Improvement of Super-RENS MO Disk Characteristics by Optimized Super-Resolution Near-Field Structure

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Abstract- As a result of applying super-resolution near-field structure to a magneto-optical disk with a non-magnetic mask layer such as a silver oxide light scattering center type mask layer, we could retrieve the signals of below 200-nm mark length. With the improved antimony transparent aperture type mask layer, in this work, we could get the polarized magneto-optical signals as well that we had not been able to obtain by using the previous antimony mask layer. This was well agreed with computer simulation result. Another optimization, such as magnetic layer thickness, dielectric materials and so on, was also investigated for a better magneto-optical disk of super-resolution near-field structure with a silver oxide light scattering center type mask layer.

Key words: near-field optics, super resolution near field structure, surface plasmon, magneto-optical disk

1. Introduction

To archive high-density terabyte media beyond optical resolution limit, several methods, such as using a solid immersion lens (SIL), a scanning near-field optical microscope (SNOM), a three-dimensional memory, a multi-level phase change memory,¹⁾⁻⁶⁾ a magnetically super resolution (MSR), a magnetic amplifying magneto-optical system (MAMMOS),⁷⁾⁻⁹⁾ have been proposed. Among these methods, MSR disk has been already developed, such as ASMO, GIGAMO, and the other methods also try to improve characteristics for their practical use. Super-resolution near-field structure (Super-RENS) disk is a promising technology in the point of view that has the removability, uses the near-field optics with constant spacing and is compatible with present system. Nowadays, Super-RENS method has advanced the signal characteristics of below 100-nm mark length size with using phase change (PC) recording layer. This Super-RENS PC disk can obtain the signal of below 100-nm mark length using both the antimony (Sb) transparent aperture (TA) type and the silver oxide (AgOx) light scattering center (LSC) type mask layers.¹⁰⁾⁻¹²⁾ On the other hand, Super-RENS MO disk could get the polarized MO signal only using the AgOx LSC type mask layer.¹³⁾ In this work, we tried to retrieve the polarized MO signal

with the Sb TA type mask layer and compare with the computer-simulation results. Additionally, for optimization of Super-RENS MO Disk with the AgOx LSC type mask layer, we investigated the effect of the interlayer thickness, the recording layer thickness and the dielectric layer species.

2. Experimental

We prepared several disks for confirming the Sb TA type Super-RENS effect with the improved Sb layer. On a polycarbonate substrate, a 1st dielectric layer of 60 nm, a mask layer of 15 nm, an interlayer of 15 nm, a recording layer of 25 nm, a 2nd dielectric layer of 25 nm and a reflective layer of 50 nm were RF sputtered continuously. This basic structure of Super-RENS MO disk with the AgOx and the Sb mask layers was depicted in Fig. 1. We also changed the interlayer thickness, the recording layer thickness and the dielectric layer species for optimizing the structure and materials of the AgOx LSC type disk. The AgOx mask layer was sputtered by RF-reactive method with a pure Ag target and the gas mixture

Fig. 1 Basic structure of Super-RENS MO disk.

of argon (Ar) and oxygen (O₂). The gas flow rate of O₂ to the total was about 0.5, and n , k values of the refractive index were about 2.7, 1.5, respectively. In order to evaluate the electrical characteristics of the disk, a Nakamichi OMS-2000 MO disk drive tester was used with the laser wavelength of 780 nm and the lens numerical aperture of 0.53. The measuring conditions for the disks were a linear velocity of 6.0 meter/sec, the magnetic intensity of 200 Oe, the duty of 50 % and the bandwidth of 30 kHz. For measuring the refractive index of n , k , we used a MIZOJIRI DHA-OLX/S4M ellipsometer.

3. Results and discussion

We have obtained the polarized MO signals of 170-nm mark length with a non-magnetic AgOx mask layer. In this case, the mask layer is partially changed to heat-generated silver (Ag) or its clusters by laser-heat, which generate surface plasmon and detect the polarized signals.¹²⁾ A Sb mask layer makes a transparent aperture, and through this aperture, we expected to detect the polarized signals with near field of the evanescent wave. But no signal at small mark-length beyond the resolution limit of 370 nm was detected in previous experiments.¹³⁾ If we can obtain the same result of C/N by a Sb mask layer, compared with a AgOx mask layer, the Sb TA type disk is more preferable considering oxidation problem of TbFeCo layer by AgOx layer and its sputtering process. In this work, by using the improved Sb mask layer, we could retrieve the polarized MO signals beyond the resolution limit, as shown in Fig. 2, although the signal intensity of C/N is small compared with the AgOx LSC type Super-RENS disk. It is thought that the improvement is caused by the optical property change of Sb mask layer, and by using the Helicon-Wave sputter equipment that has the distance of 200 mm between a target and a substrate. That, probably, result in reducing

Fig. 2 Mark length and C/N characteristics in sample-disks.

Fig. 3 Optical characteristics change of improved Sb Layer.

internal stress of layers. The improvement of optical characteristics of the Sb layer is shown in Fig. 3. Generally, a Sb layer of about 15-nm thickness has the crystalline structure and the case of about 5-nm thickness has the amorphous structure in as-deposited state. From Fig. 3, we can know that the improved Sb layer has a higher extinction coefficient (k) in crystalline state of 15-nm thickness, and has a lower k in amorphous state of 5-nm thickness than those of the previous Sb layer. This much larger difference of k value between crystalline and amorphous state probably makes the improvement of signal characteristics of Sb TA type Super-RENS MO disk. That is to say, a center amorphous transparent aperture part by laser heat becomes more transparent (low k) and the other crystalline parts become more opaque (high k). From

Fig. 4 Effect of read power in AgOx and Sb mask layer disks.

this result, we expect that clear aperture for better C/N can be obtained. In previous work, we simulated the electric field intensity of the AgOx and the Sb type Super-RENS MO disks by FDTD method. The electrical field intensity of the AgOx type Super-RENS disk was about 20 times stronger than that of the Sb type disk.¹³⁾ As shown in Fig. 2, we can know that the improved Sb type Super-RENS MO disk has the lower C/N by 10~15 dB than that of the AgOx type disk, which is well agreed with the simulation result. In the Sb TA type Super-RENS MO disk, a write power (P_w) and a readout power (P_r) are much higher than those of the AgOx type disk as shown in Fig. 4. We think that this is caused by high thermal conductivity of the Sb mask layer, which is 20 times faster than the AgOx mask layer. In this case, the mark length of the magnetic signal was 300 nm, and the writing powers of the AgOx and the Sb type disks were 4.4 mW and 8.5 mW, respectively.

The intensity of a near-field signal is generally decreased with distance, exponentially. Therefore, in Super-RENS disks, interlayer thickness between the mask and the recording layers is important in the point of view of signal intensity transferred from the evanescent near-field. Figure 5 shows the effect of interlayer thickness of the 210~250-nm mark length signals beyond the resolution limit in the AgOx LSC type Super-RENS disks. As decreasing mark size, the shorter distance between the mask and the recording layers is necessary for detecting signals. For example, the case of 250-nm signal has the minimum value of 150-nm interlayer thickness (spacing), on the other hand, that of 210-nm signal is 25-nm spacing. For optimizing magnetic layer thickness, we changed thickness from 20 nm to 30 nm as shown in Fig. 6. The composition of magnetic layer is $Tb_{21}Fe_{71}Co_8$ (at%), and Curie temperature (T_c) and compensation temperature (T_{comp}) are about 250 °C, below room temperature, respectively. The carrier to noise ratio (C/N) characteristics at relative large mark size of 300~500 nm is, a little,

Fig. 5 Effect of interlayer thickness in 210~250 nm mark length signals.

different from that of below the 300-nm signals. We could not know the reason exactly, and then much thicker or thinner magnetic-layer-thickness-change experiments will be done for understanding the reason. At the moment, we can know that thickness of magnetic layer of 20~30 nm is not so critical for characteristics of Super-RENS MO disk.

The magnetic layer, such as $TbFeCo$, can be oxidized by oxygen component of the $ZnS-SiO_2$ dielectric layer, which is used in the AgOx type Super-RENS MO disk. In this point of view, we used another dielectric layers, such as a SiN_x and a AlN_x layers, which do not have oxygen component. Figure 7 shows the change of C/N as a function of the mark length according to the dielectric layer species. As shown in Fig. 7, SiN_x dielectric layer shows the good result and is preferable. In respect to readout power, P_r , a disk using the SiN_x dielectric layer had the

Fig. 6 Effect of magnetic layer thickness.

Fig. 7 Effect of dielectric layer species

middle-Pr value of 3.8 mW among the above three-species disks. In the case of the Super-RENS MO disks using the SiNx and the AlNx dielectric layer, C/N is decreased at near the 500-nm mark length signals. It is thought that the magnetic domain is degraded by high readout power. This will be, probably, able to be resolved by reducing the 2nd dielectric layer thickness for high-transfer of heat to the reflective layer.

4. Conclusion

From this work, we could retrieve the magnetic polarized signals beyond the resolution limit by both AgOx LSC type and Sb TA type Super-RENS methods, although the characteristics of AgOx type is much better than that of Sb type. This polarized signal detection on the Sb type Super-RENS MO disks could be succeeded by improving optical properties of the Sb mask layer. As results of changing magnetic layer thickness and the dielectric layer species for optimizing disk structure and materials, it was found that the effect of the magnetic layer thickness is not so critical in 20~30 nm range, and a SiNx dielectric layer is more preferable than the other ones. We could obtain circular magnetic domain signals below 200-nm mark length, which can increase both longitudinal and radial recording density with a non-magnetic mask layer of the simple structure.

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