TbFeCo SINGLE LAYER DISKS FOR MAGNETO-OPTICAL HIGH DENSITY RECORDING

H. OHLSÉN*, H. AWANO and M. OJIMA

Central Research Lab., Hitachi Ltd., 1-280 Higashi-Koigakubo, Kokubunji-shi, Tokyo 185, Japan

*on leave from: Industrial Microelectronics Center, P.O. Box 1084, 164 21 Kista, Sweden

Abstract - TbFeCo magneto-optical single layer disks with different compositions have been investigated for recording of small size domains. Using a 830 nm wavelength laser, circular shaped domains with a diameter of 0.25 μm diameter could successfully be written. A low writing stability, dependent on the applied field, was found when recording domains smaller than 0.5 μm on a transition metal rich disk. On the contrary, a high writing stability was achieved on a disk with a highly rare earth rich composition. On this disk two 0.25 μm domains could successfully be written as close as 0.1 μm to each other. It was also possible to use this single layer TbFeCo disk for recording of domains with widths of 0.1 μm .

KEYWORDS: HIGH DENSITY RECORDING, SINGLE LAYER DISK, AMORPHOUS, TbFeCo, STABILITY

INTRODUCTION

The data storage technique utilizing magneto-optical disk media has experienced a very fast development. Today's magneto-optical disk products, with a size of 130 mm (5.25"), have a capacity of up to 2GB. This is achieved by a domain edge recording technique of domains with widths of 0.8 μm , which corresponds to a storage density of almost 0.9 Gbit/in² [1]. To prove that a single layer disk structure is a strong candidate for an even higher magneto-optical storage density in future generation of products, it is advantageous to experimentally demonstrate recording of domains with sizes much smaller than 0.8 μm . This naturally puts high demands on the material and the structure of the future products of magneto-optical disks. It is necessary that the small domains can be written in a stable way. That is, fluctuations in laser power as well as applied magnetic field can only be allowed to change the domain size within certain limits.

Once a recording technique is established, further work is needed in order to achieve a large Kerr rotation so that the very small size domains can be detected with high enough accuracy. A large carrier to noise ratio with a high degree of read-erase-write cyclability is needed to guarantee a high quality product.

To our knowledge there has been no previous stability study of domains with size smaller than 0.3 μm . The objective with this work has been to study the recording of small size domains and to find a TbFeCo composition suited for stable recording of 0.25 μm domains.

EXPERIMENTAL

An rf magnetron sputtering apparatus was used for fabrication of amorphous (confirmed by XRD and EXAFS)

films of TbFeCo with a thickness of 100 nm. The TbFeCo layer was sputtered in an argon atmosphere and sandwiched between two dielectric nitride layers with thicknesses of 80 and 20 nm. The layer sequence for all disks fabricated in this work was: substrate/nitride-80nm/TbFeCo-100nm/nitride-20nm. The composition of the TbFeCo layer was changed by varying the number of Tb and Co chips bonded on an Fe target. A protective overcoating layer was spun on top of the upper 20 nm nitride layer after removal from the deposition chamber.

Photopolymerized (2P) pregrooved glass disks with 1.4 μm track pitch have been used in this study of domain recordings. The diameter of the disks were 130 mm. Domains were recorded using a standard magneto-optical drive [2], with a numerical aperture of 0.55 and a laser with a wavelength of 830 nm. In all recordings a linear constant velocity of 4.2 m/s was used. Observations of written domains were performed by a high-resolution polarized microscope and magnetic force microscopy (MFM).

Four different compositions of TbFeCo have been studied. Their H_c as a function of temperature, determined from Kerr rotation hysteresis curves of test pieces deposited simultaneously to the disks, are presented in Fig. 1. Three of the compositions were chosen in such a way that they had similar Curie temperature (T_c) of around 300°C but with different compensation temperature (T_{comp}). One transition metal rich target composition with a T_{comp} well below 0°C (hereafter denoted: Disk A), one rare earth rich target composition with a T_{comp} around room temperature (hereafter denoted: Disk B), and finally a highly rare earth rich target composition with a T_{comp} at around 190°C (hereafter denoted: Disk C). To compare recordings on a transition metal rich and a rare earth rich disk, a fourth target composition was prepared. The composition of this disk was close to Disk C but with a somewhat lower

T_{comp} of about 160°C and a Curie temperature around 270°C (hereafter denoted: Disk D).

Fig. 1. H_c versus temperature measured by Kerr rotation loops for the four different compositions of the TbFeCo layer.

RESULTS AND DISCUSSION

The smallest possible power to write domains (P_0) for a 100 ns write pulse is around 6 mW and 6.5 mW for Disk A and Disk D, respectively, and around 8 mW for Disk B and Disk C. For a 30 ns pulse the P_0 values are close to 8 and 9.5 mW for Disk A and Disk D, respectively. The available maximum power of the disk drive was too low to allow a recording on Disk B and Disk C using a write pulse of 30 ns.

The signal level which can be calculated from the carrier level is proportional to the average domain area recorded on a one turn track. To calibrate the signal level against the domain area, recordings of domains using different writing powers were performed on a disk and then studied by the spectrum analyzer. A conversion factor from the signal level to the domain area was determined by studying the actual domain size by using a polarized microscope and from MFM observations.

A writing stability study of TbFeCo disks with the same structure and substrates but with different compositions have been performed. On Disk A, Disk B and Disk C, domains with the size of around 0.3 μm were recorded on 10 tracks (with 2 tracks in between to avoid crosstalk), with the same recording conditions on all the 10 tracks. The recordings were done with different laser power for different disks, but with the same writing pulse of 100 ns and with the same applied field of 400 Oe. The resulting average domain size obtained from the carrier level of a spectrum analyzer for each of these tracks, are presented in Fig. 2 for the three TbFeCo compositions.

The mean value of the recorded domain sizes were estimated to 0.31 μm , 0.24 μm , and 0.25 μm , with the corresponding standard deviation relative to the mean value of 26%, 16%, and 1.6%, for Disk A, Disk B and Disk C, respectively. From Fig. 2 it is obvious that the highly RE-rich disk (C) is much more suitable for stable writing of small sized domains than the TM-rich disk (A).

Fig. 2. Average domain size (diameter) estimated from the carrier level on one track versus track number for Disk A-C.

Since the writing stability is the worst for the TM-rich disk, an increase in writing stability ought to be most easily observed for this composition of TbFeCo. An experiment was performed on this disk by keeping the writing laser power constant but changing the writing time and applied field. In a similar way as described above, 10 consecutive recordings were performed, with two track separation, by using the same recording conditions. When changing the field from 400 Oe and a write pulse of 100 ns, to 100 Oe and 100 ns, and finally to 100 Oe and 30 ns, changed the standard deviation relative to the mean value from 26%, to 6%, and to 1.8%, respectively. Recordings on the TM-rich disk using a low applied field of 100 Oe and a short write pulse of 30 ns, thus gives approximately the same writing stability as the highly RE-rich disk when using 400 Oe and 100 ns.

To further investigate the influence of applied field on the writing stability on Disk A and Disk C, 10 track recordings were performed in a similar way as described above. Between different 10 track recordings the laser power and the applied field was changed. In Fig. 3 the result for the standard deviation divided by the mean value for the 10 tracks as a function of applied field and domain area is presented for Disk A. The domain area was estimated from the 10 track mean value of the carrier level. For Disk C no significant difference in writing stability could be observed by changing the applied field and laser power. This result

thus shows that for recordings of domains larger than 0.5 μm the writing stability is not to any greater extent influenced by composition or applied field. However, in Fig. 3 a clear dependence of the writing stability with applied field can be observed when recording domains smaller than 0.5 μm . The standard deviation is the smallest, and thus the writing stability is the largest, for a field of about 200 Oe when recording on the TM-rich disk (A).

Fig. 3. The standard deviation divided by the mean value as a function of applied field and domain area estimated from the carrier level mean value of 10 track recordings.

In Fig. 4 the signal level as a function of normalised power for different recording conditions on Disk D is presented. P_w is the writing laser power and P_0 is the power for which the signal level becomes close to zero. As can be seen, the slope decreases with lower applied field and a shorter write pulse.

Fig. 4. Signal level versus normalised power for an applied field of 100 Oe and 400 Oe and write time of 100 and 30 ns.

A second recording was made to verify the results presented in Fig. 4 using different recording conditions and the evaluation with the spectrum analyser. In one sequence the write power was chosen in such a way that the normalised power $(P_w - P_0)/P_0$ was kept constant at 0.12. This was done for the four combinations of field and time, and should lead to different domain areas proportional to the signal level according to Fig. 4. In yet another sequence, the write power was chosen so that the normalised power differed but the signal level was kept constant at 10 mV. Again this was done for the four combinations of field and write time. This signal level corresponds to a domain size of 0.25 μm in diameter. These recordings were then studied by polarized microscopy and MFM. The MFM result of a recording made at 30 ns and 400 Oe is presented in Fig. 5.

The MFM results strongly support the measurements using the spectrum analyser as presented in Fig. 4. However, it was noted that the domains using 100 Oe applied field and write time of 30 ns are irregular in shape. Probably the applied field is too low, so further detailed investigations using higher applied fields are needed.

A special type of recording was performed to study the possibility of writing domains close to each other. First a recording was made using a frequency of 1.0 MHz on four following tracks. After this domains were written with exactly the same conditions as the first time and on the same tracks, but with a small change of the delay between the domain pulse writings. For the pulse write time of 100 ns the delay was changed from 900 ns to 925 ns, and thus frequency was changed from 1.000 to 0.976 MHz. For a write pulse of 30 ns the delay was changed from 970 ns to 980 ns, and thus the frequency was changed from 1.000 to 0.990 MHz. Using this technique it should be possible to find domains separated by a distance smaller than 0.1 μm , provided that domains can be written with such a small distance in between.

In Fig. 6 the MFM observations of the recordings on Disk D using 400 Oe applied field and 30 ns write pulse are presented. As can be seen in this figure, it is clear that as small distance as 0.1 μm between adjacent domains with the size of 0.25 μm , can indeed be written on this disk.

Finally a recording was made with the intention to study how close domains can be written on Disk D. The pulse from the pulse generator is somewhat irregular for a 30 ns write pulse. To receive a zero amplitude of 30 ns between the 30 ns pulses (FWHM), a delay of 50 ns had to be chosen for the pulse generator. Using an applied field of 100 Oe and a 30 - 50 ns writing sequence (frequency of 12.5 MHz), recordings were performed at different laser powers. The recordings were done with laser powers close to where no resulting signal could be noticed on an oscilloscope after writing. The samples were then subject to MFM studies and the result is presented in Fig. 7.

Fig. 5. MFM image of 0.25 μm domains recorded using a 30 ns write time and 400 Oe applied field (signal level of 10 mV in Fig. 4). The track pitch is 1.4 μm .

Fig. 6. MFM image of two closely recorded domains by using a small shift in writing frequency. The track pitch is 1.4 μm .

Fig. 7. MFM image of domains with widths of 0.1 μm recorded on Disk D. The track pitch is 1.4 μm .

As can be seen, it was possible to write domains with a very high density on this single layer RE-rich TbFeCo disk. From the MFM measurements the width of the domains are estimated to 0.1 μm . The recording period was 80 ns, corresponding to a 0.34 μm period (disk speed was 4.2 m/s). In Fig. 7 the domains seem to be somewhat elongated and the length is estimated to 0.17 μm with a distance of about 0.17 μm in between. Note that the recordings were made with an applied field of 100 Oe. Probably further achievements can be made by recordings using a laser with a shorter wavelength than 830 nm and at other applied field strengths. Further investigations are needed to clarify this.

CONCLUSIONS

TbFeCo single layer magneto-optical disks with a highly rare earth rich composition have been shown to have promising properties for recording of small size domains, and may be candidates for high density recording in future products. Using a disk drive with a laser wavelength of 830 nm, circular shaped domains with a diameter of 0.25 μm diameter could successfully be written on this type of disk. The recording stability of small sized domains was found to be higher for a rare earth rich disk than for a transition metal rich disk. For the latter disk a low stability, dependent on the applied field, was found when recording domains smaller than 0.5 μm . On the rare earth rich disk, two 0.25 μm domains could be written as close as 0.1 μm to each other. Furthermore, it was found that it was possible to write domains even smaller than 0.25 μm . Domains with a width of only 0.1 μm and a length of 0.17 μm could successfully be recorded with a distance of 0.17 μm in between.

ACKNOWLEDGEMENTS

H. Miyamoto, J. Ushiyama, K. Andoh and Y. Anzai are gratefully acknowledged for scientific and technical assistance during this work. We would also like to thank H. Kuroda, at Hitachi Construction Machinery Co., Ltd, for the MFM measurements.

REFERENCES

- [1] T. Maeda, T. Toda, H. Ide, F. Kirino, S. Mita, and K. Shigematu. IEEE Trans. Magn., **29**, 3787 (1993)
- [2] M. Ojima, A. Saito, T. Kaku, and Y. Tsunoda, SPIE **529**, 12 (1986)