New High Density Recording Technology: Energy Assisted Recording Media

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ABSTRACT

Energy assisted recording, is a next-generation high-density recording technology. This method enables writing even in the case of a low magnetic field by providing external energy to a recording layer, onto which the writing of signals has been difficult at room temperature. Fuji Electric is evaluating two methods of energy assisted recording; thermally assisted magnetic recording and microwave assisted magnetic recording. With thermally assisted magnetic recording using laser light as a heat source, an approximate 3 dB improvement in the SN ratio was confirmed and the inherent feasibility was verified. As material for this application, the coercive force temperature gradient of Co-based materials was improved to −85 Oe/K from the prior value of −15 Oe/K. With microwave assisted magnetic recording, the Pt in Co-Pt was replaced with another element, and a material having a low damping factor is being developed.

1. Introduction

There has been explosion of various information including images and music in our daily lives. In order to store such information, the recording density of the magnetic recording media used in hard disk drives (HDDs) has been increasing at a rapid annual rate of about 40%. In 2010, the recording density achieved at the research level is expected to exceed 1 Tbits/in^2 (equivalent to approximately 1.3 TB per 3.5-inch hard disk).

To realize recording densities higher than 1 Tbits/in^2, the mutually conflicting "trilemma" of reducing media noise, improving thermal stability (long-term reliability) of recorded information, and ensuring the ease of writing must be resolved. Improved noise reduction and thermal stability, in particular, lead to an increase in the coercivity H_c of the media. If the H_c value is greater than the maximum magnetic field that can be output from the existing magnetic recording head, the magnetic field will be insufficient for writing signals, and the signal quality will deteriorate.

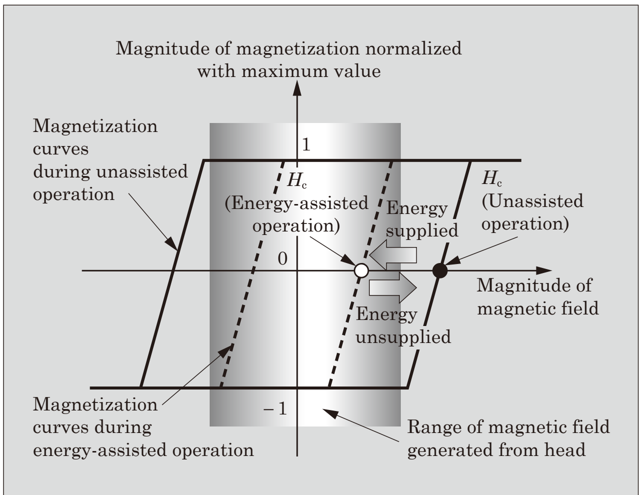

Fig.1 Concept of energy-assisted magnetic recording

As shown in Fig. 1, energy-assisted magnetic recording methods, whereby energy in some form is provided externally, the H_c value when writing signals is made smaller, signal writing is assisted, and the ease of writing is enhanced, are being studied actively to resolve this problem. Of these methods, thermally-assisted magnetic recording and microwave-assisted magnetic recording are introduced in this paper, and the present status of Fuji Electric's media development is discussed with a focus on improving the ease of writing to magnetic recording media.

2. Thermally-Assisted Magnetic Recording Media

2.1 Overview

The H_c value, which determines the ease of writing a signal to the magnetic recording media, is itself determined by the magnetocrystalline anisotropy energy that indicates the strength with which the magnetization attempts to align in one direction. This H_c value differs according to the magnetic material of the recording layer, and decreases with increasing temperature. Accordingly, if the recording layer is heated, the energy barrier that must be overcome in order to reverse the direction of the magnetization will drop, and signal writing will become easier. The thermally-assisted magnetic recording method is a signal writing method that utilizes this characteristic and applies heat only when writing. Fuji Electric is using computer simulations and the like to develop suitable media layer structures and materials.

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2.2 Present status of thermally-assisted magnetic recording media development

Fuji Electric has modified the recording head of a device (spin stand) for evaluating the playback performance of actual HDDs by adding a heating laser (wavelength = 830 μm) having a spot diameter of 10 mm, and is conducting proof-of-principle testing of thermally-assisted magnetic recording. Fig. 2 shows overwrite and playback signal output measurements when the laser power is varied during signal recording in order to vary the temperature while recording. Values of the playback signal output are shown normalized to the output value in the state without an incident laser. The overwrite characteristic shows, when a high-frequency signal having been pre-recorded and then overwritten with a signal having a lower frequency than the previous signal, the extent to which the previously recorded signal has been erased, and is generally used as an indicator of the ease of writing to media. In the experiment, perpendicular magnetic recording media in which film had been deposited on only the front surface of a glass substrate was used, and laser light was irradiated from the back surface of the glass substrate to heat the recording layer and the like, and recording was performed with a magnetic head positioned at the front side of the substrate. Additionally, so that only the thermally-assisted effect would be measured in this experiment, the current flowing through the writing head was not varied so that the magnetic field from the head would be held constant. In the case of no laser irradiation (equivalent to 0 mW), i.e., when a signal is written without heating the media, the signal strength of the overwritten output was approximately −13 dB, but as the laser power increases, the ease of writing improves, and at a laser power of 130 mW, a value of −28 dB was attained. Because of the increased ease of writing to the media, the playback signal output was also found to increase, thereby verifying the thermally-assisted effect resulting from a rise in temperature.

Fig. 3 shows the results of SNR (signal-to-noise ratio) measurements when the laser power is varied during signal recording so as to cause the temperature to vary during recording. The SNR was found to improve with increasing laser power. This behavior is thought result from the increased ease of writing signals to media. Heating with 130 mW of laser power results in a 3 dB improvement compared to a record and playback system in which laser power is not applied. The obtained results clearly show the thermally-assisted effect, thus completing the proof-of-principle testing.

Further study is needed before thermally-assisted magnetic recording media can be used in practical applications, however. Fig. 4 shows the layer structure of the present magnetic recording media without energy assistance, and of the magnetic recording media

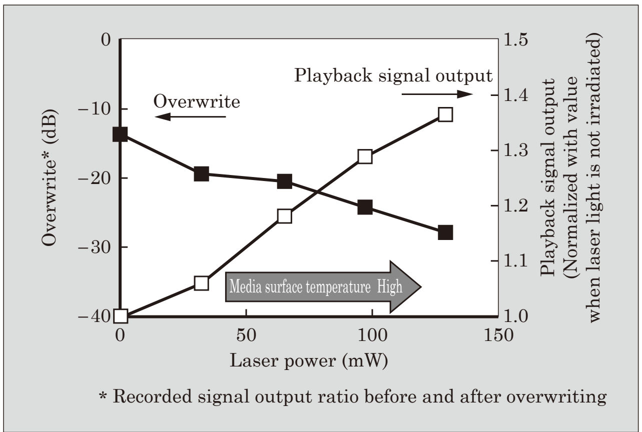

Fig.2 Changes in overwrite and playback signal output according to laser power

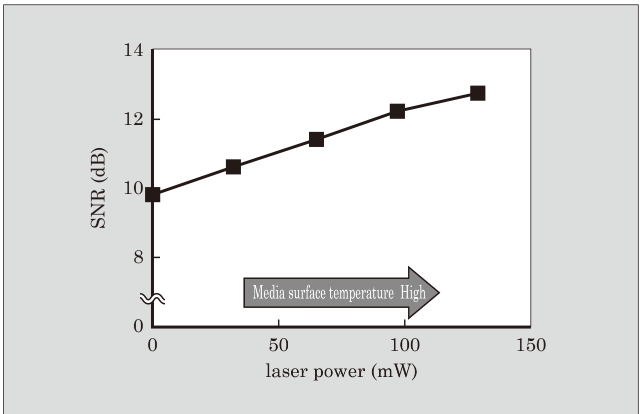

Fig.3 Change in SNR vs. laser power

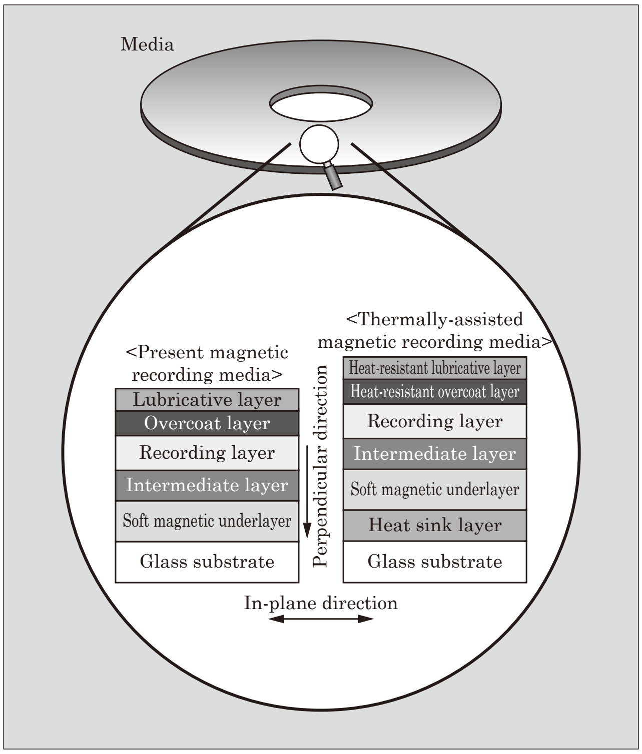

Fig.4 Configuration of thermally-assisted magnetic recording media

under development for thermally-assisted magnetic recording. The design of thermally-assisted magnetic recording media must build upon previous media designs and incorporate new design guidelines for light and heat. So that the recording layer can be heated with good efficiency, not only must the reflectivity be suppressed to a small value and the efficiency of heat absorption from the heating light increased, but other improvements such as providing a heat sink layer to release heat from the recording layer after the recording is complete are also needed. Additionally, improving the thermal resistance of the lubricative layer and the overcoat layer is also an important topic. The upper limit of temperature used with thermally-assisted magnetic recording is determined chiefly by the heat-resistant temperatures of those materials. To achieve the thermally-assisted effect at low-temperatures, the material of the recording layer is desired to have a low Curie temperature and to exhibit a large rate of decrease of the H_c value in response to increasing temperature.

An example of the materials development being undertaken at Fuji Electric is described below. Fig. 5 shows the H_c temperature gradient dHc/dT versus a process parameter. In this paper, the thermally-assisted ease of writing is expressed by the rate of decrease of H_c, and therefore values are expressed as negative numbers, with the assist effect becoming larger as the absolute value increases. The temperature gradient of the Co-Pt-Cr recording layer material used in the non-assisted magnetic recording media presently being mass-produced is −15 Oe/K at most. To limit the value of H_c during heating to less than the maximum magnetic field of the write head, the heating temperature must be rather hot, but this is not suitable for practical use. For large H_c temperature gradient materials, such as Fe-Pt-Cu (−180 Oe/K[1]) and Tb-Fe-Co (−240 Oe/K[2]), that have been studied so far, the thin film deposition temperature has been high, which would make mass-production difficult, and refining of the crystalline grains would also be difficult.

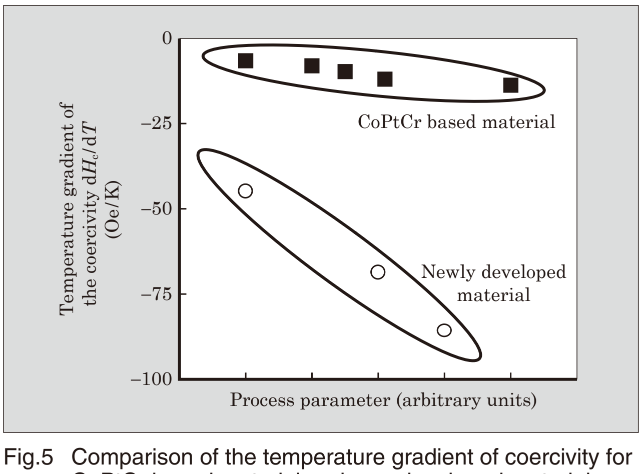

Fig.5 Comparison of the temperature gradient of coercivity for CoPtCr based material and new developed material

Furthermore, because good recording and playback characteristics cannot be obtained, these materials are not considered to be suitable for the recording layer of the media, and have not yet to be commercialized. On the other hand, as shown in Fig. 5, the Co-based new material developed by Fuji Electric exhibits a temperature gradient of more than 3 times that of conventional Co-Pt-Cr material and, at certain process parameters, reaches −85 Oe/K. If the new material is used in the same temperature region as is conventional materials, H_c will be decreased effectively and a high thermally-assisted effect can be expected.

Using media that incorporates this newly developed material, Fuji Electric plans to evaluate thermally-assisted magnetic recording and playback characteristics.

3. Microwave-assisted Magnetic Recording Media

3.1 Overview

In 2007, Zhu et al. proposed, as a novel type of energy-assisted magnetic recording, a microwave-assisted magnetic recording method whereby, instead of thermal energy, an AC magnetic field of high frequency (microwave frequency in the GHz band) is applied to the recording layer to improve the ease of writing[3],[4]. This method, as shown in Fig. 6, applies an AC magnetic field in a microwave band that matches the ferromagnetic resonance frequency of the recording layer material such that the magnetization tilts away from the direction of the easy axis of magnetization, and drives the precession (oscillating movement) of the magnetization, thereby assisting in the magnetic reversal. In principle, the absence of the necessity for significant changes to the configuration of present unassisted media is a large advantage. Presently, research involving both simulations and experiments is being advanced throughout the world mainly by universities.

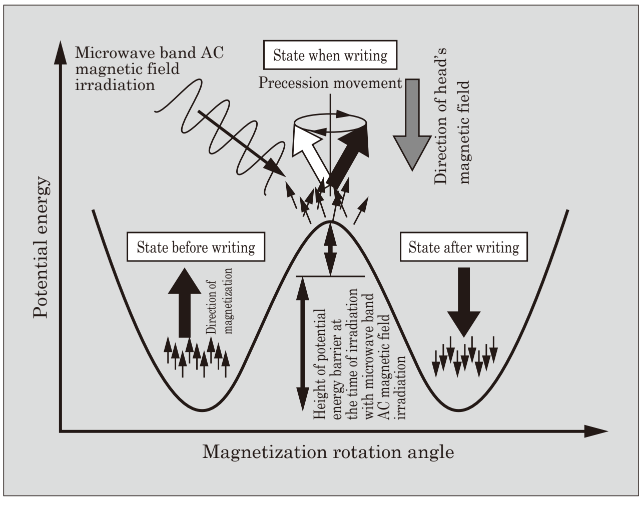

Fig.6 Principles of microwave-assisted magnetic recording

The principles of microwave-assisted magnetic recording have been announced only relatively recently. Verification of assisted magnetization reversal in a magnetic thin film using a microwave-band AC magnetic field was first reported in 2007 using Ni-Fe, which is a soft magnetic material[5]. Then, in 2009, assisted magnetization reversal using Co/Pd multilayer film having perpendicular magnetic anisotropy was reported[6]. Research of the latter has continued, especially as a material for perpendicular magnetic recording media. As a result of this report, the effectiveness of applying microwave-assisted magnetic recording to perpendicular magnetic recording media has become clear and this technology has attracted attention. Currently, efforts to apply microwave-assisted recording to perpendicular magnetic recording media are accelerating.

3.2 Present status of microwave-assisted magnetic recording media development

Generally, when an external magnetic field is applied to change the direction of magnetization in magnetic material, the magnetization begins a precession motion (oscillation) as shown in Fig. 6. With the passage of time, the angle of oscillation becomes larger, and finally the magnetization becomes aligned in the same direction as the applied magnetic field and the reversal is complete. In the magnetic material, a force acts to align the oscillating magnetic field in the direction of the applied magnetic field, and the strength of that force is called the damping constant. The damping constant is an intrinsic value of the magnetic material, and as the value of damping constant decreases, the reactivity to externally applied microwaves increases and the assisted reversal effect becomes greater as a result. Accordingly, in the development of materials for the microwave-assisted magnetic recording magnetic layer, materials having a small damping constant must be investigated.

As the recording layer material presently used in perpendicular magnetic recording media, hcp-CoPt based alloy material is actively being studied, and by varying the amount of Pt to adjust the magnetic anisotropic energy, long-term stability of the recorded signal can be ensured. Additionally, ordered alloy based materials such as Co-Pt and Fe-Pt, which have ordered structures on the atomic layer level, hold promise as materials that exhibit large magnetic anisotropic energy for next-generation high-density media. The Pt contained in these materials has a large orbital magnetic moment, however, and experiments have shown that the damping constant tends to increase due to the spin-orbit interaction, making these materials unsuitable for microwave-assisted magnetic recording media. Fuji Electric is moving ahead with the development of magnetic material using an element that can substitute for Pt to lower the damping constant and that is able to maintain the same characteristics as existing media. The ultimate aim is the application to recording media of a material that uses less of the scare resource of Pt.

4. Postscript

Fuji Electric continues to study how to use energy-assisted magnetic recording in order to provide magnetic recording media having a recording density of greater than 1 Tbits/in^2. Media material development, with a different approach than before, is needed for both thermally-assisted magnetic recording and microwave-assisted magnetic recording methods. Through working ever more closely with not only the materials development department, but also with the simulation department and outside agencies, Fuji Electric is committed to promoting the early realization of energy-assisted magnetic recording media.

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