iD PHOTO, a New MO Disk for Digital Still Cameras

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Abstract- A new MO (magneto-optical) disk has been developed as a new memory for digital still cameras, named "iD (image/intelligent disk) PHOTO". Advantage of the iD PHOTO disk is a larger recording capacity of 730 MB, than those of semiconductor memories on current digital still cameras. The field modulation method for recording and Center Aperture Detection (CAD) type magnetic super resolution for reproducing are employed to achieve this capacity.

This disk is designed considering mobile use. For the first point, high field sensitive CAD media is realized so as to reduce electric power consumption. By the addition of the capping layer, the recording field has been reduced to be smaller than 100Oe. For the second point, as well as the mechanical stability, write/read characteristic is enhanced in broad environmental temperature range. More than $\pm 12\%$ read power margin is obtained on each temperature area from -5°C to $+60^{\circ}\text{C}$.

Key words: magneto-optical disk, digital camera, CAD, magnetic field modulation recording, low power consumption, stable recording.

1. Introduction

The market range of digital still cameras is rapidly increasing and is forecast to exceed 10 million in the fiscal year 2000. The demand now is for high-speed, high capacity media.

Recently, flash memory cards have been generally employed for storage on digital still cameras, represented by compact flash cards and smart media. However, the small capacity means that they can be used only as a temporary memory.

The iD PHOTO disk described herein is the next generation high capacity, high-speed MO disk for digital still cameras. The "iD format" is standardized based on the AS-MO (Advanced Storage Magneto Optical Disk) standard [4,5,9]. As well as being a 50.8 mm diameter rewritable optical disk, it also realizes a high recording capacity, 730 MB, so it exceeds CD capacity. It is possible to store roughly 1,800 pictures per disk of still images with a 2-million pixel equivalent (400 KB/picture), or approximately 20 minutes of moving pictures at 30 fps (frames per second) with 320×240 pixels (4.8 Mbps), or a mixture of both. It is also possible to rewrite data at

high speed over 20 Mbps. Furthermore, this disk enables saving image data for long periods.

2. Main features of the "iD PHOTO" disk

Table I shows technical main specifications of the iD PHOTO disk. This is a single sided disk with a 0.6 mm thick substrate. The high recording density of 4.6 Gb/in^2 has been achieved by the adoption of key techniques mainly as follows.

- (1) CAD (center aperture detection) type Magnetic Super Resolution reading [1,2]
- (2) Magnetic field modulation recording with pulsed laser irradiation [3].
- (3) Recording both on land and in groove with a track pitch of $0.6 \mu\text{m}$.

A laser diode of 650 nm wavelengths and object lens of NA 0.6 are used so as to achieve higher resolution in the optical pick-up. The field modulation recording method, using a flying type magnetic head and CAD type Magnetic Super Resolution reproducing method are employed to overcome the recording/reading limitation caused by the laser beam spot size.

Memory capacity	730 MB
Surface memory density	4.6 Gb/in^2
Disk diameter	50.8 mm
Substrate thickness	0.6mm
Laser wavelength	650 nm
NA of objective lens	0.6
Track pitch	$0.6 \mu\text{m}$
Minimum mark length	$0.235 \mu\text{m}$
Data modulation code	NRZI Plus
Data detection method	PR(1,1)+Viterbi

Table I. Main specifications of the iD PHOTO disk.

3. High field sensitive design

As the iD PHOTO is mobile use media for digital cameras, the power supply is limited to batteries. Electric power consumption therefore should be kept to a minimum. This media realizes low power consumption by magnetic design.

For recording, the magnetic field modulation method

is used. In the recording process, an external magnetic field is modulated according to the data to be recorded. Since the recording marks are defined by the field switching, very small marks can be recorded accurately. A pulsed laser beam is irradiated in the recording process. This assists to clarify the mark boundary. The smallest recording mark size is $0.235\ \mu\text{m}$ (1T) on this disk. It is possible to record with a high speed even exceeding 20 Mbps.

In general, decrease of the magnetic field for recording is effective to reduce the power consumption for MO media using the field modulation method. We have been studying this theme applying the "magnetic

Fig.1 Recording field dependence of the bit error rate for the CAD disks .

capping effect" [6-8]. We found previously that depositing a magnetic capping layer, such as PtCo alloy layer, in direct contact to the TbFeCo recording layer, can control the switching field response.

Herein this "capping effect" is applied on the iD PHOTO, a CAD disk which has a GdFeCo readout layer and a TbFeCo recording layer. The two layers are magneto-statically coupled each other for the MSR function. Another GdFeCo layer, having in-plane magnetization, was deposited on the TbFeCo recording layer as a magnetic capping layer.

The mechanism of the capping layer effect is as follows. As the demagnetizing energy is a little larger than the perpendicular anisotropic energy, this GdFeCo layer shows in-plane magnetization from room temperature to the Curie temperature. The Curie

temperature of the capping layer is almost the same as that of the recording layer. In this condition, the magnetization of the capping layer easily rotates to the direction of the magnetic field during the recording process. Since the TbFeCo recording layer and the GdFeCo capping layer is directly coupled, the exchange coupling effect works between the transition metal elements in each layer at the interface surface. The effect works to make them parallel to each other, so that when the magnetic moment of the capping layer rotates in the external field direction, the exchange coupling force works in the same direction as the external field, and this then acts to assist the external field on the recording layer.

Concerning the iD PHOTO disk, the recording layer should satisfy some special magnetic properties to be suitable for the CAD function. In this CAD media case, the recording layer has larger magnetization than that found in conventional MO media. The capping layer therefore should be designed with cancellation of that. The external field response has been totally controlled.

Consequently as shown in Fig.1, a high field sensitive disk was obtained by optimizing magnetic properties of the capping layer. For the conventional media, more than 200 Oe was needed to obtain the bit error rate (BER) of under 10^{-4} . While the improved media achieved less than 100Oe to obtain the same. The necessary recording field for the attainment of sufficiently low BER has been reduced to half of that of a conventional CAD disk. The addition of the capping layer enabled to realize both high field sensitivity and good CAD function. As a result, the power consumption of the magnetic head in the camera has been cut down to 1/4.

4. High stable working in wide temperature range

4.1 Mechanical stability

Stable working in a wide environmental temperature range is also important for mobile use. At first, mechanical characteristics should be stable. Mainly it depends on a design of the disk shape. The disk thickness of the iD PHOTO is 0.6 mm, which is half of the CD or other optical disks. Here the diameter, 50.8 mm is settled to be smaller than half of those disks so as to maintain the mechanical strength. We assume that the mechanical strength is represented by the axial deflection, which is occurred under stress strain condition when homogeneous pressure is applied on the whole disk surface. Under such condition, the axial deflection is in proportion to the fourth power of D, and in inverse proportion to the third power of T (where D is a diameter and T is a thickness of a disk). As a result, a small diameter is more effective to the mechanical stability than the thin thickness.

Fig. 2 shows environmental temperature dependence of radial tilt measured in the range of -20°C through

70°C. An iD PHOTO disk was put into a temperature-controlled chamber and the tilt was measured directly as in the condition changing the temperature. It was confirmed that the variation of the radial tilt was sufficiently small on this disk.

Fig.2 Environmental temperature dependence of the radial tilt in the iD PHOTO disk, measured at a radius of 24.0 mm.

4.2 Write/read characteristics

As well as the mechanical stability, recording and readout characteristics must be assured in broad environmental temperature range.

Magnetic super resolution method generally uses temperature distribution in the readout laser spot to compose a small aperture. When the environmental temperature changes, base temperature for such distribution has some offset. So a suitable readout power to get low BER changes according to the environmental temperature.

Fig. 3 Disk layer structure of the iD PHOTO.

Basic design of layer structure to reduce such influence is necessary. At first, the temperature distribution in the laser spot should be controlled relatively steep, so that the aperture side change becomes smaller when the environmental temperature changes.

To achieve this thermal conduction, the upper layers of the CAD structure are arranged as thermal control layers. Those are composed of SiN and Al alloy layers. To make the temperature distribution steep, thermal conductivity of the layers should be relatively low. At the same time, total thermal capacity should be large to arrange the readout power sensitivity.

From those points, thickness and composition of the thermal control layers were examined. As a result, wide read power margin is realized on the media as shown in Fig.4. Then Fig.5 shows the temperature dependence of such read power margin. Each bar shows read power area in which lower BER than 10^{-4} was obtained. The black circle is the BER minimum point on each temperature. While the minimum point moves to lower power area according as the environmental temperature increases, more than $\pm 12\%$ power margin is obtained on each temperature area from -5 to $+60^\circ\text{C}$. Combining a test W/R method, this media should be well controlled through wide temperature range. Those techniques make the iD PHOTO disk stable in practical mobile use.

Conclusion.

A Magneto-Optical disk system, iD PHOTO has been developed as media for digital still cameras. It realizes 730MB capacity with a 50.8mm diameter. It employs the field modulation method for recording and Center Aperture Detection (CAD) type magnetic super resolution for readout.

The media is designed to suit for mobile use in the following points

- (1) High field sensitive CAD media is realized so as to reduce electric power consumption. The recording field has been reduced to be smaller than 100Oe with a sufficiently acceptable low bit error rate.
- (2) As well as the mechanical stability, write/read characteristic is enhanced in broad environmental temperature range.

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Linear velocity : 5m/s,
Recording power : 7mW,
Recording field : 150 Oe

Fig.4 Change of the bit error rate with the readout power.

Fig.5 Temperature dependence of the suitable readout power area.