20 GBIT/INCH² RECORDING ON MAGNETO-OPTICAL DISK USING NA 0.85 AND 405nm OPTICS

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Abstract- Various technique to reproduce magneto optical signals from high-density recorded patterns are reported, for example DWDD, MAMMOS, CAD, etc. In this paper we propose a method with NA 0.85 lens and a 405 nm laser. We search the feasibility of conventional MO media by laser-pulsed magnetic field modulation (LP-MFM) method having a target of high-density 20Gbit/inch². We had the method of UV irradiation to suppress the media noise, thermal control layer to prevent the decay of the Kerr rotation angle, and optical phase shift method to reduce the cross-talk. And we could be making sure the feasibility of 20Gbit/inch² observing a low error rate of less than 10⁻⁵ at the bit length of 0.13 μ m.

Key words: magneto-optical recording, blue laser, High NA, land and groove recording, UV irradiation, thermal control layer, magnetic field modulation, optical phase shift

1. Introduction

An optical spot size controlled by both the wavelength of laser and the numerical aperture (NA) of objective lens is an important parameter for determining a storage density of optical disk such as magneto-optical (MO). We have already demonstrated the high density MO recording comprising an NA 0.85 lens and a 635 nm laser with a magnetic field modulation method [1]. In its report, we analyzed origin of media noise during increasing a track density and improved SNR by means of deforming the groove shape on substrate. We could confirm sufficient SNR at bit length of 0.21 μ m and wide power margin on groove substrate with track pitch of 0.55 μ m. On the other hand, we also tried a higher density recording with shorting wavelength of laser diode of 405 nm and applied a land and groove substrate [2]. In a blue laser recording, it is necessary to increase a readout power because a sensitivity of photo detector decreases and MO signal will not be sufficient. The new media structure adopting the thermal control layer adjacent to MO layer was introduced for controlling thermal characteristics during a reproducing with blue laser [3]. Sufficient system margin was obtained at bit length of 0.184 μ m and track pitch of 0.35 μ m using the NA 0.6 lens [2].

The main purpose of this paper is making sure the feasible density of conventional MO media with NA 0.85

lens and a 405 nm laser by laser-pulsed magnetic field modulation (LP-MFM) method. We tried several method, such as UV irradiation to suppress the media noise, thermal control layer to prevent the decay of the Kerr rotation angle, and optical phase shift method to improve the readout signal and reduce the cross-talk. The effects of these method will be reported.

2. Experimental conditions

Fig. 1 shows a schematic diagram of our experimental system. We used a blue laser diode of 405 nm wavelength as a light source. The 2-element objective lens of NA 0.85 focused a laser light on a MO film through 0.6mm thickness glass substrate. The flying magnetic head was adopted for laser-pulsed magnetic field modulation recording. To reduce the cross talk from the adjacent tracks, we used an optical phase shifter composed of a half wave plate between a pair of fixed quarter wave plates [4]. It was placed between the beam splitter and the Wollaston prism. We changed the phase shift value by rotating the half wave plate.

We prepared a conventional structure media that was constructed with thin magnetic layer of 20 nm, dielectric layers, thermal control layer, and heat sink layer, as shown in Fig.2. As a magnetic layer, TbFeCo/GdFeCo

Fig.1 Schematic diagrams of the measurement optics

Fig.2 The structure of the MO media

hybrid layer is used and the Curie temperature of TbFeCo was set around 260 °C. Ag-metal was used as a thermal control layer and a heat sink layer, because of its high thermal conductivity [3]. These recording films were sputtered on a land and groove glass substrate, which was 0.6 mm thickness, with varying the track pitches from 0.25 μm to 0.35 μm . The substrate was exposed by the UV irradiation before sputtering films in order to suppress the media noise [3]. After the UV irradiation, groove depth of substrate was measured by atomic force microscope.

(1,7) RLL data was recorded by using a magnetic field modulation method with pulse irradiation of 33% duty. The clock-to data jitter and bit error rate by decoding by PR(1,2,1) and Viterbi detection method were measured with channel clock of 40MHz. We controlled the bit length by changing the liner velocity (ex. 3.45 m/s at 0.13 $\mu\text{m}/\text{bit}$).

3. SNR improvement of media

In order to achieve a high density recording with high NA and blue laser optics, we considered two kinds of SNR. One is an individual SNR of media, which means the noise from substrate, film surface, and recorded domain. The other is an SNR within a total system. Especially in a blue laser system, MO signal is not sufficient because of the decay of detector sensitivity.

In order to improve the media SNR, we applied an UV irradiation of 15 min before sputtering films [1]. Figure 3 (b) show the spectra of electric circuit noise, laser and detector noise, and media noise, when UV irradiated substrate was used. Readout power was set at 2.5 mW. The disk noise has been improved over 7 dB at 2MHz compared with the case of non-UV irradiated substrate, as shown in Fig.3 (c). We considered that 15 min UV irradiation was sufficient condition for improving a media SNR.

Figure 3 (a) shows a noise spectrum from erased groove of 0.28 μm track pitch with readout power of 0.8 mW. In a MO system using blue laser, system noise and

Fig. 3 Noise spectrum from electric circuit, laser, detector, and media in groove. (a) UV irradiation of 15min, 0.8mW readout power, (b) UV irradiation of 15 min, 2.5mW readout power, (c) non-UV irradiation, 2.5mW readout power.

laser shot noise are more dominant than disk noise, so higher readout power is necessary for sufficient MO signal. We measured CNR from recorded mark of 0.23 μm (6.7 MHz) with a readout power of 0.8 and 2.5 mW, and obtained the CNR of 37.2 dB and 43.7 dB, respectively. So it was confirmed that a high readout power is effective to obtain a sufficient SNR. An increasing of readout power, however, causes an

increasing a media temperature. Because of a decayed Kerr rotation angle, it is considered that sufficient SNR is not obtained only by means of increasing the readout power. So we controlled thickness of the thermal control layer for adjusting a readout power so as to obtain a sufficient SNR. Fig. 4 shows the readout power dependence of carrier levels and CNR of 0.61 μm mark and 0.23 μm mark, respectively, with various thickness of the thermal control layer from 4 nm to 18 nm. It is clear that the carrier levels are proportional to readout power up to 2.8 mW with 18 nm thickness of thermal control layer, and then we could obtain sufficient CNR. We set the thermal control layer to 18 nm and the readout power to 2.5 mW for a measurement.

In order to improve the readout signal and reduce the cross-talk signal from adjacent track, we adopted an optical phase shift method [4] for land and groove recording. The measured 2T carrier level and 8T

Fig. 4 Readout power dependence of (a) carrier level and (b) CNR of 0.61 μm mark and 0.23 μm mark for disks with different thickness of the thermal control layer (Ag).

Fig. 5 Measured phase dependence of 2T carrier and 8T cross-talk level. The groove depth is (a) 55 nm and (b) 40 nm.

cross-talk level on land and in groove are shown in Figure 5. T means a data window width. The substrates have 0.30 μm -track pitch and the groove depth of 40 nm and 55 nm, respectively. As shown Fig. 5, the characteristics of the optical phase shift change by the groove depth of the substrate. When the groove depth was 55 nm, we couldn't have any advantage. We adjusted the groove depth of substrate to 40 nm, i.e. equal to $\lambda/6n$, then maximum carrier level and minimum cross-talk signals were obtained.

4. Signal evaluation of high density recording

Fig. 6 Read/write characteristics of MO media with 0.85 NA lens and (a) 405 nm laser and (b) 650 nm laser.

In order to confirm the contribution of spot size effect on liner density, we compared with the results measured under condition of 650 nm laser, NA 0.85, as shown in Fig. 6. We recorded (1,7) RLL data under a channel clock of 40 MHz and changed the liner density by changing the liner velocity. We can observe the jitter value of 10 % at 0.21 μm/bit in the case of 650nm, as shown in Fig. 6 (b). Bit length of 0.21μm at 650 nm is theoretically equal to the length of 0.13 μm at 405 nm. In the case of 405 nm and NA 0.85 (Fig. 6 (a)), we can observe the jitter value of 10 % at the 0.13 μm/bit on the track pitch of 0.35 μm and 0.30 μm. But jitter increased as the track pitch decreased, jitter of 12% was obtained on 0.25 μm track pitch. It's considered that the disk noise attributed to a groove boundary wall, occupies relatively larger ratio to the recording area as the track pitch is narrower. About liner density, it is able to conclude that our MO system and media have a consistent performance concerned with

wavelength. And NA dependence of read/write performance was also estimated and we could obtain consistent results.

We measured a dependence of bit error rate on bit length in one track, as shown in Fig. 7. The track pitch of the substrate was 0.25 μm. Sufficient low error rate less than 10^{-5} was obtained at the bit length of 0.13 μm in groove, and this result means that high density recording up to 19.8 Gbit/in² is feasible with using a NA 0.85 and wavelength of 405 nm optics.

Fig. 7 Dependence of bit error rate on liner bit length at a 0.25 μm track pitch.

5. Summary

The read/write performance of MO disk was estimated by using a blue laser of 405 nm and high NA objective lens of 0.85. The substrate was exposed by the UV irradiation before sputtering films in order to suppress the media noise, the thermal control layer was adjusted so as to obtain a sufficient SNR. We could confirm a consistent performance and sufficient low bit error rate of less than 10^{-5} at the bit length of 0.13 μm, and conclude that high density of 19.8 Gbit/in² was feasible with optics of NA 0.85, 405nm.

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