Aluminum Substrate for 3.5-inch 1 TB Magnetic Recording Media

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ABSTRACT

By 2011, the recording capacity of commercially available magnetic recording media in a single 3.5” disk format is forecast to reach 1 TB. The formation of an ultra-smooth surface and the reduction of 100 nm-class small defects are technical challenges that must be overcome in order to realize higher recording densities. For this purpose, Fuji Electric is improving its aluminum substrate manufacturing processes, which include a ground substrate production process, a plating process, a polishing process, a washing process and the like. The small defects typically occurring during these processes include foreign particles, scratches, pits and so on. By analyzing defects one-by-one, classifying them and then determining their cause, the individual processes can be improved and quality enhanced to establish a substrate manufacturing process suitable for next-generation media.

1. Introduction

In recent years, the hard disk drive (HDD) has been the mainstream large-capacity storage device. With the widespread use, since the first half of 2008, of SSDs (solid state drives) using flash memory, however, requests for even larger capacity HDDs have intensified and the competition for their development has increased. For magnetic recording media used in HDDs, a recording capacity of 500 GB per 3.5-inch disk (500 GB/3.5-inch disk, hereinafter) was the mainstay in the market in 2009. Subsequently, the trend toward higher recording densities has accelerated and a hard disk drive having a recording capacity of 1 TB/3.5-inch disk is expected to be released in 2011.

Two types of substrates, aluminum or glass, are available for use with the magnetic recording media in HDDs. For notebook PCs, mobile consumer electronics and the like, glass substrates are used because of their excellent impact resistance and low power consumption. On the other hand, highly cost-effective aluminum substrates are used for desktop PCs and servers.

Fig. 1 shows the basic layer structure of magnetic recording media that uses an aluminum substrate. The magnetic recording media is fabricated by depositing on the aluminum substrate a soft underlayer, followed by an interlayer, a magnetic layer, carbon overcoat, and then a lubricative layer. A magnetic head flies over this surface of this magnetic recording media at a height of several nanometers to read and write information. Attaining the ability to control surface roughness and micro-waviness on the sub-nanometer order and the ability to reduce surface defects of 100 nm size so that a magnetic head flying at a height of several nanometers is able to record and playback information stably are technical challenges to be overcome in the development of substrates for magnetic recording media.

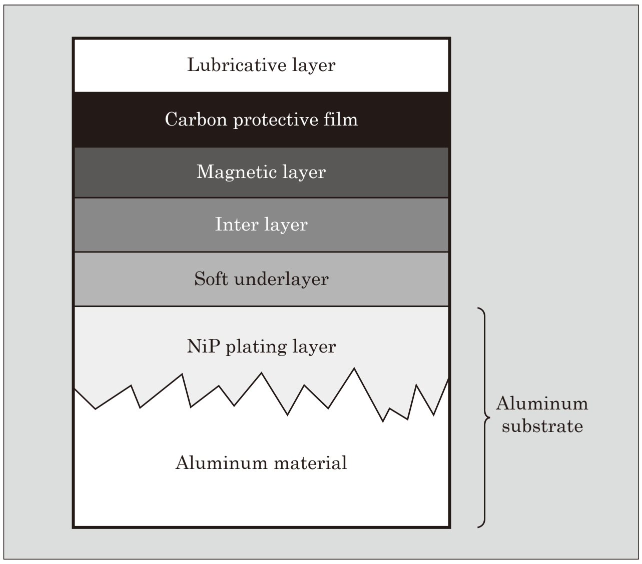

Fig.1 Basic structure of magnetic recording media

With increasing recording densities, the smoothness and uniformity of the substrate surface, which are factors that affect the electromagnetic conversion characteristics and HDI (Head Disk Interface) characteristics, are becoming increasingly important year-by-year. Surface defects include concave defects such as scratches and pits, and protruding defects formed by residues such as abrasives, detergent and NiP polishing residue. The complete elimination of these defects is impossible, but to meet satisfy requirements that become increasingly demanding year-by-year, efforts are particularly focused on reducing the incidence of such defects.

Fuji Electric has been developing, manufactur-

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ing and selling aluminum substrates for magnetic recording media for some time, and has continuously developed technology that supports higher recording densities. This paper introduces Fuji Electric's efforts toward attaining ultra-smooth surfaces and reducing defects in the development of aluminum substrates for magnetic recording media of 500 GB to 1 TB/3.5-inch per disk.

2. Substrate for Magnetic Recording Media

The aluminum substrate manufacturing process, as shown in Fig. 2, is sub-divided into a substrate grinding process wherein a disk of aluminum material is ground into the aluminum substrate known as the ground substrate (G substrate), a plating deposition process wherein NiP plating is formed on the aluminum substrate, and a polishing and washing process that smoothes the surface of the NiP plating.

(1) Ground substrate (G substrate)

An aluminum alloy is melted, casted and rolled, and then cut into a disk shape to form the aluminum material, the inner and outer end surfaces of which are then cut and the surface is ground to produce the G substrate. The dimensional accuracy of the media is determined by this substrate grinding process, and therefore the cutting and grinding are performed with high precision. Additionally, because the composition and cleanliness of the G substrate affect the defects and quality of the plating in the next processing step, the G substrate manufacturing process is constantly under review for improvements. Fuji Electric procures G substrates externally, but performs the plating deposition processing and subsequent manufacturing steps.

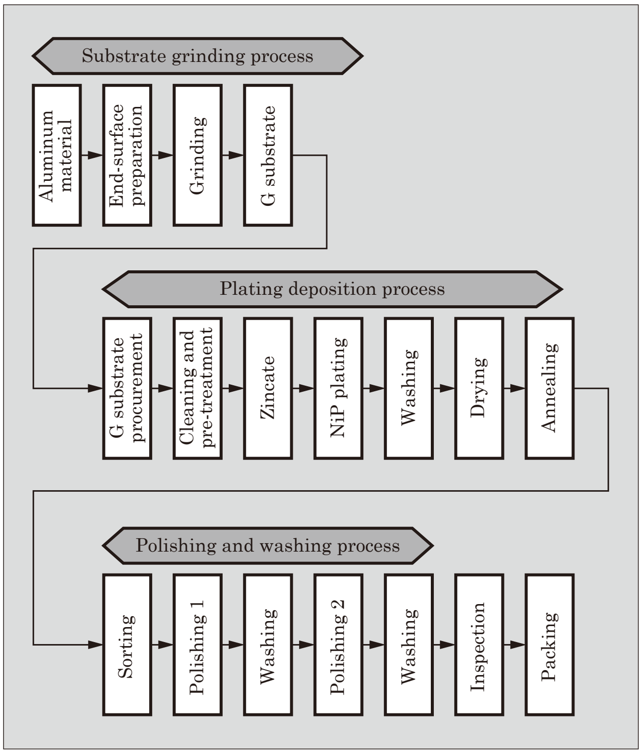

Fig.2 Overview of aluminum substrate manufacturing process

(2) Plating deposition processing

The aluminum alloy is lightweight and is easy to process, but its surface hardness does not meet the requirements for HDDs sufficiently. Therefore, in order to prevent damage when the magnetic head collides with the magnetic recording media, the surface of the substrate is plated with NiP.

The surface of the G substrate is chemically adjusted by cleaning, pre-treating and zincate processing, and then amorphous NiP is deposited to a thickness of ten-odd microns onto the surface by an electroless plating technique. Additionally, annealing is performed to release the internal stress generated during plating.

(3) Polishing process

The substrate surface is polished in order to smooth the substrate surface after plating and to remove grinding machining marks, waviness (wavelength: several tens to several hundred millimeters) and micro-waviness caused by internal stress during the plating.

Using urethane foam pads and a polishing liquid (slurry) containing dispersed abrasive grains, the NiP-plated surface is precision polished in two steps. Typically, the 1st polishing step uses a slurry or the like containing alumina abrasive powder and that is compatible with high-speed processing to remove grinding marks and waviness. The 2nd polishing step uses a colloidal silica slurry or the like to adjust micro-waviness and surface roughness. Furthermore, in order to use the outer peripheral area of the disk more widely as a recording area, it is also important that the end portion of the substrate be flat. A trade-off relation exists between smoothness and edge roll-off, however, and this is one reason why the development of advanced polishing techniques is requested[2].

Quality requirements for micro-waviness and surface roughness are becoming more demanding every year, and therefore the selection of components for the polishing process and optimization of the processing conditions are extremely important[3].

(4) Washing process

If the slurry used in the 1st polishing step remains beyond the 2nd polishing step, there will remain particles (Fig. 5(a)) formed from stuck abrasive grains, scratches (Fig. 5(b)) caused by aggregation of the abrasive grains, and pits (Fig. 5(c)) where the stuck abrasive grains have been removed. The washing after the 2nd polishing step must completely remove residue slurry material (abrasive grains and chemicals) and NiP residue from the surface after polishing.

Residue remaining on the substrate surface after washing will remain intact after the magnetic recording media is processed and may cause damage by colliding with the magnetic head. Therefore, residue and crud taller than the head flying height cannot be allowed. Residue on the substrate surface prior to deposition of the magnetic film is directly related to product defects, and therefore, as the recording density of magnetic recording media increases, higher quality is required of the substrate washing process each year.

3. Relationship Between Technical Issues and Processes for The Aluminum Substrates Used in Magnetic Recording Media

To support higher recording densities of magnetic recording media, aluminum substrate technology must overcome three major issues involving: (1) smoothness, (2) end shape, and (3) micro-defects and residue. Fig. 3 shows the linkage between these major issues on the left side, and the materials used and relevant processes on the right side. Intertwined relationships are shown, with each technical issue being related to multiple material and process technologies. An understanding of these relationships is necessary when promoting improvement and development work for aluminum substrates.

Table 1 shows representative surface characteristics required of aluminum substrates according to the recording capacity of the media. Requirements of the four parameters listed in the table become more demanding as the recording capacity of the magnetic recording media increases. In particular, improvement that reduces the number of defects is an important topic for development.

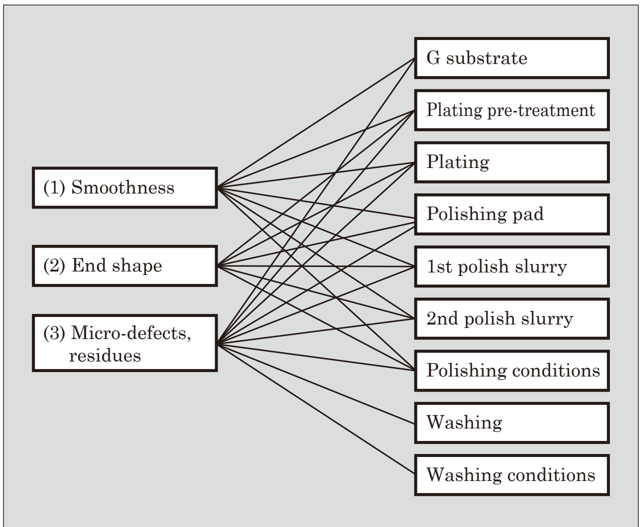

Fig.3 Relationship between main technical issues and materials/processes for aluminum substrates

Table 1 Required surface characteristics for aluminum substrates (3.5-inch)

	250 GB substrate	500 GB substrate	1 TB substrate
Surface roughness (AFM-R_a)	≤0.15 nm	≤0.14 nm	≤0.12 nm
Micro-waviness (W_q)	≤0.23 nm	≤0.14 nm	≤0.12 nm
Edge roll-off	≤15 nm	≤10 nm	≤7 nm
Relative number of defects*	100	70	30

* Relative number of defects assuming the average number of defects for a 250 GB substrate to be 100

4. Surface Smoothing Techniques

As noted in section 3, as recording densities increase year-by-year, the smoothness requirements of the substrate surface become more demanding. In order to develop an aluminum substrate able to satisfy these requirements, Fuji Electric has continuously been improving the polishing technology.

At the time of the transition from 160 GB/3.5-inch disks to 250 GB/3.5-inch disks, development focused mainly on the slurry (2nd step). In the development of substrates for 500 GB/3.5-inch disks and 1 TB/3.5-inch disks, all pad, slurry (1st step, 2nd step) and polishing conditions were reviewed, and technical development was advanced to attain both quality and ease of manufacturing.

The four key points in the development of the slurry are as follows.

(a) Optimization of the average size and distribution of abrasive grains in the slurry
(b) Optimization of chemical ingredients such as surfactants contained in the slurry composition
(c) Optimization of the polishing conditions
(d) Excellent rinsing characteristics

Also, the four key points in the development of pads are as follows.

(a) Provision of a foaming state that stabilizes the polishing rate on upper and lower surfaces
(b) Reduction of particles that cause scratches
(c) Optimization of elasticity to reduce edge roll-off
(d) Minimization of changes with aging (improved ease of production)

To improve the surface precision of the aluminum substrates, Fuji Electric jointly develops various components, such as the slurry and pads, and collaborates closely with the component manufacturers to develop sophisticated new materials and to improve the sub-

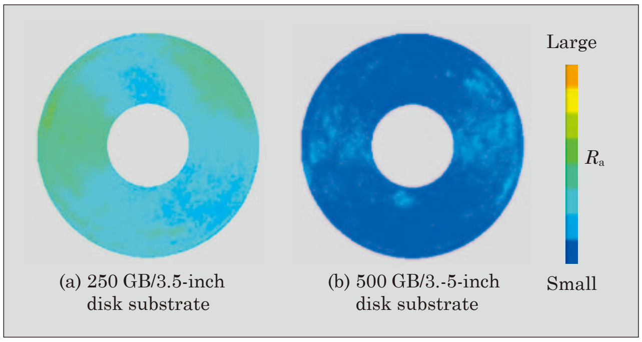

Fig.4 Aluminum substrate surface roughness distribution (R_a)

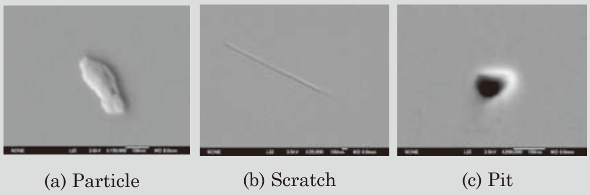

Fig.5 Representative micro-defects in aluminum substrates

strate characteristics.

Fig. 4 shows the surface roughness of a conventional 250 GB/3.5-inch disk substrate and the 500 GB/3.5-inch disk substrate presently being mass-produced as measured by an OSA (Optical Surface Analyzer). The 250 GB/3.5-inch disk substrate, measured with an atomic force microscope, achieves a surface roughness AFM-Ra of less than Ra 0.12 nm, which is a requirement of the 1 TB/3.5-inch disk substrate. As shown in Fig. 4(a), however, there is a wide distribution of roughnesses on the surface. For the 500 GB/3.5-inch disk substrate, slurry conditions for the 2nd polishing step and the like are improved, and as shown in Fig. 4(b), uniformity has been enhanced significantly by lowering the absolute value and reducing the width of distribution of the surface roughness.

5. Efforts Toward Defect Reduction in Aluminum Substrates for 1 TB/3.5-inch Disk Aluminum Substrates

Of the four surface characteristics listed in Table 1, surface roughness, micro-waviness and end shape have already been confirmed as attaining the required characteristics for 1 TB/3.5-inch disks. The most important issue facing development of 1 TB/3.5-inch disk substrates is reducing the number of defects, especially the reduction of the 100 nm class of defects known as micro-defects. Fig. 5 shows SEM (scanning electron microscope) photographs of typical micro-defects.

(a) Particles

Particles adhere mainly from the content of slurry residue, NiP polishing residue, and from the external environment. The majority of particles are removed by precision washing prior to deposition of the magnetic layer. Remaining particles that adhere or stick to the surface, however, may cause defects in media products.

(b) Scratches

Scratches are often caused by aggregation of abrasive grains and by external contamination of the polishing equipment or washing equipment. The occurrence of scratches is limited by controlling the equipment environment and filtering the slurry.

(c) Pits

Pits are caused by erroneous etching or by the removal of abrasive grains that had become stuck during plating deposition, polishing or washing.

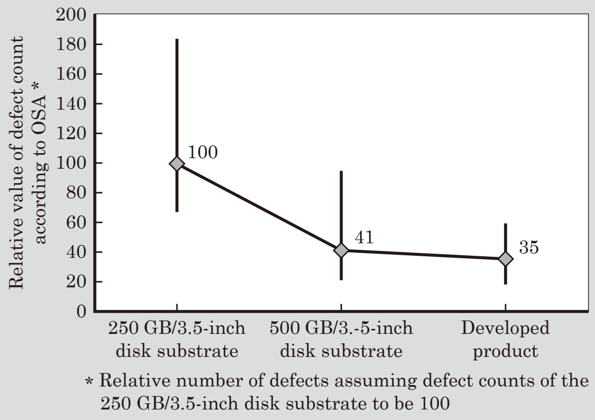

Fig.6 Comparison of number of defects for each generation of substrates

In the development of aluminum substrates for high recording density media, the reduction of micro-defects is a particularly important issue. As described with Fig. 3, because defects involve all materials and processes, optimization of materials and process conditions is being considered for processes ranging from plating deposition to polishing and washing.

Fig. 6 compares the number of defects measured by an OSA for various substrates, according to the recording capacity of the media. For the 500 GB/3.5-inch disk substrate, the plating pre-treatment, which includes the zincate treatment, and the polishing and washing processes have been improved, and all the required characteristics, including the number of defects, listed in Table 1 have been achieved. For 1 TB/3.5-inch disks, further improvements are being developed. The largest source of aluminum substrate particles is abrasive grains in the slurry; NiP polishing residue also tends to remain and presents a challenge for washing. In order to attain a smooth surface, the abrasive grains in the slurry are being made finer, and accordingly, NiP polishing residue is also becoming finer and more difficult to remove. Therefore, the surfactants and other chemical content in the slurry, and the detergent used in the washing processing are becoming more important.

Moreover, in order to eliminate slurry content residue and the NiP polishing residue, Fuji Electric is working to develop a cleaning agent. Accordingly, Fuji Electric is focusing on the following three items.

(a) Surfactant

Improving surfactants, which are low-molecular weight materials, to have high penetration toward particles and excellent rinsing characteristics.

(b) Alkali agent

Aiming to achieve a lift-off effect from etching action, an alkali agent applies an appropriate zeta-potential to a NiP plated surface and adhered particles, thereby enhancing the repulsive force and preventing re-adhesion.

(c) Chelating agent

A chelating agent having a high chelating effect on metal ions (Ni or the like) and excellence dispersion characteristics for abrasive grains.

6. Postscript

This paper has described the development status of Fuji Electric's aluminum substrates. The main challenge facing the development of aluminum substrates for 1 TB per 3.5-inch disks is the reduction of defects. Fuji Electric will continue to focus on this challenge while advancing development. The recording density of magnetic recording media is expected to continue to increase in the future, and further improvement of surface precision is required. This challenge will be solved by new technologies, and in order to attain the aluminum substrate characteristics suitable for evolving generations, Fuji Electric intends to pursuit improvements to plating technology, polishing technology and washing technology.