Current Status and Future Outlook for Magnetic Recording Media

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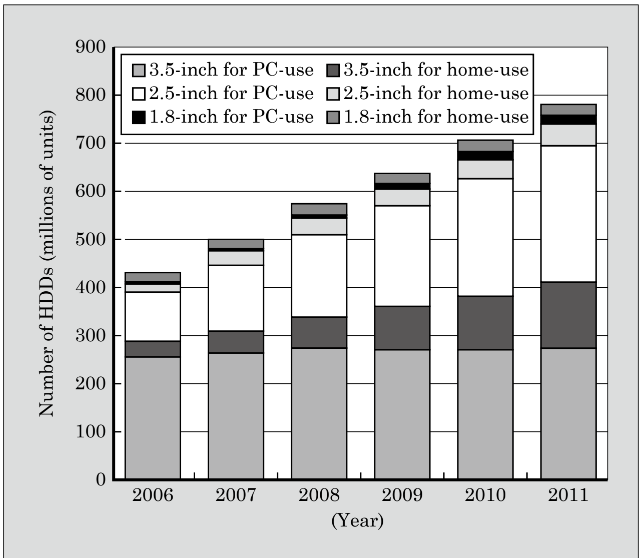
1. Introduction

With the commercialization of hard disk drives (HDDs) employing perpendicular magnetic recording technology, areal densities are once again increasing at faster rates and are growing by approximately 40% per year, new products such as HDD recorders (for non-PC use) and portable music players that advantageously utilize the large capacity and small size of these drives have been created, and the HDD market is continuing to expand (Fig. 1[(1)]). Moreover, HDDs are manufactured in 3.5-inch, 2.5-inch and other sizes according to their intended use, i.e., whether for stationary applications or mobile applications. Market trends for each size of magnetic recording media are described below.

For 3.5-inch HDDs, the arrival of 1 terabyte (TB) large-capacity drives is creating a new market for HDD recorders and for applications with IT companies that operate Internet portal sites such as Google*1 and Yahoo!*2 This market is called "near line storage" and represents a group of products (requiring relatively low-cost and large capacity HDDs) that connect the desktop PC to a server. Media manufacturers expect this market to have significant volume since each drive is equipped with 3 to 4 disks. As a result, the market for 3.5-inch HDDs is growing at an annual rate of more than 9%.

Fig.1 HDD market forecast



2.5-inch HDDs are increasing in popularity as notebook PCs achieve higher functionality and as a result of lower costs due to intense competition among HDD manufacturers, and this market is growing at an annual rate of more than 20%. In the future, as areal densities increase and recording capacities exceed 250 gigabytes (GB), the installation of 2.5-inch HDDs in desktop PCs becomes increasingly likely.

1.8-inch HDDs are used in the specialized market for portable music players such as the iPod*3 and are also creating a new market for ultra-slim notebook PCs. Competition from semiconductor memory technology, however, is expected to prevent large future growth of this market.

Small size HDDs such as 0.85-inch and 1.0-inch drives are expected to be installed in portable music players and cell phones, but market share will be lost to semiconductor memory, which has the advantages of lower cost, better resistance to mechanical shocks, and lower power consumption.

In order for the HDD market to continue its steady growth, larger capacities must be achieved and the cost-per-bit advantage compared to semiconductor memory must be maintained.

This paper discusses the status of technical development and the future outlook for Fuji Electric's magnetic recording media.

2. Technical Trends of Magnetic Recording Media

Longitudinal recording method, the former mainstream method for recording, has reached its limita-

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*1: Google is a trademark or registered trademark of Google Inc. in the United States and other countries.
*2: Yahoo! is a trademark or registered trademark of Yahoo! Inc. in the United States and other countries.
*3: iPod is a trademark or registered trademark of Apple Inc. in the United States and other countries.

Fig.2 Timing of market deployment of new technology products

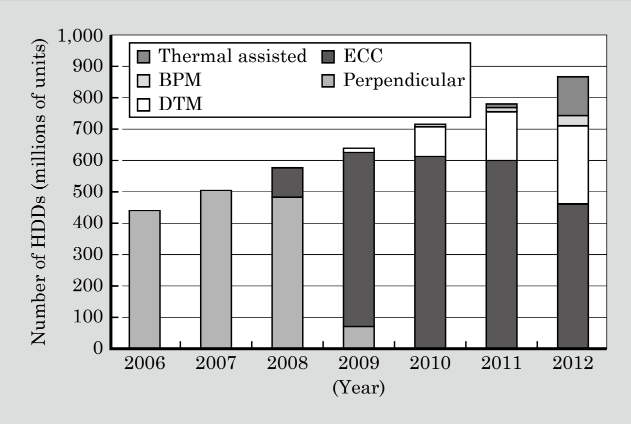
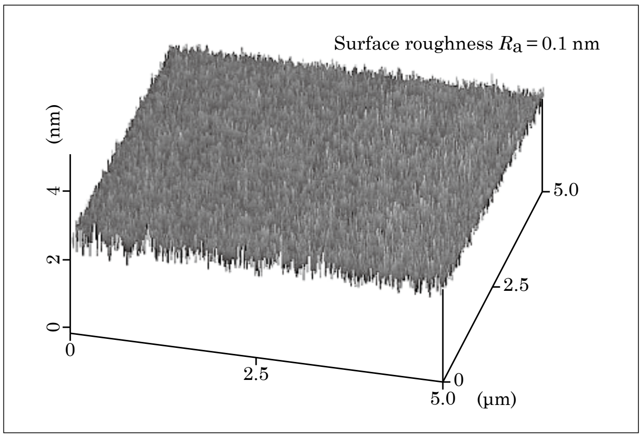


Fig.3 Surface topography of aluminum substrate for perpendicular magnetic recording media (AFM image)



tion for higher areal density, and from 2006 to 2007 was successively replaced by the perpendicular magnetic recording method. Fuji Electric commercialized the industry's first 2.5-inch glass perpendicular magnetic recording media (80 GB/disk) in 2006 and the industry's largest capacity (334 GB/disk) 3.5-inch aluminum magnetic recording media in 2007. Fuji Electric is presently manufacturing 3.5-inch products with 160 GB/disk, 250 GB/disk and 334 GB/disk capacities, and 2.5-inch products with 120 GB/disk and 160 GB/disk capacities. In 2008 there was a migration from the previous perpendicular magnetic recording media to ECC (exchange-coupled composite) perpendicular magnetic recording media (ECC media) capable of higher areal densities, and the development of 3.5-inch 500 GB/disk and 2.5-inch 250 GB/disk products are planned.

The new key technologies presently being developed in order to realize higher areal densities are as follows.

(a) Super smooth surface finishing technology
(b) ECC media
(c) DTM (discrete track media)
(d) BPM (bit pattern media)
(e) Thermal assisted media

Figure 2 shows a forecast of the timing of product development using these new technologies. As in the case of perpendicular magnetic recording media, Fuji Electric aims to be an industry leader for these new technologies and is advancing their development.

3. Technical Development Trends of Magnetic Recording Media

3.1 Super smooth surface finishing technology

To increase the recording density, the spacing between the R/W (read/write) element and the magnetic layer of the media should be as small as possible. In a 3.5-inch HDD, stable flying performance by the magnetic head is required at flying heights of 3.0 to 4.0 nm for 334 GB/disk media, at 2.5 to 3.0 nm for 500 GB/disk media, and at 2.0 nm for higher capacity disk media. Moreover, because of the heat generated in the vicinity of the R/W element and the mechanism used to control narrowly the spacing with the magnetic layer, the absence of surface micro-defects and projections is required in order to ensure stable flying characteristics. Fuji Electric independently develops and manufactures aluminum substrates, and in response to these types of requests, is independently developing aluminum substrates having high levels of smoothness and cleanliness suitable for perpendicular magnetic recording media, and is also applying proprietary texture technology to realize even smoother surfaces. (See Fig. 3.)

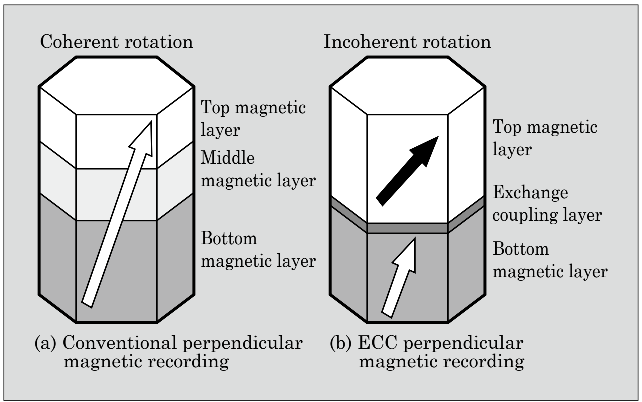
For glass substrates, as in the case of aluminum substrates, Fuji Electric's proprietary texture technology realizes the highest level of surface smoothness in the industry. In addition to surface smoothness, Fuji Electric has also developed washing technology that removes extremely minute and small amounts of residue, enabling finishing to a clean surface. Surface finishing technology and washing technology both contribute to long-term reliability and help distinguish Fuji Electric from its competitors.

3.2 ECC media

Limitations of the recording density of conventional perpendicular magnetic recording media are coming into view. ECC media products, capable of even higher recording densities, were deployed in 2008. One problem in achieving higher recording densities is a phenomenon known as adjacent track erasing, whereby adjacent tracks on both sides of a recorded track are erased during recording. The magnetic field from the head is obliquely incident on adjacent tracks, and the conventional perpendicular magnetic recording media is characteristically predisposed to magnetization reversal when exposed to an obliquely incident magnetic field. Increasing the density in the track direction and reducing the spacing between tracks causes the problem of adjacent track erasing to become more noticeable.

As shown in Fig. 4, ECC media features a structure

Fig.4 Structure of conventional perpendicular magnetic layer and ECC perpendicular magnetic layer



provided with coupling layer for controlling exchange coupling energy between the top and bottom magnetic layers, whereby the top magnetic layer which is predisposed to magnetization reversal reverses first and then the bottom magnetic layer, which is resistant to magnetic reversal, is encouraged to reverse so as to facilitate writing. Also, the ECC media has the significant advantages of being resistant to magnetic reversal when exposed to an oblique magnetic field and of being highly resistant to adjacent track erasing when the track density is high.

The ratio of the magnetic anisotropy K_u values of the bottom and top magnetic layers is important for ECC media, and the development of the materials used in these layers is a key factor. Fuji Electric is advancing its proprietary ECC media development work, and expects to be able to realize recording capacities greater than 750 GB/disk for 3.5-inch media.

3.3 DTM

As explained for ECC media, increasing the density in the track direction causes the tracks to become closer to one another and cause mutual interference. With DTM, semiconductor lithographic technology is used to pattern the magnetic layers, and this technology isolates adjacent tracks as shown in Fig. 5 to increase the density in the track direction. Technical development is presently underway, and the following items are important when etching a structure formed from deposited magnetic and protective layers.

(a) Reliability when etching the magnetic layer

(b) Limiting cost increases due to added processes

Issues associated with (a) include corrosion performance, head flyability, and so on. Issues associated with (b) include the capital investment to install semiconductor processing equipment and the limited number of times the servo pattern master can be used.

Fuji Electric completed development of the basic processes in the first half of 2008, started-up a pilot line in the second half of 2008, and aims to commercialize products in the first half of 2009.

Fig.5 Comparison of conventional media and DTM

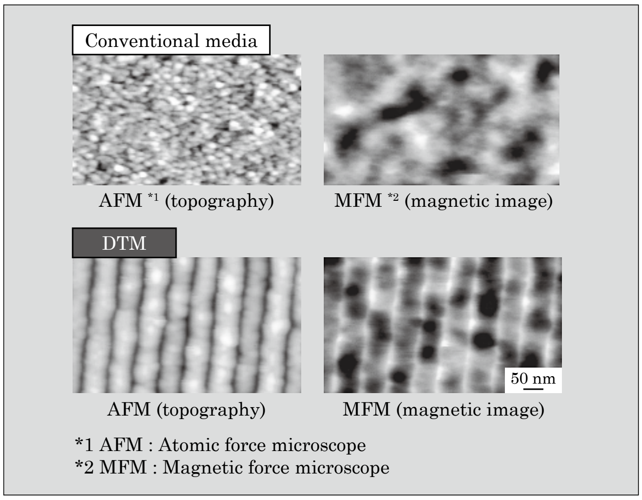
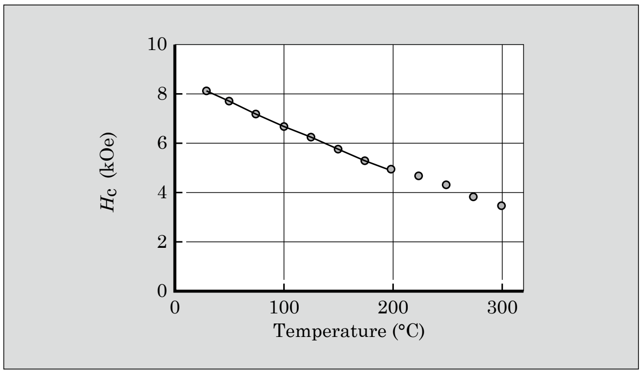


Fig.6 Temperature dependence of H_c



3.4 Thermal assisted recording media

The coercivity H_c of magnetic recording media is dependent on temperature, and for example, as shown in Fig. 6, H_c decreases by approximately 20 Oe for a 1 °C rise in temperature. H_c decreases at high temperatures and increases at low temperatures.

Previously, media in which H_c did not change in response to temperature fluctuations was sought. However, thermal assisted recording media is based on a contrary philosophy and utilizes the temperature dependency of H_c to increase the recording density.

Increasing the recording density typically results in smaller-sized individual bits and instability due to thermal fluctuations. To ensure thermal stability, H_c must be increased. If H_c is increased, however, the head magnetic field will have difficulty writing. To overcome these contradictory characteristics, a laser element is attached to the head, and when writing, the light irradiated from the laser causes temperature to rise at the part to be recorded instantaneously, and H_c decreases to facilitate the writing operation. After returning to room temperature, the H_c has a high value, and thermal stability can be ensured. For example, in a magnetic layer having an H_c of 8 kOe at room temperature, the H_c drops to 5 kOe when irradiated with laser light, the head magnetic field is applied at that instant, and the magnetization of the magnetic layer can be reversed.

Thermal assisted media faces the following two challenges.

(a) Development of materials and processes having a large H_c temperature dependence

(b) Durability of the protective layer and lubricant film against heating by laser irradiation

Fuji Electric is advancing materials development for these types of magnetic layers, protective layers and lubricant films, and aims to commercialize thermal assisted recording media.

4. Postscript

2008 was the year in which our approach to post-perpendicular magnetic recording media gained momentum. So that HDDs continue their stable market growth over the long-term, recording densities must continue to increase and the cost-per-bit advantage compared to semiconductor memory must be maintained.

Based on the core technologies described in this paper, and in cooperation with customers, head manufacturers, equipment manufacturers and materials manufacturers, Fuji Electric intends to achieve early commercialization of these products, and contribute to the expansion of the HDD market.

Reference

(1) TrendFOCUS, Inc. Annual report. 2006-2007.