UDC 621.382:681.327.63

SPUTTERED Co-ALLOY THIN FILM DISK

Tadaomi Kato
Akihiro Ohtsuki
Nobuyuki Takahashi

1 INTRODUCTION

Hard disk drives are taking up more and more important position as computer peripheral memory equipment in information processing system. This hard disk drive, following their success in practical use for a large-capacity system, are now making headway to evolute themselves into versatile systems like personal computers and word processors, so that they are sure to grow into a very large market in the immediate future.

There are two series of materials for magnetic disk that bear the most important burdens in the hard disk drive: namely, r-Fe_2O_3 series and Co alloy series. Among them, at present, the coatings type r-Fe_2O_3 series disk have a wider market share, however, there is a tendency also that appreciate more the adaptability of plating type Co alloy series disk, supported by market needs for more advanced compactness and further miniaturization of hard disk drive. The latest trends are to seek for still higher performance and many enterprises are studying on the possibility of adopting sputtered Co-alloy disk. Fuji Electric, taking full advantage of its advanced material technology, has started developing sputtered type Co-alloy disk permitting higher density recording, and succeeded in serializing the products of disk excellent in anticorrossive properties by adding a third element to Co-Ni alloy.

Fig. 1 Outer view of magnetic disk

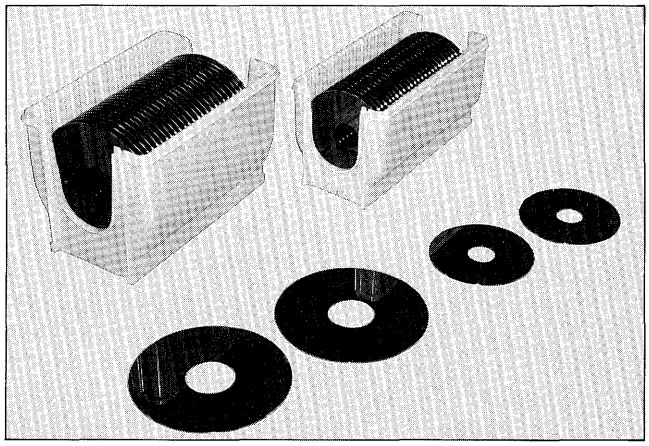
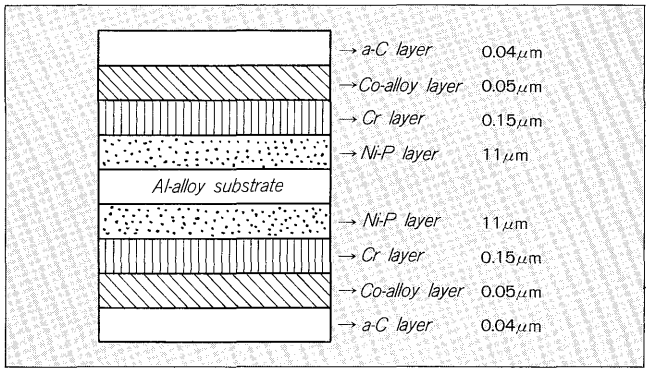


Fig. 2 Composition of basic layer of magnetic disk



2 BASIC STRUCTURE OF LAYERS

Fig. 2 shows a basic structure of layers of sputtered-type three-element alloy in Co base magnetic disk.

For disk incorporated into hard disk drive functioning as external memory equipment of the information processing system, the following features are required:

(1) High resolution
(2) Good gliding properties of magnetic heads
(3) That there should be free of error defects

And for these quality characteristics, a long-term reliability must be secured.

In order that a high resolution, that is, capability of high-density recording should be secured, the magnetic layer carrying out the function of electromagnetic conversion must be a super-thin and continuous film. For that, we have designed the magnetic layer thickness to be about 500 Å.

As for good running properties of the magnetic heads, we have provided Ni-P alloy layer on the Al alloy substrate and, at the same time, a carbon layer in amorphous state of 400 A in order to provide a protection for the magnetic layer and lubricating function between the media and the head.

In order to free from error defects, each of these layers

must be formed continuously in homogeneous condition, so that a high degree of control on processing of Al alloy substrates besides the film formation control techniques are required.

For attaining the required reliability, mechanical characteristics withstanding the repeated running of the head, as well as anti-corrosive properties are particularly required, so that in order to provide our products with that characteristic, Cr is added as the third element to Co-Ni alloy magnetic layer. That makes up one of the most important characteristics in our products.

3 OUTLINE OF MANUFACTURING PROCESS

Fig. 3 shows the outline of the manufactuing process.

The above-mentioned quality and characteristics are made real only through film forming technology of magnetic layer and amorphous carbon layer that carry a fundamental function, as well as Al-alloy substrate super-precision turning technology, pit-free non-electroless Ni-P alloy plating technique, super-specular processing technique controling surface roughness in the level lower than 0.01 μm, then, high-level environmental cleaning technique that eliminates even the smallest particles of dust. An accumulation of all these technoloogies are required to attain the quality of the products.

In order to control these qualities of manufacturing process, it is necessary that the enterprise should have technique for assessing the material characteristics, in the level of nano-microns, and further, for measuring the functional characteristics, including the electromagnetic conversion characteristics and reliability establishing the standards of the products, an analytical techniques on signal waveform in the order of nano-seconds are required.

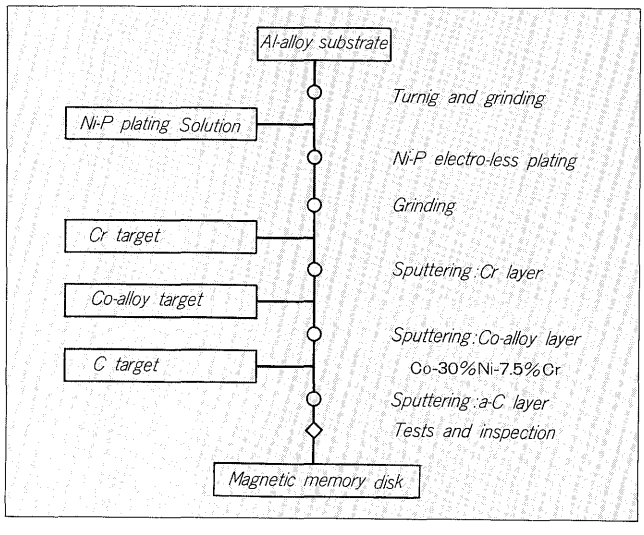
3.1 Al-alloy substrate manufacturing

Qualities required for Al-alloy substrates are:

(1) That there should be no defects causing signal error.

(2) That they should have high-level precision of shape and position in order to make head gliding and flying evenly.

Fig. 3 Manufacturing process of magnetic disk



As for (1), the important matter is how to choose Al-alloy having a high purity without non-metal inclusion and, at the same time, control on tools during the turning process, choice of grinding stone in the grinding process and cleaning method would be most important. For (2), it is important to choose homegeneous materials having no deforma and chucking method of substrates during the manufacturing process. In order to obtain high-quality products, we have carried out total quality assessment on each process of turning inner and outer diameters of Al-alloy substrates, surface turning, grinding and cleaning, as well as on manufacturing conditions including loading and unloading of substrates and method of transport, in order to construct an automaticized process line having a high throughput.

3.2 Ni-P alloy plating

We can state as the fundamental function that Ni-P alloy layers should have, as the following:

(1) A hardness that can withstand the shock from the head,

(2) Non magnetic properties and its high thermal stability.

Further, as their film forming qualities, they are required to have no defects causing signal errors, and that they have no local potentials that may constitute a core for developing corrosion.

In order to bring the fundamental functions into reality, we have established a plating condition together with a recipe for plating solution for making the phosphorus concentration in the plating film to be more than 11%. As the measures for suppressing causes of local defects and local potentials, we have adopted the method of continuous circulation of plating bath and pre-treatment solution by filtering with a filter of order of submicrons. Further, we have introduced a system permitting automatic measurements and controls on pH values of plating bath, phosphorus concentration and bath temperature through use of a computer.

3.3 Grinding

The surface qualities required for Ni-P layers are:

(1) That the head should be able to run stably with a flying height of 0.15 μm.

(2) That there should be a suitable roughness on the surface in order to prevent stiction of heads.

In order that the heads run stably, it is desirable that the surface of the Ni-P alloy layer be more specular. So we have decided to grind the surface up to average roughness of 0.005 μm, then in order to control the disk/head friction coefficent to a suitable value that would not hinder the stable running of the head, we did roughen the surface. For controling this roughness, we have adopted the tape texturing method.

Irregularities of grinding and redust of grind particles and stains during the grinding process would constitute film defect in later sputtering film formation process, causing

signal errors or head crashes, so that a high degree of quality control on grind particles, texturing tape and detergent liquid would be necessary.

3.4 Sputtering film formation

The grind substrates are brought to sputtering process after having undergone the super-high precision cleaning line. Film formation through sputtering method is carried out continuously by an in-line sputter equipment, first for Cr layer, Co-alloy layer and carbon layer by this order. The role played by Cr layer is to align the crystal growth of Co-alloy layer to a desirable direction, therefore, the control on Cr layer film formation is, together with that of Co-alloy layer, very important for obtaining good magnetic characteristics.

We can mention as the control factors determining the quality of film formation of each layer in sputtering process as follows: vacuum quality, argon gas pressure, sputter power and magnetic field. Furthermore, a fourth dimensional control, considering the time factor, becomes very important for securing the uniformity of orientation and thickness. Consequently, we have introduced a system by which these factors are monitored and controlled by computers.

Also, in order to prevent adherence of foreign matters that may cause signal errors or head crashes, for loading and unloading substrates to sputter equipment, robots are used, and maintenance works are brought periodically to the loading system of the sputter equipment and peripheries of targets.

3.5 Tests and inspections

Sputting film-formed disks are carried to test line passing through the burnish process, in order to eliminate surface in the submicron level. Blide height tests for checking the existence of minute proteberances and read/write tests for checking the electromagnetic conversion characteristics and existence of signal errors are routinized. This lines of tests are all controlled down to the environment of class 100 or less, and the test are conducted on whole numbers of disk in every aspect.

For measurement of protuberances and errors, high-degree signal detecting techniques are required, and in order to guarantee the quality of products, the test lines are systematized by adopting our own unique technology.
unique technology.

4 ELECTROMAGNETIC CONVERSION CHARACTERISTICS

The electromagnetic conversion characteristics, the principal functional characteristics in disk drive, are determined by the magnetic characteristics of disk and magnetizing characteristics of magnetic head. Among the quality characteristics representing the magnetic characteristics of the disk, residual magnetic flux density *Br*, coercivity *Hc*, their square ratios *S* and *S**, and the film thickness *S* are important. These characteristics values are determined to suitable values depending on the characteristics of the head to be used, however, each value does not exist independently one from another, but, the controllable range will be limited.

As the result of our studies on the correlation of electromagnetic conversion characteristics for each magnetic head emphasizing the importance of the following two points:

(1) High output voltage and high SNR.
(2) Good resolution and high recording density.

We are given to understand that as a magnetic characteristic for disk, it is more advantageous if *Hc* is higher. *Fig. 4* shows a typical magnetic characteristic for Co-alloy disk designed on the basis of the above finding by Fuji

Fig. 4 B-H loop

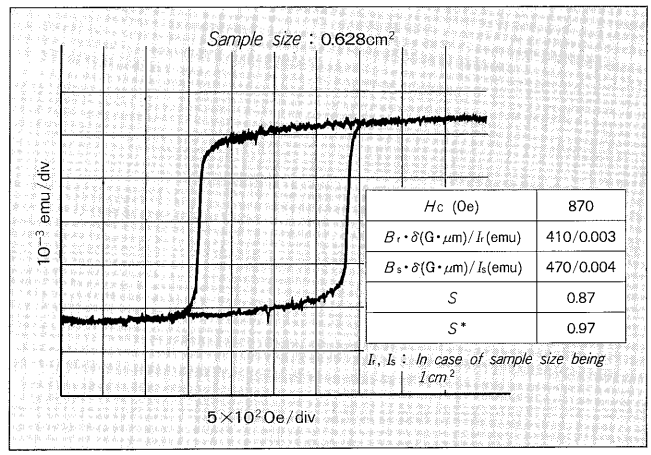
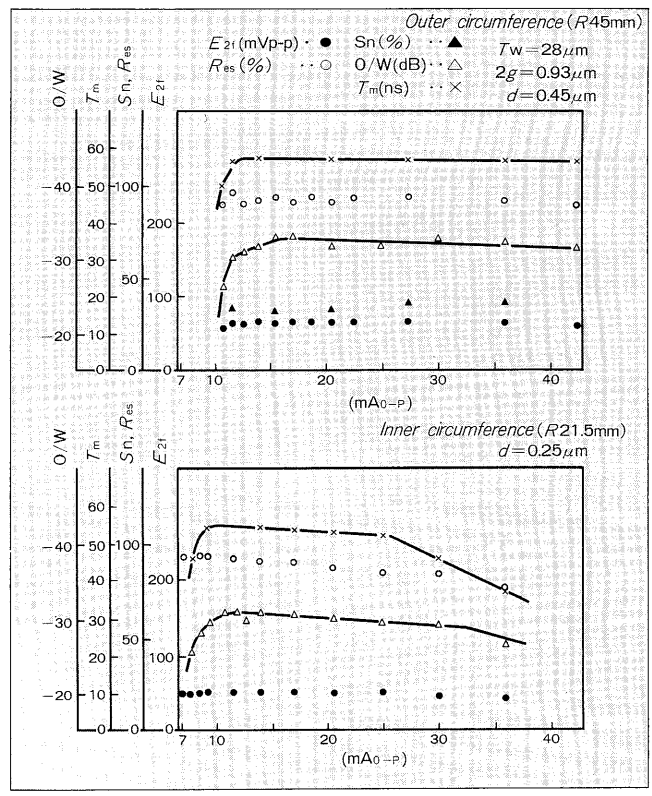


Fig. 5 Margin characteristics



Electric.

One of the most characteristic features in our product is that their *Hc* has been set higher than those of Co-alloy disk developed by other companies that are being introduced in the market now. Consequently, as the electromagnetic conversion characteristics of our products, we can mention the following, that is, that their output voltage has little dependency on frequency and they have high resolution, then, their over write characteristics, SNR and output voltage has little dependency on current, as well as they have ample margin of tolerance for variation in the head's secifications that determine the electromagnetic conversion characteristic as the flying height and the gap length of the head. *Fig. 5* shows the results of measurement of the margin characteristics.

Improvement of magnetic heads aiming at higher density and larger capacity of disk drive is expected to progress in a quick pace from now on. Together with this progress, the demand for high functionality of magnetic characteristics of the disk will also be larger. Fuji Electric has a technology that can control *Hc* and δ at will, and can swiftly cope with such demand.

5 MECHANICAL CHARACTERISTICS

Mechanical characteristics required for disk are:

(1) Good running properties of the head.

(2) That the disk must withstand the repeated use.

And these quality characteristics must hold for a long time.

The good running properties of the head are the factors evaluated by the increase of stiction generated at the time of contact between head and disk, increase of coefficient of dynamic friction in the sliding contact test, or increase in coefficient of friction after CSS (Contact Start Stop) test. When the coefficient of friction between head and disk increases, it not only impedes good running of the head but also, in extreme cases, causes head crashes.

Fig. 6 shows the result of stiction/friction test, and *Fig. 7* that of sliding contact test. Fuji Electric's disk, thanks to optimization of amorphous carbon layer film control and surface micro shape, have attained excellent low-adsorption and low friction coefficient properties. In disk devising improvement of lubricating performance by coating liquid lubricant, an increase with time of adsorption is recognized, and depending on the type of head materials, a large increase of friction coefficient is observed.

The evaluation of adaptability for repeated use of

Fig. 6 Stiction/Friction characteristics

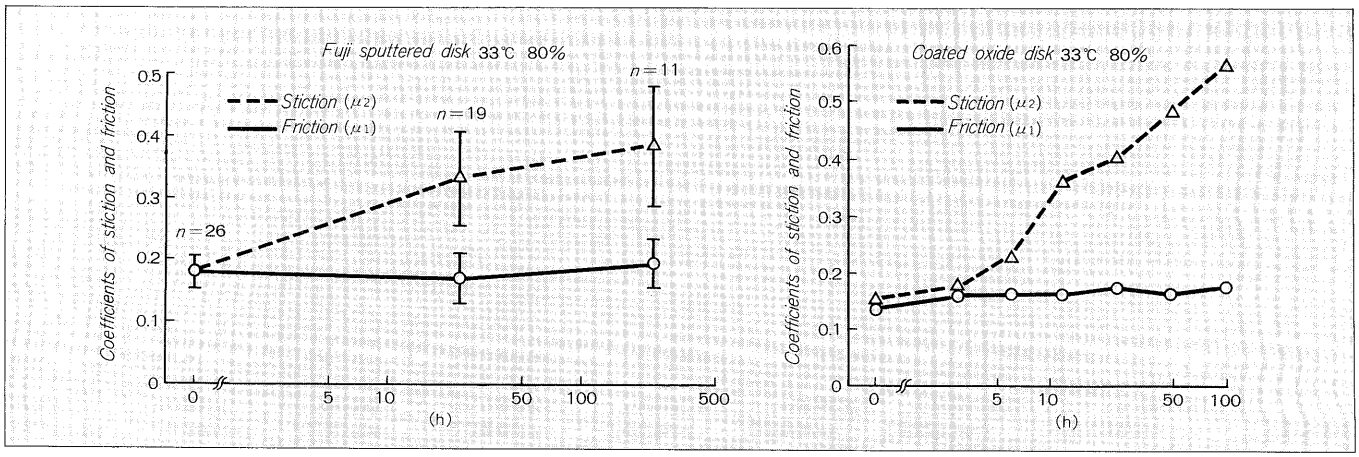


Fig. 7 Sliding contact test

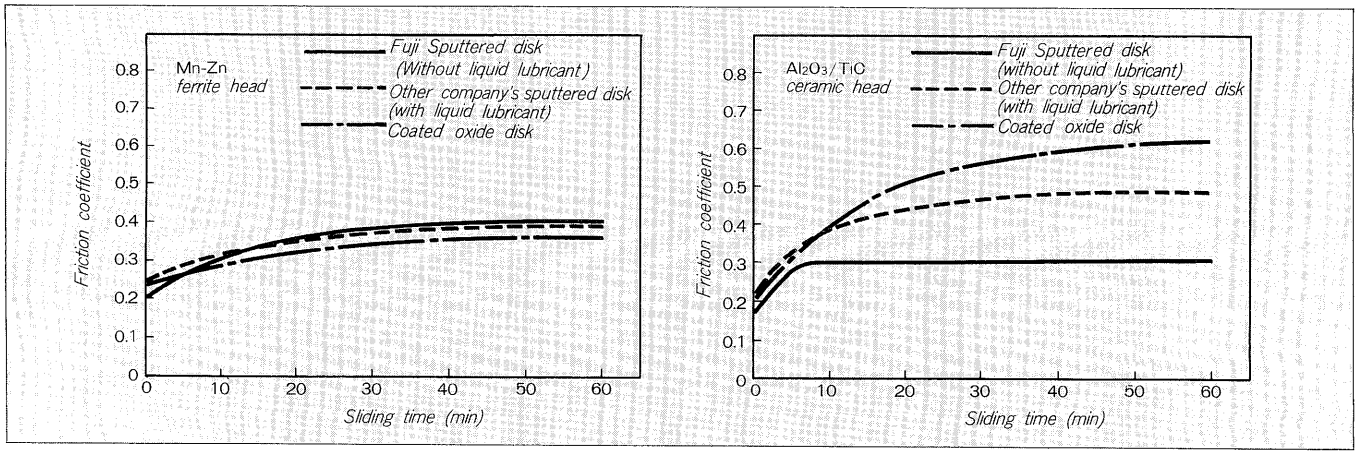
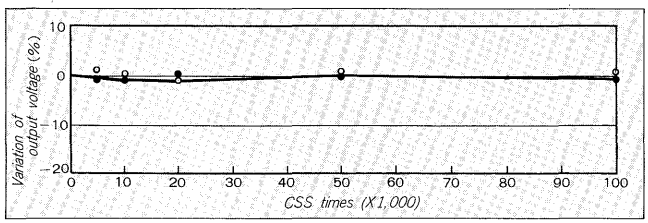


Fig. 8 CSS Test



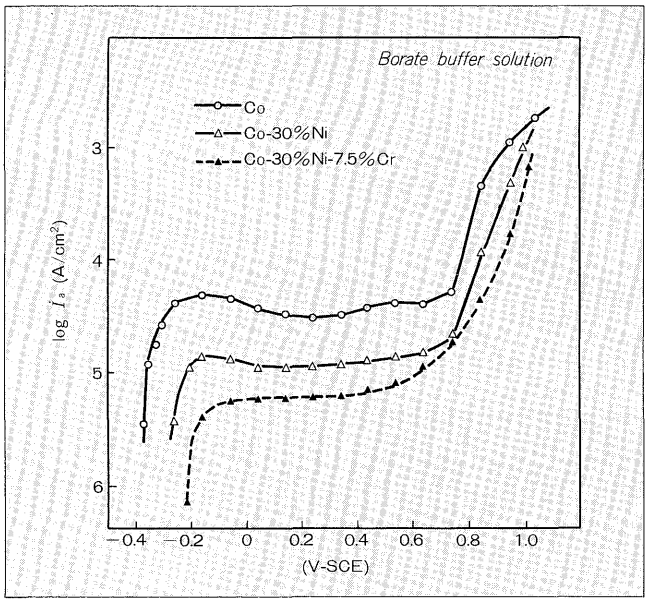
disk is, in the final character, confirmed by CSS tests. *Fig. 8* shows an example of the result of CSS test. Already, nearly 100 examples of CSS tests have been conducted on various type of heads under various environmental conditions, and we have not experienced any problem at all with the CSS tests. It is due, as we believe, to the fact that we carry out a rigorous quality control in a global way by constructing the whole process of the work after substrate manufacturing process, besides the optimization of carbon layer and surface micro shapes.

6 CORROSION PERFORMANCE

The corrosion performance of the disk is determined decisively by, besides the corrosion performance of magnetic layer, the quality of substrates and handling methods of media in and out of manufacturing process. For the quality and handling methods of substrates, we are trying to get the global improvement of quality by pursuing automatization of processing to the extreme through coherent control of the whole work.

The corrosion performance of the magnetic layer is ruled greatly by the chemical stability of passive-state film formed on the surface and their material and, for example, in the evaluation of anodic polarization curve in borate buffer solution, it is known that by adding Ni to Co,

Fig. 9 Anodic polarization curve



chemical stability is increased. Furthermore, when Cr is added to that composition, stability is further increased and corrosion will be inhibited, and its development will be much less. (*Fig. 9*)

This is proven true, if we observe the transit of magnetic characteristics when the substrate is left under the condition of 80°C, 85% high temperature, high humidity, that is comparatively near to the environment of use of the disk. In such environment, it was proved that the three-element alloy of Co-Ni alloy added with Cr, has shown the

Fig. 10 Test leaving under high temperature high humidity environment

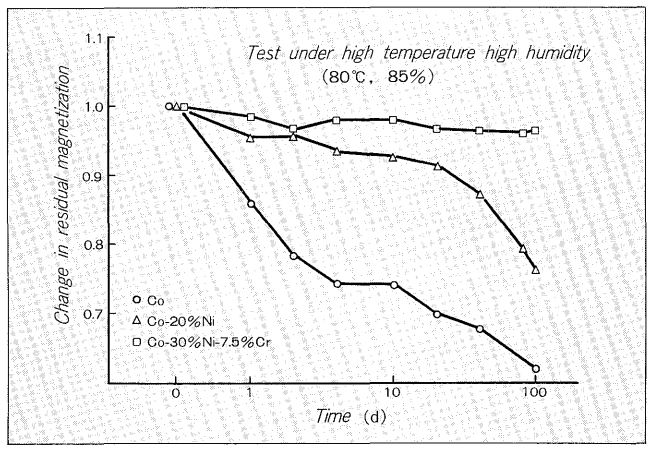


Fig. 11 Water dipping test (5 x 10^6 Ω-cm dipping in pure water for 900 hours)

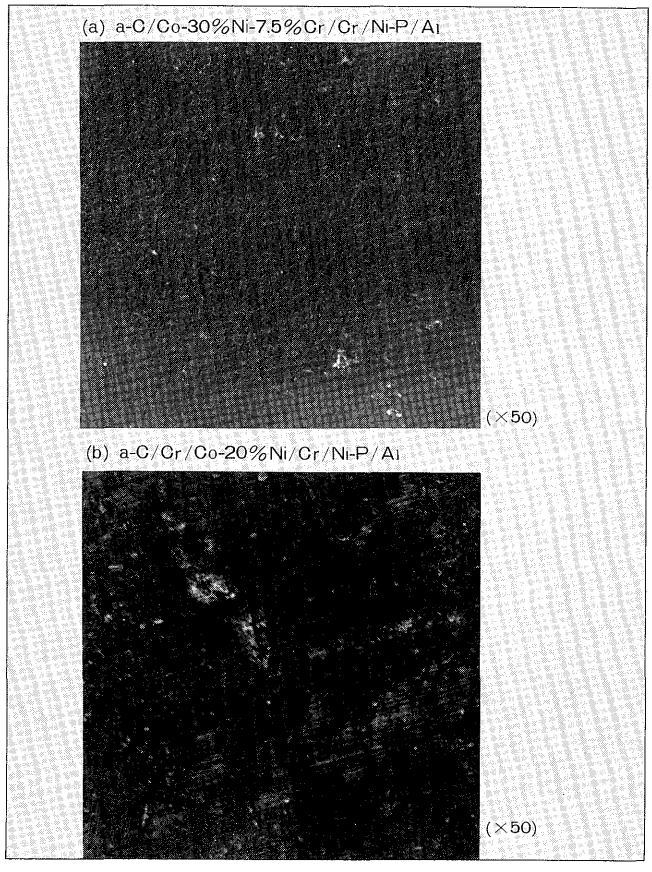


Table 1 Results of damp proofing test

Type of disk	No.	Drive	○: Good, ×: No good	Remarks
Fuji Sputtered disk, three elements of Co-Ni-Cr	1	A	○	N = 8 (NG: 0)
	2		○	
	3	B	○	
	4		○	
	5	C	○	
	6		○	
	7	D	○	
	8		○	
Sputtered disk, two elements of Co-Ni	1	B	×	→ Increase of error in 384 h.
	2		○	
	3	E	○	
	4		×	→ Increase of error in 1,000 h.
	5	E	×	→ Increase of error in 96 h
	6		×	
	7	C	○	
	8		–	→ Head crash generated (Evaluation suspended)
	9	A	○	N = 10 (NG: 5)
	10		○	
Plated disk Co-P two elements	1	D	○	N = 2 (NG: 0)
	2		○	

Test environment: 80°C, 80%, class 1,000
Test time: 1,000 hr. Drive operation mode: Non operating
Slice level: MP (55%), PMOD (135%), EP (35%), NMOD (65%)

most excellent corrosion performance. (*Fig. 10*)

Both anodic polarization curve evaluation and magnetic characteristic acceleration test aim at evaluation of global corrosion of the magnetic layer, but not the local corrosion presenting actual and effective problem of "new situation of generation of signal error". For qualitative comprehension of local corrosion, there is water dipping test. When the test piece left dipped in pure water is observed with an optical microscope, the local corrosion of magnetic layer observable with Co-Ni alloy is not at all observable in three-element alloy of Co-Ni-Cr. (*Fig. 11*)

The same can be said about the transition of error characteristics when the materials are left under high temperature, high humidity environment of 80°C and 80% by incorporating the disk into drive, and in comparison with disk manufactured by other companies in which Co-Ni alloy magnetic layers are adopted, the three-element disk of Co-Ni-Cr developed by Fuji Electric, are far more excellent in its anti-corrosion performance than any other disk of other maker. (*Table 1*)

7 CONCLUSION

As the needs for the next generation industrial technology to bring about the high-degree information society, the following attract the attention of great many:

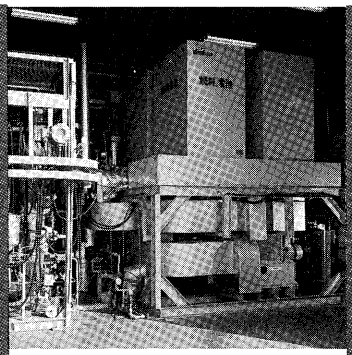
(1) Technology of measuring substance in submicron levels, then of processing and operating it
(2) Technology of analyzing state of substance and of controling with computers its central force.
(3) Technology of diversifying plural materials taking good advantage of the materials themselves, and of laminating them.

The accumulation of these material technologies has born already various sorts of memories and sensors counting from VLSI, and play a big role in information processing system. But further accumulation of these technologies will, as we foresee, make appearance of super-high density multi-function elements as super-latticed or three-dimensional possible in not so distant future.

Fuji Electric aims at development and manufacture of function elements that take up an important position in the sector expected as the next-generation fast growing industry as information processing system or mechatronics on the basis of pioneer material technology, and we endeavor for propelling formatization and complexification and micronification of material technology in those concerned with sputtered Co-alloy magnetic disk to improve the quality and, at the same time, we would like to combine effectively the techniques we have acquired here with development of next functional elements.

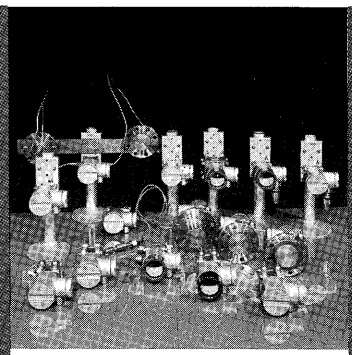
Outline of Products

Power and Industrial Electrical Machinery



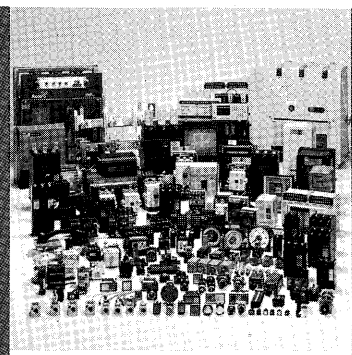
- Nuclear Power
- Power Generation and Distribution
- Transportation
- Environmental Equipment
- Industry
- Electrical Installation
- Mechatronics Equipment

Instrumentation



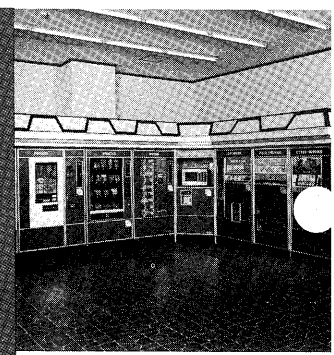
- Industrial Instrumentation
- Water Treatment
- Data Process Engineering

Standard Electrical Products



- IC (Integrated Circuit)
- Semiconductors
- Rotating Machines
- Standard Electrical Equipment

Vending Machines and Specialty Appliances



- Vending Machines
- Freezing & Refrigerating Open Showcases
- P.O.S. for Versatile Purpose Appliances
- Air Conditioning