Polished Aluminum Substrates

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1. Introduction

Hard disk drives (HDDs) are a low-cost memory device capable of handling large amounts of data at rapid speeds. A market has been established for HDDs as external memory for computers, and the anticipated future applications to in-vehicle devices and home-use information appliances are expected to drive even higher rates of market growth. Accordingly, the development of higher recording densities has been remarkable and, in 2006, products that exceed 160 Gbits/in^2 were released to the market.

In the past, various materials have been studied for use in the substrate of magnetic recording media for HDDs, but for the types of HDDs installed in desktop PCs, servers, the recently popular HDD-DVD recorders, and the like, no alternative to high-quality and low-cost aluminum substrates has emerged, and future demand for aluminum substrates is expected to remain strong.

Fuji Electric has been developing, manufacturing and selling aluminum substrates for magnetic recording media, and has accumulated a wealth of world-class technology relating to plating and polishing and the know-how to manufacture aluminum substrates.

For aluminum substrates, technical challenges in achieving even higher recording densities are the control of 0.1 nm-order micro-waviness and surface roughness of the substrate and the reduction of surface defects of several nanometers in size so that recording and reproduction can be performed with the magnetic head flying stably above the surface of the media, even at 10 nm or lower ultra-low flying heights. Technical development is already making progress toward higher recording densities.

2. Aluminum Substrate Manufacturing Process

The manufacturing process for aluminum substrates is summarized below (Fig. 1(a)). Fuji Electric purchases grinded substrates and uses them to mass-produce aluminum substrates from the plating process onward.

(1) Blank process and grinding process

These processes consist of a blank process that melts, molds and rolls an aluminum alloy and then stamps out a disk shape, and a grinding process that mills inner and outer ends, performs chamfering, and then mills and planes the substrate.

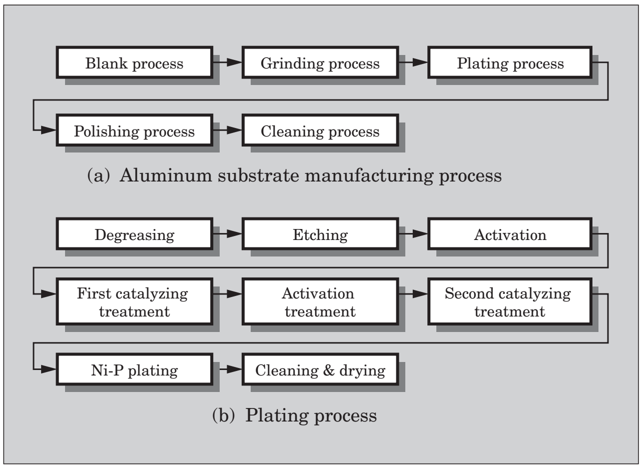
(2) Plating process

In the plating process, the surface of the grinded substrate is chemically de-oiled and cleaned by degreasing, etching, surface activation and catalyzing, and then is coated with an amorphous Ni-P film deposited to a thickness of several tens of microns by an electroless plating technique. The Ni-P film plating provides strength and hardness to the substrate so that it does not become damaged if the magnetic head crashes into the magnetic disk and also functions to provide a smooth surface by burying concave defects existing in the grinded substrate and by polishing the plated surface.

(3) Polishing process

In the precision polishing process, the substrate is heat treated to release stress created during the deposition of the film plating, and then using a foam pad, the substrate surface is polished with a polishing slurry (liquid mixture of processing liquid and polishing particles) containing freely dispersed polishing particles. The required level of quality for typical surface

Fig.1 Polished aluminum substrate and details of plating process



characteristics such as surface roughness, waviness and defects is continuing to increase toward higher recording density.

(4) Cleaning process

After polishing, precision cleaning is performed to remove completely from the substrate surface any remaining particulate residue containing slurry, residue of various component elements and dust from shavings of the film plating, and to complete the polished aluminum substrate.

3. Aluminum Substrate Plating Technology

The technology used in the main processes for obtaining a polished aluminum substrate, the plating and polishing processes, is described in detail below.

The processes for forming a Ni-P plating on an aluminum grinded substrate consist of pre-processing and plating processing. (See Fig. 1(b).)

(1) Degreasing process

The degreasing process removes metallic or organic residue contaminants adhering to the surface.

(2) Etching process

The etching process reduces the surface roughness of the grinded substrate, removes stray micro-pits, and removes the surface oxide film.

(3) Activating process

This process activates the surface so that catalyst particles will form uniformly and efficiently on the substrate surface in the catalyzing process that follows.

(4) Catalyzing process

This process is a surface catalyzing treatment prior to deposition of the Ni-P film plating. Differences in the composition, catalyst particle size and particle distribution of the catalyst solution cause variances in the uniformity of catalyst molecules on the substrate surface. Accordingly, this is a crucial process in which differences in stress, adhesiveness, and incidence of pit and nodule defects occur according to the control state of the initial deposition reaction of the film plating, and greatly impacts the roughness, waviness and quality of the substrate surface.

(5) Ni-P plating process

The Ni-P plating solution consists of many components, including a Ni metal salt, a reducing agent that initiates the reaction, a complexing agent for stabilizing metal ions, a buffer agent that suppresses fluctuations in the pH of the solution, a stabilizing agent that suppresses breakdown of the solution, a surface activating agent that enhances wettability of the surface, etc. In order to retain the aforementioned 0.1 nm-order surface precision, the composition of the Ni-P plating solution is also required to be highly optimized. If the composition is inappropriate, surface strength decreases, plating adhesiveness decreases, thermal resistance decreases due to increased film stress, pit and nodule defects increase, surface roughness increases, and decomposition of the plating solution causes the lifespan of the solution to decrease and other various problems to occur. Thus, in order to improve the characteristics (roughness, waviness) of a substrate surface capable of supporting the higher recording densities of the future, and to reduce surface defects and to improve throughput by increasing the lifespan of the plating solution, the pursuit of an optimized plating solution composition is becoming increasingly important for technical development.

4. Aluminum Substrate Polishing Techniques

(1) Advanced polishing technology

Increasingly higher levels of surface smoothness and cleanliness characteristics, i.e., surface roughness, micro-waviness, defect level, etc., are being required in aluminum substrates that support high recording densities. Table 1 lists the required surface characteristics of polished aluminum substrates. The development of polishing techniques is steadfastly continuing to achieve ultra-smooth and ultra-clean polished aluminum substrates, and polishing techniques are constantly being improved.

The polishing technique is determined by the type of foam polishing pad, polishing slurry and process conditions used, and the four main control parameters are listed below.

① Appropriateness of chemical etching components included in the slurry composition
② Appropriate control of size and shape of grinding particles (such as alumina and silica) contained in the slurry
③ Improved pad hardness and compressive elasticity modulus according to the materials and foaming process used to fabricate the polishing pad
④ Appropriate conditions for the polishing process

Aiming to improve the surface precision of present-day aluminum substrates, Fuji Electric is developing advanced new materials and improving substrate characteristics by working closely with materials manufacturers to develop jointly the representative polishing materials of slurries and pads.

Also, as methods for reducing residue, i.e., the particles and processing dust contained in the slurry during cleaning after the polishing process, Fuji Electric is

Table 1 Surface characteristics required of polished aluminum substrates

	80 GB substrate	160 GB substrate
Surface roughness (R_a)	≦ 0.30 nm	≦ 0.20 nm
Micro-waviness (W_a)	≦ 0.10 nm	≦ 0.06 nm
Defect size	≦ 0.20 µm	≦ 0.10 µm
No. of scratches*	1.00	≦ 0.03

* Relative number of defects where the number of defects for an 80 GB disk are denoted as 1.

Fig.2 Surface roughness of polished aluminum substrate (AFM)

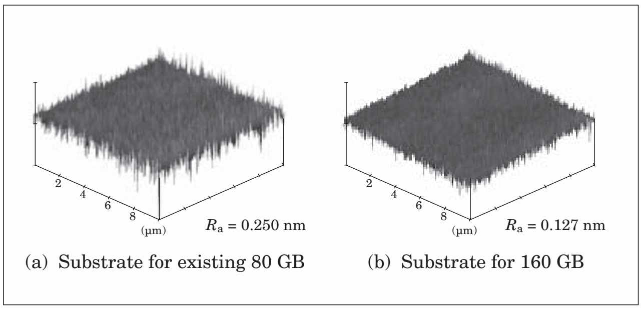
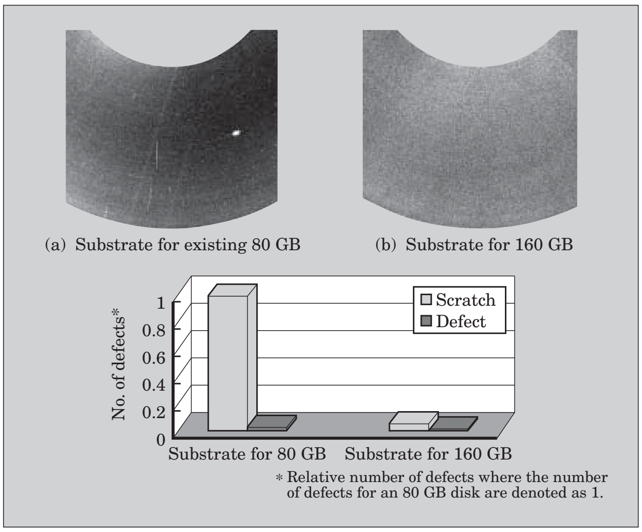


Fig.3 Surface defects of a polished aluminum substrate



studying the

① use of a slurry process solution having good detergency, and

② application of a detergent having good detergency and rinsing performance for the particles and process dust,

and is also simultaneously increasing the cleanliness of the polished aluminum substrate.

(2) Improved surface characteristic of polished aluminum substrates

As examples of the results of the technical development described above, Fig. 2 compares the surface roughness of an aluminum substrate for magnetic recording media having a conventional 80 GB/disk (3.5-inch) recording capacity and the surface roughness of a newly developed aluminum substrate with the next-generation specification of 160 GB/disk, as observed with atomic force microscopy (AFM). The amount of surface defects on these two types of media, as measured with optical defect detection equipment, is compared in Fig. 3.

With the next-generation 160 GB/disk aluminum substrate, excellent results of a halving of the surface roughness and a steep decrease in surface defects have been achieved by using mainly a new type of polishing slurry in combination with appropriate process conditions, and it has been decided that this substrate will be used in mass-production.

5. Conclusion

The longitudinal magnetic recording method, having been used in HDDs for many years, is approaching its technical limits. But in recent years, an innovative perpendicular magnetic recording method that breaks through these limits has advanced, and perpendicular magnetic recording media has begun to be mass-produced.

Aluminum substrate media is also slated for use in perpendicular magnetic recording in the future, and vigorous technical development is underway for that purpose. In an aluminum substrate for perpendicular magnetic recording, distinctive phenomena that could not be confirmed with the conventional longitudinal magnetic recording method have been observed, and even higher levels of surface precision are being required of polished aluminum substrates. In order to meet such difficult challenges Fuji Electric will continue to develop new technology capable of meeting these challenges and will continue to search for substrate technologies, plating technologies, polishing techniques and cleaning techniques in order to realize aluminum substrate characteristics capable of supporting the future evolution of recording methods.