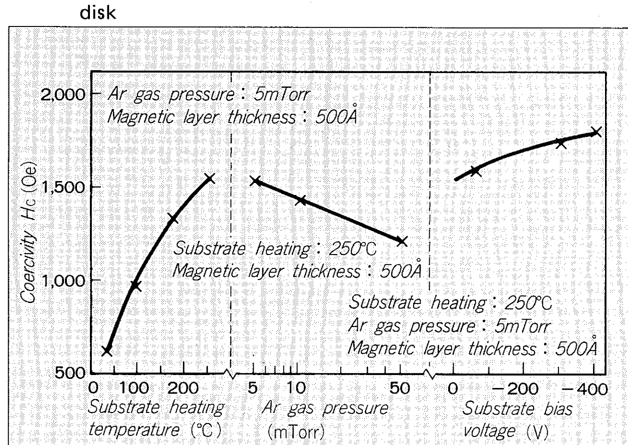
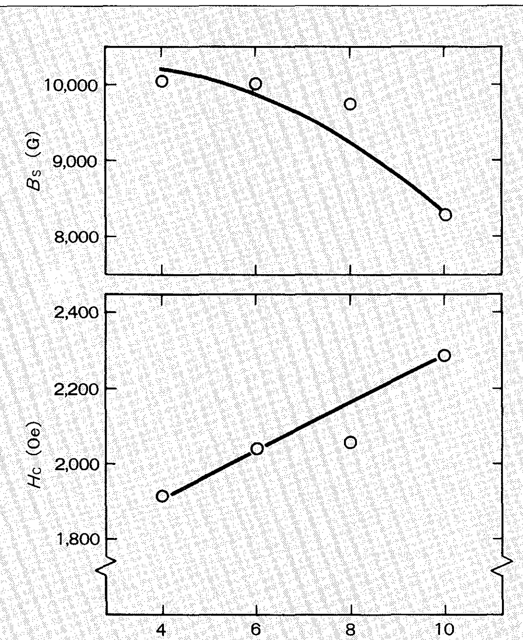


Fig. 3 Magnetics dependence on Pt content in CoCrPt disk



Pt contents x (at %) : ($Co_{90-x}\cdot Cr_{10}\cdot Pt_x$)
Sputtering conditions Substrate heating 250°C, Ar gas pressure 5mTorr, substrate bias voltage 400V, Cr underlayer thickness 1000Å, magnetic layer thickness 500Å

Fig. 4 Depth profile analysis of CoCrTa disk with S.A.M.

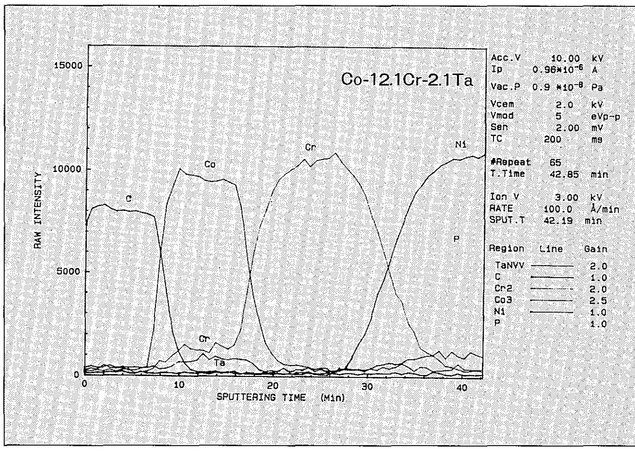
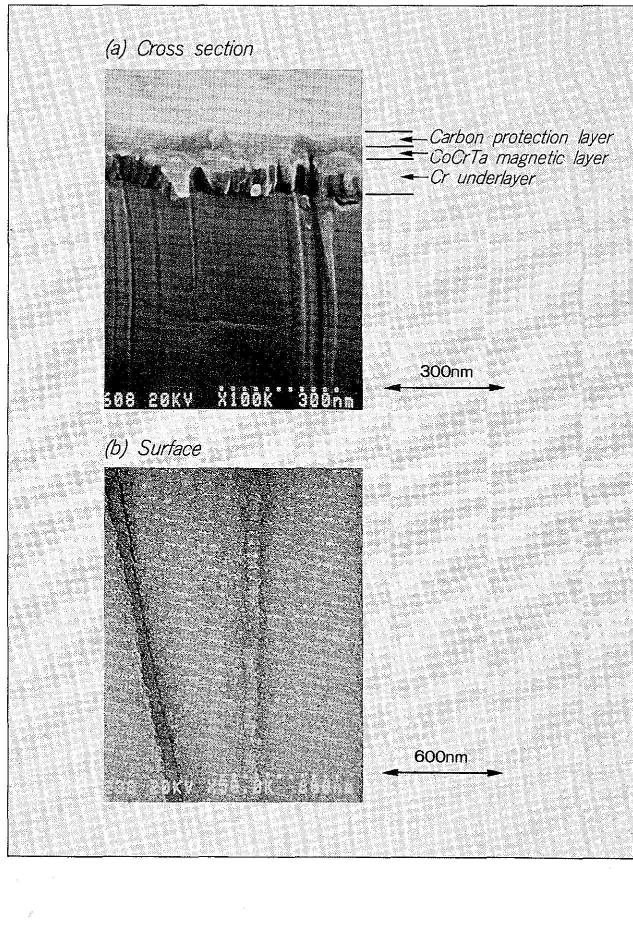


Fig. 5 Observation of CoCrTa disk with S.E.M.



Currently, CoNiPt and CoCrPt type disks are being practicalized. The former eliminates the need for a Cr underlayer by adding Ni and Pt, which increases the crystallographic magnetic anisotropy. However, to realize low noise, a means of increasing the grain boundaries of the Ni-P or other underlayer used instead of the Cr layer is necessary. The latter requires a Cr underlayer, the same as the CoCrTa disk. Basically, achieving high coercivity depends on the Pt contents. An example is shown in *Fig. 3*. For instance, a coercivity of 1,900 Oe can be achieved with 5% Pt and a coercivity of 2,300 Oe can be achieved with 10% Pt. Pt is a desirable material for the future.

The high coercivity and low noise conditions above can be summarized as follows:

(1) Shape induced magnetic anisotropy due to texturing on the Al/Ni-P substrate
(2) Crystallographic anisotropy due to Ni, Pt, and other additive elements
(3) With decreasing of grain size and decoupling of magnetic interaction between grains due to Ta and other addiitive elements
(4) Crystallographic orientation related to control of the interface fitting of underlayer and magnetic layer

3. MAGNETIC DISK MICROSTRUCTURE AND MAGNETIC CHARACTERISTICS

3.1 Analysis of magnetic disk microstructure

Making the structure clear by physical analysis of the high coercivity disk obtained by optimizing the various supttering processes as previously described is the guide to certification of models and to future material research. Some approaches to the analysis method are discribed, with our analyzed data as an example.

Figure 4 is data obtained with SAM (Scanning Auger Microscope). The composition ratio and homogeneity or impurity of the magnetic layer can be checked by analysis in the depth direction, as well as by surface element analysis.

Fig. 6 Observation of Co-alloy disk with T.E.M.

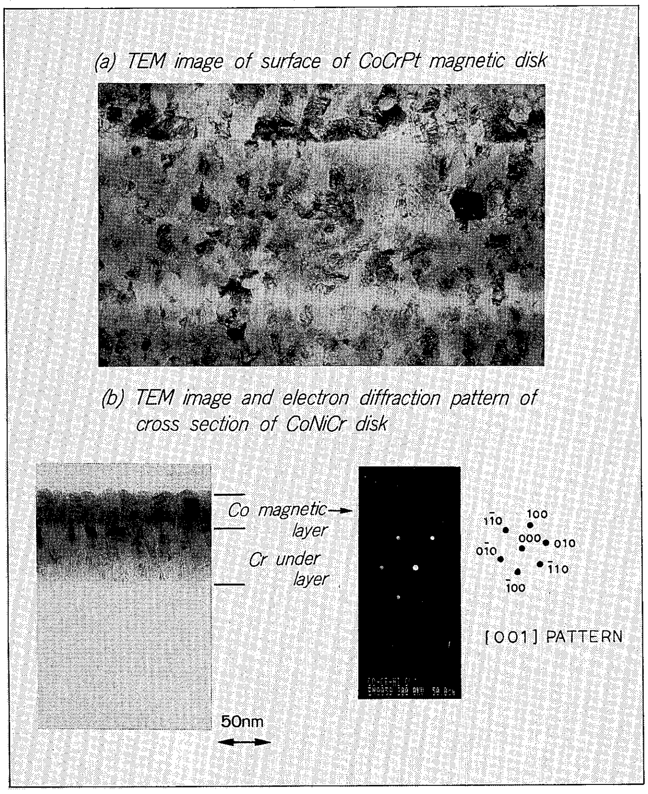


Fig. 7 X-ray diffraction measurement of CoCrTa disk

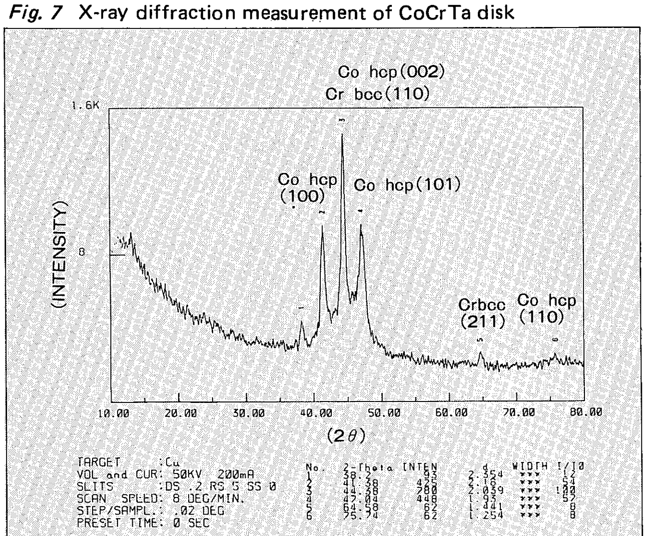


Figure 5 shows the data obtained with SEM (Scanning Electron Microscope). The structure of the film can be visualized by observation from the surface and cross section.

The appearance of each columnar structure and the clearness of the column boundaries or the interface fitting of the magnetic layer on the Cr underlayer and the isolation of the magnetic layer due to the Cr underlayer columns are seen. Moreover, the film growth influenced by roughness obtained by texturing of the substrate is observed from the cross section.

Fig. 8 Hystresis curves and remanence curves for Co-alloy disk

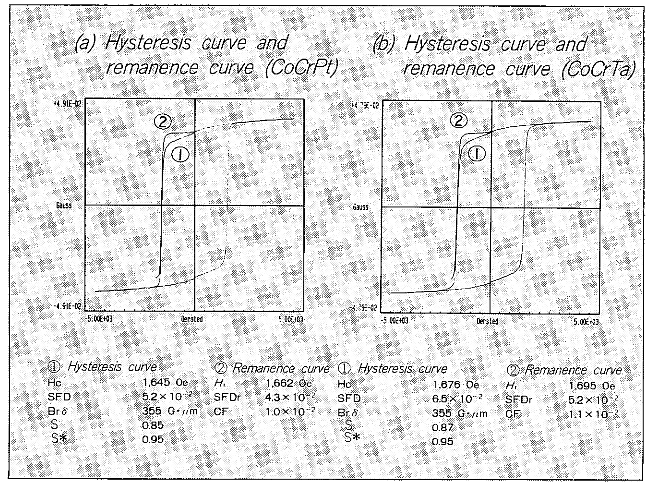


Fig. 9 Evaluation about decoupling of magnetic interaction with magnetic torque measurement

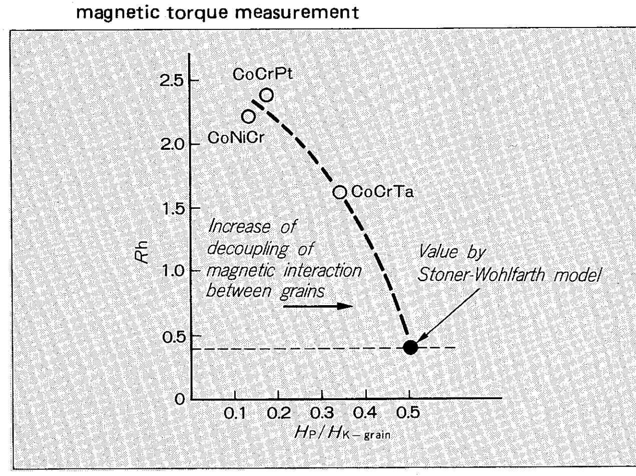


Figure 6 shows the results of observation with TEM (Transmission Electron Microscope). A larger image than that of the SEM image is obtained. The crystallographic grains themselves and the grain growth according to the texturing direction can be checked from the film surface. Its segregating structure can also be checked by combination with some etching method. From the cross section, analysis is on the Si wafer, but from electron diffraction directly irradiated on the Co layer, it was found that the same columnar structure as the SEM image had a C-axis in the plane.

The previously described Cr underlayer orientation and the orientation of the magnetic layer on the Cr layer can also be investigated from the X-ray diffraction shown in *Fig. 7*.

3.2 Disk magnetic characteristics analysis

In the past, magnetic characteristics were generally discussed by VSM (Vibrating Sample Magnetometer) hysteresis loop. Recently, however, several techniques based on magnetic recording or related to theory based on a model considering isolation among magnetic particles have been announced. One of these is the remanence curve on VSM. Another is magnetic torque curve.

Since the former is discussed in the magnetization state in which the applied field is zero, conforming to write and read mode correct correspondence with the parametrics is easy. Typical remanence curves are shown in *Fig. 8*. For the latter, from magnetic torque measurement, the rotational hysterisis loss Wr is derived, and the ratio Hp/Hk-grain of the applied field Hp that shows that Wr is maximum to the applied field Hk-grain by which that Wr disappears and the Wr integlated value Rh are obtained.
As shown in *Fig. 9*, which plots these, it is expected that the grain orientation and magnetic isolation increase from CoNiCr to CoCrTa.

4. HIGH COERCIVITY TECHNOLOGY

4.1 High coercivity technology

As previously described, if the Pt content is made large, the high coercivity needed for high density recording of the future can be amply secured with CoCrPt magnetic disk. However, if the disadvantages of use of Pt exist from the standpoint of cost, and if the Pt is excessive, the noise characteristics are also undesirable. Reducing the Pt content or aiming at a Pt-free magnetic disk without degrading the high coercivity characteristic will become a future problem. One thing currently being tried is a multi-element system and another is a multi-layered system.

Fig. 10 Coercivity dependence on doping elements to Co film

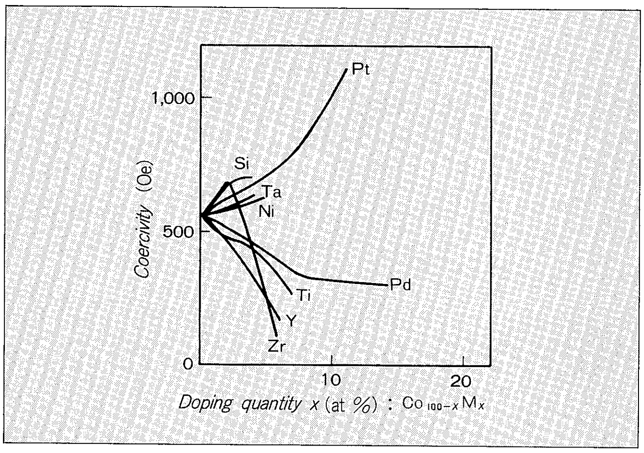
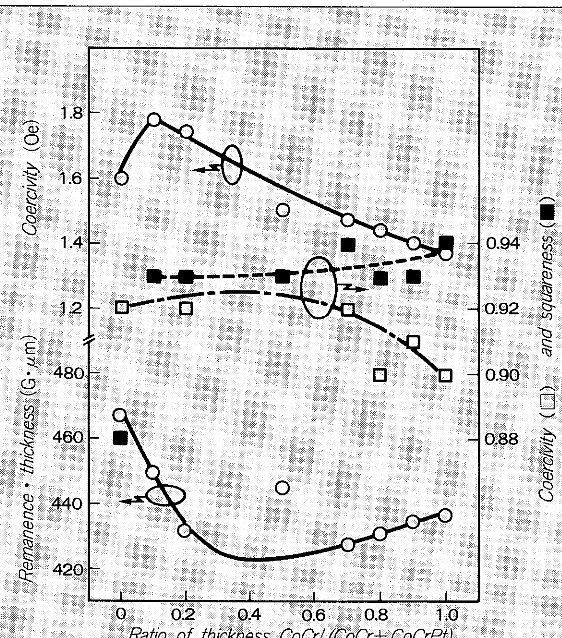
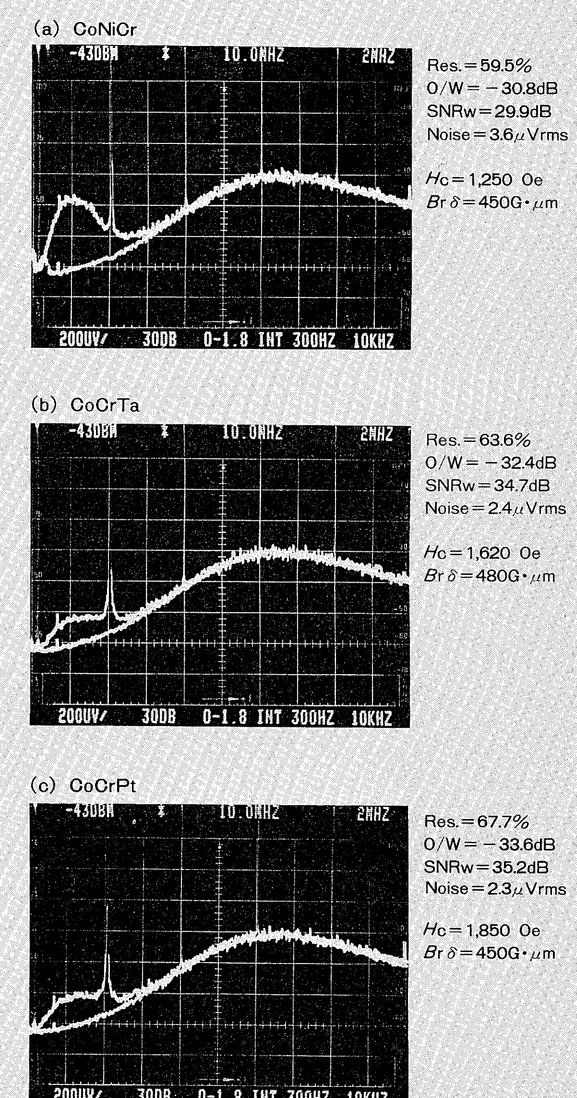


Fig. 11 Magnetics of CoCrPt/CoCr double layered disk



Sputtering conditions Substrate heating 200°C, Co total magnetic layer thickness 500Å, Ar gas pressure 5mTorr, substrate bias voltage −200V, Cr underlayer thickness 1,000Å

Fig. 12 Parametrics of CoNiCr, CoCrTa, and CoCrPt disks



Measurement conditions
Head : MIG monolithic
Gap length : 0.45μm
Flying height : 0.13μm
Recording density : 40kFCI

Fig. 13 Parametrics of CoCrPtX (X: 4th element) disk

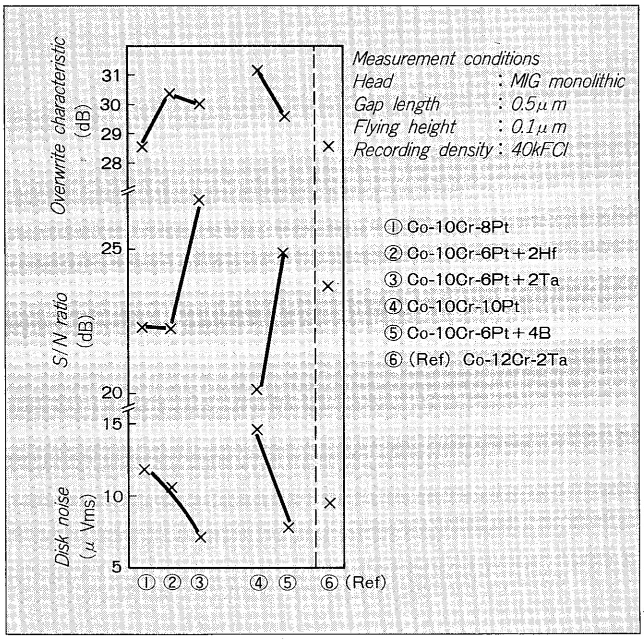
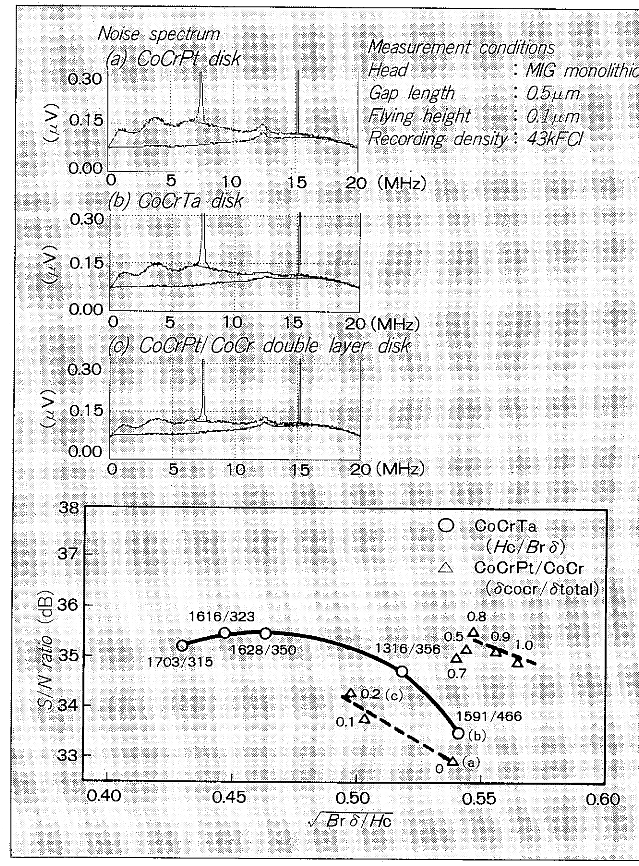


Fig. 14 Parametrics (SNR) of CoCrPt/CoCr double layered disk and CoCrTa disk



The former envisages the addition of Ta, B, Hf, or other fourth elements, in addition to CoCrPt. Conventional CoNiPt is also considered a Cr doping as a fourth element. CoCrPt, in particular, is expected to reduce the Pt content and lower the noise while providing the same coercivity by doping element.

As shown by the example in *Fig. 10*, the effect of Pt and Ni is greater than single doping to Co. It appears that a small amount of Ta, Si, or Zr also contributes to an increase of coercivity.

On the other hand, the multi-layered system is aimed at higher coercivity and many combinations are being studied. These are classified into two types. One consists of magnetic layers laminated through Cr or other non-magnetic layers and is an attempt to cut the magnetic interaction in the normal direction of the film. The other consists of magnetic layers laminated by changing the composition or the preparation conditions of the layers. A high coercivity and high squareness film is provided at the surface side and a comparatively low coercivity and low squareness (that is, low noise) film is provided at the underlayer side to improve the overall characteristics. The magnetic characterisitcs of the CoCrPt/CoCr double layered structure are shown in *Fig. 11* as an example.

4.2 Low noise technology

The actual read and write characteristics, including the output amplitude characteristic with actual magnetic head, are discussed. Since the output amplitude, overwrite characteristic, and S/N ratio are traded off with the magnetic characteristics of the disk, balanced overall performance must be realized.

The suppression of disk noise, together with high coercivity, is an important point in achieving high density recording. Just because low noise is obtained does not mean that squareness must be sacrificed. This is because it leads to a decrease of high frequency signal output and degradation of the overwrite characteristic.

The noise of the CoCrTa disk currently practicalized is shown in *Fig. 12*. Compared to the CoNiCr disk of the conventional composition, the Hc is increased and the low noise characteristics is improved considerably. The same noise characteristics are obtained at the CoCrPt disk, which provides higher coercivity.

As previously described, the adaptability of the sputtering conditions is taken into account and deduced from microstructure, the CoCrTa disk includes many elements which realize low noise. If pursued still farther with the CoCrTa disk, greater squareness is pursued and high frequency signal and overwrite characteristics are pulled up. Therefore, texturing of substrate, operation gas composion during sputtering, or review of the composition of the Co-alloy should be considered as future problems.

Speaking of CoCrPt, which is gaining attention in high coercivity, a study of the preparation process is thought to be necessary to realize low noise. As a result, how can high coercivity be realized based on how to reduce the Pt content? Examples of the study results are shwon in *Fig. 13* and *Fig. 14*. *Figure 13* shows the results by various doping elements to CoCrPt. *Figure 14* shows the data about

CoCrPt/CoCr multi-layer structure. The superiority and an un-deteriorated characteristic to CoCrTa shown as reference are known.

5. AFTERWORD

As also described at the beginning, magnetic recording technology is forecast to exceed 1G bytes/in^2 in the year 2,000 and has already been technologically established. The optimum technology to reach these targets must be taken from now. In these circumstance, availability of perpendicular magnetic recording should be confirmed, investigating contact recording method.

On the other hand, the magnetic head mounting an MR (magnetic resistance) element is expanding to the market as the next generation technology of the thin film head. At this time, the remanence of the magnetic disk can be reduced more than in the past, but the demand for high coercivity and low noise is expected to increase further during the study of the PRML (Partial Response Maximum Liklihood) modulation system.

In any case, the trend toward higher coercivity and lower noise of sputtered magnetic disk is considered to be common. Fuji Electric is scheduled to improve overall magnetic disk technology to meet these problems of the future.