Influence of Layer Structure on Write/Erase Repetition Characteristics of Magneto-Optical Disks

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The relationship between erase-write characteristics or write/erase repetition characteristics and the layer structure of magneto-optical disks, was studied both experimentally and by computer simulation. For tri-layer structure disks such as Sub./SiN/TbFeCo/SiN, an erase power of 11.5 mW is needed to erase a recorded domain, perfectly. The carrier level of tri-layered disks decreases with increasing write/erase repetition cycle. This is due to structure relaxation in the recording film which is caused by heating above a maximum temperature of 350°C.

A quadri-layer structure is studied which has a thinner recording layer and a metal layer, whose thermal conductivity is low. With this structure, the carrier level decreases after repeated write/erase processes. As the maximum temperature on the recording film is higher than 370°C, there is also structure relaxation in the recording film. When Al, whose conductivity is large, was used as the metal layer, the number of the write/erase repetition cycles was increased and there was no structure relaxation when the maximum temperature was lower than 300°C. The disk incorporating this structure has a larger carrier to noise ratio. Using these results, the disk structure was optimized. After repetition of erase and write, C/N did not change. This disk has high reliability against thermal resistance.

**Keyword:** structure relaxation, tri-layer structure, quadri-layer structure, magneto-optical disk, write/erase repetition cycle, thermal conductivity

I. Introduction

Amorphous rare earth-transition metal (RE-TM) alloy films have a large potential for use as magneto-optical recording media. Various characteristics of disks with such films have been reported\(^{(1)}\)\(^{-}(3)\). They include the write-read characteristics, the write/erase repetition cycle, and reliability. These characteristics, especially the write/erase repetition cycle, were found to depend on the layer structure of the disk.

After the film is exposed to a maximum temperature higher than 350°C, structure relaxation occurs in the amorphous film, and the magnetic properties such as perpendicular anisotropy, coercive force, saturated magnetization and the Kerr rotation angle change. As a result, the carrier to noise ratio decreases.

This paper reports on the relationship between the layer structure of the magneto-optical disks and disk characteristics such as write-erase characteristics and write/erase repetition characteristics, through both experiment and computer simulation.

II. Experimental

1. Disk preparation

The structure of the magneto-optical disks investigated is either of the following two; a tri-layered disk or a quadri-layered disk (Fig. 1). Photopolymerization (2p-method) pre-grooved glass disks (130 mm diameter) were used as substrates. The track pitch of the pre-grooved disks was 1.6 μm. For the tri-layered disk, TbFeCo alloy was used as a magneto-optical recording film (80 or 100 nm thick) which was sandwiched between silicon nitride layers; the Kerr enhancement layer was 85 nm thick, and the protective layer was either 150 nm thick or 200 nm thick. For the quadri-layered disk, the first Kerr enhancement layer (silicon nitride) was 85 nm thick, TbFeCo alloy layer as the magneto-optical recording film was 30 nm thick, the second Kerr enhancement layer (silicon nitride) was 150 nm thick, and the protective layer was 200 nm thick.

![Tri Layer Disk](image1)
![Quadri Layer Disk](image2)

Fig. 1 Disk structures.

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nitride) was 20 nm thick, and the metal layer (a thermal diffusion layer or a reflective layer) was 50 nm thick. Aluminum and stainless steel (SUS316) were used as the metal layer. These films were deposited by sputtering. The silicon nitride layer was prepared with a silicon target (purity: 99.999% up) and a mixture of Ar/N₂ (90/10 volume ratio) as the sputtering gas. The TbFeCo recording layer was sputtering from a TbFeCo alloy target in Ar gas. The metal layer, was sputtering from either an aluminum or stainless steel (SUS316) target in an Ar atmosphere. The composition analysis of each recording film was performed by inductive coupled plasma spectroscopy (ICPS).

2. Measurement of magnetic properties

The saturation magnetization (Ms) and the coercive force (Hc) were measured with a vibrating sample magnetometer (VSM) at a maximum applied field of 1600 kA/m (20 kOe). The Kerr rotation angle (Θk) and the coercive force (Hc) were measured using a Kerr effect measurement apparatus at a wavelength of 830 nm in fields up to 1120 kA/m (14 kOe). The Curie temperature (Td) and the compensation temperature (Tcomp) were obtained from the temperature dependence of Θk and Hc. The perpendicular anisotropy (Ku) was measured with a torque magnetometer at a magnetic field of 1120 kA/m (14 kOe).

3. Measurement of disk characteristics

The dynamic write-read characteristics and write-erase characteristics were studied using a magneto-optical disk drive (NAKAMICHI OMS-1000) with an objective lens of numerical aperture (NA) 0.53. This drive had a 30 mW semiconductor laser with a wavelength of 830 nm. The disk rotation speed was 1800 rpm.

The domains recorded on the non-grooved flat area and grooved area of the disks were observed from the film side using a TV camera mounted on a high resolution polarized microscope (Carl Zeiss, Photomicroscope III). The total magnification was 1600, and the typical resolution, wavelength and NA were 0.1 μm, 550 nm, and 1.2, respectively.

III. Results and Discussion

1. Computer simulation of the relationships between magnetic and magneto-optical properties and disk layer structure

There are two important points which must be considered when designing the disk layer structure: perfect erasure and a high carrier to noise ratio (C/N). The width of the recorded domains was conventionally designed to be 0.8 μm. A off track distance of ±0.1 μm may occur in opposite directions for writing and erasing. Therefore, for perfect erasure, the erasing width should be designed wider than 1.2 μm, as illustrated in Fig. 2.

C/N is dependent on the Kerr rotation angle. In general the C/N is in proportion to \( \sqrt{R \cdot \Theta_k} \), where, R is the reflectivity. \( \sqrt{R \cdot \Theta_k} \) is a figure of merit of the medium (CNR \( \propto P_0 \cdot R \cdot \Theta_k \), \( P_0 \) laser power/\( R \)-reflectance/\( \Theta_k \)-Kerr rotation angle). Thus, a high C/N is obtained when \( \sqrt{R \cdot \Theta_k} \) is large. The relationship between the disk layer structure and the disk characteristics was simulated using a computer. This included both thermal and optical calculations.

(1) Thermal calculation

The important point in a thermal calculation is to obtain a maximum temperature on the recording film when the data is erased or recorded. In the experiment, the erasing domain width was 1.2 μm when the recorded data was being erased, perfectly. The maximum temperature was calculated at the outermost track of 5.25° magneto-optical disks (r=60 mm, linear velocity: \( v = 15 \text{ m/s, external magnetic field } H_a = 32 \text{ kA/m (400 Oe).} \)) There were two disk structures: Sub./SiN₅ (85 nm)/TbFeCo (100 nm)/SiN₅ (200 nm) (DISK I) and Sub./SiN₅ (85 nm)/TbFeCo (80 nm)/SiN₅ (150 nm) (DISK II). Table 1 shows the calculated results. As can be seen, the necessary laser power is 11.6 mW for DISK I and the maximum temperature of the recording layer is about 309°C.

Figure 3 shows a temperature distribution which is a function of the distance from the center of the laser spot. There is a difference in the temperature slope between the innermost area \( v = 7.5 \text{ m/s, } r = 30 \text{ mm} \) and the outermost area \( v = 15 \text{ m/s, } r = 60 \text{ mm} \). The temperature slope at the innermost point is sharper, and the maximum temperature is higher.

The protective SiN₅ layer and the recording layer for DISK II was thinner than that for DISK I, so that the recorded domain width of 1.2 μm was formed at the laser power of 10 mW. The maximum temperature of the recording film at the outermost track was 277°C, this temperature was lower than that of DISK I. These results demonstrate that the recording and erasing sensitivity of magneto-optical disks can be engineered by controlling the thickness of the SiN₅ layer and the TbFeCo recording layer.
Table 1  Disk characteristics of several disk structures.

<table>
<thead>
<tr>
<th>Disk structure</th>
<th>Disk I</th>
<th>Disk II</th>
<th>Disk VII</th>
<th>Disk III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disk film</td>
<td></td>
<td></td>
<td>30 nm (50 nm)</td>
<td></td>
</tr>
<tr>
<td>SIn film</td>
<td>200 nm</td>
<td>150 nm</td>
<td>30 nm</td>
<td>50 nm</td>
</tr>
<tr>
<td>TbFeCoNb film</td>
<td>100 nm</td>
<td>80 nm</td>
<td>20 nm</td>
<td>50 nm</td>
</tr>
<tr>
<td>SIn film</td>
<td>85 nm</td>
<td>85 nm</td>
<td>85 nm</td>
<td>85 nm</td>
</tr>
</tbody>
</table>

Laser power at 1.3 \( \mu \)m

| Domain width of erasing | 11.6 mW | 10.0 mW | 9.1 mW | 6.6 mW |

Maximum temperature at erasing of 1.3 \( \mu \)m width

| 310°C | 277°C | 281°C | 350°C |

Erasing condition; linear velocity; \( v = 15 \text{ m/s} \) \( (r = 60 \text{ mm}) \)

magnetic field; \( H_{e} = 32 \text{ kA/m (400 Oe)} \)

Fig. 3  Thermal distribution obtained by crossing over a guide track.

Figure 4 shows the temperature distribution under conditions at which a domain of 1.25 \( \mu \)m width is formed, for both the tri-layered disk and the quadri-layered disk. The laser power needed to form a 1.25 \( \mu \)m domain width was 11.6 mW at the outermost area \( (r = 60 \text{ mm}) \) for the tri-layered disk (Table 1). The maximum temperature was 310°C, which is identical to that of the tri-layered disk. On the other hand, for the quadri-layered disk, the laser power needed to form a 1.25 \( \mu \)m domain width was 9.1 mW at the outermost area.

The light transmittance to the recording layer can increasing by using a thinner recording layer, the utility efficiency of light is decreasing. In this case, a metal film as a light reflective film is needed to increase the utility efficiency of light. This film provides both a light reflectivity effect and a thermal diffusion effect. Figure 5 shows the relationship between reflectivity and thermal conductivity. The laser power to form a recorded domain of 1.3 \( \mu \)m width, and maximum temperature was calculated when Al, high thermal conductivity and high reflectivity, and SUS316 stainless steel, low thermal conductivity and low reflectivity, were used as the light reflective layer.

Figure 6 shows the temperature distribution under the conditions at which a domain of 1.3 \( \mu \)m width is formed for disks with Al and stainless steel reflective layers. The laser power needed was 9.1 mW for the disk using the Al reflective film (Table 1). The maximum temperature was 300°C, which is identical to that of the tri-layered disk. For the disk using stainless steel, the laser power was 6.6 mW, and lower than that of the disk using an Al reflective film. In this case, the maximum temperature was 370°C, which was too high for the stability of the record-

Fig. 4  Thermal distribution obtained for two disk structures by computer simulation.

Fig. 5  Relationship between thermal conductivity and reflective index.
ing film. This result shows that the disk, with a stainless steel reflective film, has a problem in the write/erase characteristics, as compared with the disk using Al reflective film.

(2) Optical design

A thinner recording film results in reduced optical efficiency. To improve this point, a fourth layer was formed as an optical reflective layer. This structure, called the quadri-layer structure, utilized not only the Kerr effect, but also the Faraday effect.

From an optical viewpoint, the thickness of the recording film and the second dielectric film are important factors as they enhance the Kerr effect and the Faraday effect. Thus, the relationship between the reflectivity \( R \) or the Kerr rotation angle \( \Theta_k \) and the thickness of the recording film and the dielectric film was calculated. The reflectivity of the multi-layer structure was calculated by the following equation\(^{40}\):

\[
R_i = \frac{r_i + R_{i-1}}{1 + r_i \cdot \exp \left\{ (-2n_i d_i / \lambda) i \right\}}
\]

\[
/ \left[ 1 + r_i \cdot \exp \left\{ (-2n_i d_i / \lambda) i \cdot R_{i-1} \right\} \right]
\]  

(1)

\( R_i \): the reflectivity,  
\( d_i \): the thickness of the \( i \) layer,  
\( r_i \): the complex reflective index at the interface between the \( i \) layer and the \((i+1)\) layer,  
\( n_i \): the complex reflective index of the light incident from the \( i \) layer to \((i+1)\) layer.

Figure 7 shows a surface with a coating of thickness, \( d \), which is optically equivalent to a surface with reflectivity, \( R_i \). The Kerr rotation angle was calculated by the following equation:

\[
\Theta_k = (1/2) \tan^{-1} i \left\{ (R_s R_p - R_p R_s) / |R_s|^2 - |R_p|^2 \right\}
\]

(2)

Figure 8 shows the results of the calculation. This figure shows the relationship between \( \Theta_k \) or \( R \) and the thickness of the second Kerr enhancement film for several values of the thickness of the recording film. According to this figure, as the recording film becomes thinner, the transmittance to the recording film increases. The
enhancement of the Kerr effect strongly depends on the thickness of the second enhancement film. With regard to the compatibility with the standard disk drive, the reflectivity of an optical disk should be more than 20%. Thus, the lower limit of the recording film thickness is determined to be 30 nm, using this calculation.

2. Write-erase characteristics and repeatability of the tri-layered magneto-optical disks

(1) Write-read characteristics
Two types of disks were compared: SiN<sub>x</sub> (85 nm)/TbFeCo (100 nm)/SiN<sub>x</sub> (200 nm) (DISK I), and SiN<sub>x</sub> (85 nm)/TbFeCo (80 nm)/SiN<sub>x</sub> (150 nm) (DISK II). Figure 9 shows these disk structures. The coercive force (Hc) and the Kerr rotation angle (θ3) of DISK II did not change, even though the thickness of recording film was about 80% thickness of DISK I. Figure 10 shows the dependence of carrier and noise level on external magnetic field and recording laser power. The dependence of carrier and noise level on external magnetic field is identical between DISK I and DISK II. The minimum laser power for recording is 4.5 mW for DISKII, and 6.5 mW for DISK I. The recording sensitivity for DISK II is higher than that for DISK I. In the case of DISK II, the carrier level first increases and reaches its peak at 7.5 mW, and then slowly decreases. The decrease in carrier level indicates that the recording resolution ratio becomes lower as the formed domain becomes larger and closer to the next recorded domain.

(2) Write-erase characteristics
The erasing laser power at r=60 mm was measured as a function of off track distance for DISK I and DISK II. Figure 11 shows the obtained results. From this figure, the perfect erasing laser power is found to be 13 mW for DISK I, and 11 mW for DISK II, considering ±0.1 μm off track allowance.

(3) Characteristics of write/erase repeatability
The change in carrier level was measured, after write/erase was repeated at r=30 mm (the innermost area of a 5.25" magneto-optical disk). These results are presented in Fig. 12. The laser power was set at a power for achieving maximum C/N. For an accelerated repeatability test the erasing laser power was set at 1.2 times the power for the 1.2 μm written domain width, at which perfect erasure is achieved, considering off track of ±0.1 μm.

![Fig. 9](image_url) Dependence of carrier and noise level on external magnetic field and recording laser power.

![Fig. 10](image_url) Relationship between erase laser power and track offset.

![Fig. 11](image_url) Change in carrier level after write/erase repetition.
On DISK I, the carrier level decreased, after write/erase repetition of $10^4$ cycles by 3 dB. On DISK II, on the other hand, the carrier level decreases by 18 dB, after $10^5$ repetitions.

Figure 13 shows the recorded domain for Disk II after write/read repetition of $10^3$ cycles, using with a polarizing microscope. Along the center of the recorded domain, a gray belt like region can be seen. A microscopic area of reversed magnetization may be present around the center of the track. A possible explanation for this phenomenon is that, in that region, some change has occurred in the magnetic properties such as the perpendicular anisotropy energy, $K_u$, through the elevation of temperature during the write/erase process. As the recording film thickness for the DISK II is thinner than that DISK I, its minimum laser power is smaller. However, since the maximum temperature of the recording film is higher, it induces structural relaxation of the amorphous magneto-optical recording film for DISK II.

3. The write-erase characteristics and repeatability of quadri-layered magneto-optical disks

(a) Read-write characteristics dependence on the disk structure

The quadri-layered disks were studied, because they have suitable magneto-optical properties as well as recording sensitivity. A metal layer with a high light efficiency and thermal diffusivity was formed as the fourth layer of the magneto-optical media. The relationships between the thickness of the recording film and the magnetic properties such as the curie temperature ($T_c$), the compensation temperature ($T_{comp}$) and the coercive force ($H_c$) are shown in Fig. 14. As the recording layer become thinner, $T_{comp}$ decreases, $H_c$ increases, but $T_c$ remains constant. The origin of the change in magnetic properties is unknown; however, internal stress and film oxidation is suspected.

The metal reflective materials were classified into three groups with regard to their thermal conductivity and reflectivity (Fig. 5). From amongst them, stainless steel, of low thermal conductivity and reflectivity, and Al, of high thermal conductivity and reflectivity, were selected.

At first, four types of magneto-optical disks, were formed with the stainless steel as a reflective layer, and the disk characteristics were measured. The disk structure is shown in Fig. 15, and the magnetic and magneto-optical characteristics are given in Table 2. Figure 16 shows the recording laser power dependence of the carrier level. From this figure, it is concluded that the minimum recording laser power changes in proportion to

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Fig. 12 Microscopic observation of recorded domain after write/erase repetition of $10^3$ cycles.

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Fig. 13 Dependence of Curie temperature, compensation temperature and coercive force on recording film thickness.

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Fig. 14 Disk structures.
the total layer thickness, i.e., recording layer and reflective layer. For DISK III, whose recording layer thickness is 30 nm, the minimum recording laser power is 3.5 mW, at $r=30$ mm. For DISK IV and V, whose stainless steel layer (reflective layer) come in contact with the recording layer, the recording laser power is 4.5 mW. The value at the peak carrier level is the same in spite of the difference in the disks. But the noise level is 4 dB higher for DISK IV, V and VI than the other disk structures. These results are due to the uneven surface of stainless steel. The characteristics are, however, identical at the outer-most track ($r=60$ mm).

Next, the magnetic field dependence of the recorded signal was measured. Figure 17 shows the obtained results. The difference in the disk structures is not considered. The noise level for DISK III is the lowest. Moreover, the modulation noise is high for DISK IV. This result shows that this noise is due to the Fe rich composition(3).

The write-read characteristics of DISK VII, whose reflective layer was of Al, are shown in Fig. 18. Figure 18(a) shows the dependence of the carrier and noise level on the external magnetic field. The carrier level is constant above 150 Oe. At the erasing side, the magnetic field for perfect erase is determined to be 150 Oe. Figure 18(b) shows the dependence of the carrier and noise level on the recording laser power. The minimum laser power for recording at $r=30$ mm is 3.5 mW. The peak of the carrier level is at a power of $6 \sim 7$ mW; the carrier level decreases with increasing a laser power. It is caused by the increase in the recorded domain length.
The minimum laser power at \( r = 60 \text{ mm} \) is 5.0 mW, and the carrier level increases suddenly at a laser power of 5.5 mW. Then, the carrier level increases slowly as the recording laser power increases.

(2) Relationship between the disk structure and the write-erase characteristics

The write-erase characteristics of a quadri-layered disk was measured: its structure was: Sub./SiN\(_x\) (85 nm)/TbFeCo(30 nm)/SiN\(_x\) (20 nm)/metal layer (50 nm).

Stainless steel (DISK III) and Al (DISK VII) were used as the metal layer. Figures 19 and 20 show the write-erase characteristics. Figure 19 shows the relationship between recording laser power and recorded domain width at \( r = 60 \text{ mm} \) on 5.25" magneto-optical disks. A laser beam was continuously or intermittently irradiated on the disks. The recorded domain formed on DISK VII was larger than that on DISK III. In Fig. 20, the relationship between recorded domain width and laser power is shown for DISK II, which is without the metal layer, DISK VI, whose metal layer was formed with the stainless steel, and DISK VII, whose metal layer was formed with Al. The slope of the line for DISK II and DISK VI are identical, but the slope for DISK VII is larger. These results show that heat diffuses widely when an Al metal layer is used. As a result, the width of the recorded domain is large. The diffusion coefficient for DISK VII which used an Al metal layer was larger than that of the disk which used stainless steel. For the disk which used stainless steel, the heat did not diffuse in the direction parallel to the substrate.
The relationship between linear velocity and the recorded domain width of 1.2 \mu m was measured for DISK II, DISK III, and DISK VII. Figure 21 shows the obtained results. The slope for DISK II is the largest and the slope for DISK VII is the smallest. It indicates that DISK VII has a large diffusion coefficient compared with other two disks. It needed larger laser power to erase at the outermost area (r=60 mm) on DISK II and DISK III than on DISK VII.

(3) Layer structure and write/erase repetition characteristics

The relationship between repetition cycle and carrier level is shown in Fig. 22 for disks using a metal layer such as stainless steel or Al, and tri-layered disks. In this figure, DISK III, whose recording film thickness was 30 nm, shows a drop in the carrier level by 18 dB after repetition cycles of 10. The carrier level decreases by 25 dB after repetition of $5 \times 10^2$ cycles. At repetition of more than 100 cycles, the change velocity of the carrier level slows. DISK VI, whose recording film thickness was 80 nm, shows a carrier level change similar to that of DISK II, which is a tri-layered disk, for the repetition of 100 cycles. The carrier level continues decreases at $10^3$ cycles.

The use of stainless steel slightly suppresses the decrease in carrier level. The carrier level for DISK IV and DISK V decreases slowly. After 10 cycles of write/erase repetition, the decrease in carrier level is 4 dB, and then the carrier level decreases in proportion to the number of write/erase repetition cycles. After $10^4$ cycles, for DISK IV, the decrease in carrier level is 18 dB. For DISK V, the change in carrier level is 13 dB after $10^4$ cycles. Thus, the disks using the stainless steel as the metal layer, have the same degree of change in the carrier level. These phenomena agree with the computer simulation, which indicate that the maximum temperature is so high that structure relaxation occurs.

Next, the change in carrier level was measured for DISK VII which used Al as the metal layer, after write/erase repetition as shown in Fig. 23. The carrier level does not change after $10^4$ cycles under the accelerated conditions.

The experimental results were compared with the computer simulation (Fig. 6). For the disk using the stainless steel, the center of the laser spot is easily heated, and this heat is not easily conducted around the laser spot. Therefore, forming a wide recorded domain requires high laser power, where the temperature of the recording
film increased higher than 300°C, causing structure relaxation in the amorphous film, and reducing the perpendicular anisotropy, and subsequently changing the carrier level.

For the disk using Al film, on the other hand, the heat produced by the laser beam easily diffuses around the laser spot. It means that a wide recorded domain can be formed at a low laser power. The temperature of the recording film for DISK VII is lower than 300°C. Accordingly there is no structural relaxation in the recording amorphous film. The recording sensitivity is controlled by changing the thickness of the metal layer and the thermal conductivity of the metal layer.

The magneto-optical disk with a Sub./SiN₈ (85 nm)/TbFeCo (30 nm)/SiN₈ (20 nm)/Al alloy layer (50 nm) structure featured write/erase repetition (Fig. 24). The carrier and noise ratio did not change at more than 10⁷ erase and write cycles, under the following conditions: recording laser power of 7.5 mW, erasing laser power of 7.5 mW, reading laser power of 1.5 mW, pulse width of 63 ns at recording, recording area of r = 30 mm, and external field of 32 kA/m (400 Oe). The results show that these disks have high reliability under thermal conditions.

IV. Conclusion

The relationship between the layer structure of magneto-optical media and the disk characteristics such as write-read characteristics, write-erase characteristics, and write/erase repetition characteristics have been studied through both computer simulation and experiment. The following conclusions have been made.

1. The relationship between the thickness of the recording layer and SiN₈ layer and the disk characteristics for tri-layer structure disks such as Sub./SiN₈ (85 nm)/TbFeCo (100 nm)/SiN₈ (200 nm) is investigated. The write-read characteristics were studied for recording layer thicknesses of 80 to 100 nm and SiN₈ layer thicknesses of 150 to 200 nm. The carrier to noise ratio (C/N) of both disks are 45 dB (recording area: r = 30 mm, recording frequency: 3.7 MHz, and domain size: 0.8 μm). A laser power of 11.5 mW is needed to form a recorded domain of width 1.3 μm, under which the recorded data is perfectly erased, from the measurement of the write-erase characteristics. From the write/erase repetition cycle measurement, the carrier level decreases faster with the write/erase repetition, as the thickness of the recording layer and SiN₈ layer become thinner. This phenomenon is caused by the decrease in perpendicular anisotropy from the structure relaxation of the amorphous film. The structure relaxation is caused by the temperature of the recording layer exceeding 350°C at the innermost area (r = 30 mm).

2. The quadri-layer structure disk is measured on condition that its recording layer is thinner than that of the other disks and that a reflective layer is formed to increase the light efficiency. From computer simulation, disk structures such as Sub./SiN₈ (85 nm)/TbFeCo (30 nm)/SiN₈ (20 nm)/metal layer (50 nm) were matched with the disk drive’s requirement. Moreover, this structure is the best for mass production because the change in thickness of each layer has little effect on the change in disk characteristics. The disk, using either Al or stainless steel for the metal layer, is studied to obtain the write-read characteristics. The C/N is 48 dB (r = 30 mm, recording cycle: 1.5 T). This value is 3 dB higher than that for tri-layer structure disks. From the measurement of the write-erase characteristics, the laser power for perfect erasure is 11 mW when a stainless steel layer is used, and 10 mW when an Al layer is used.

3. The change in disk structure for the quadri-layered disk is determined by measuring the write/erase repetition cycle characteristics. For the disk structures such as Sub./SiN₈ (85 nm)/TbFeCo (80 or 30 nm)/SiN₈ (20 nm)/stainless steel (50 nm), and Sub./SiN₈ (85 nm)/TbFeCo (40 or 50 nm)/stainless steel (40 or 50 nm)/SiN₈ (150 nm), the carrier level decreases as the write/erase repetition cycle increases. On the other hand, the disks such as Sub./SiN₈ (85 nm)/TbFeCo (30 nm)/SiN₈ (20 nm)/Al layer (50 nm), the carrier level does not decrease. Computer simulation indicates that the temperature at the center of the laser beam is identical to that of the tri-layered disk and higher than 350°C when stainless steel is used. It indicates that structure relaxation occurs in the recording film just as for the tri-layered disks. However, when Al is used as the metal layer, the maximum temperature on the recording film is less than 300°C, from computer simulation. It indicates that there is no structure relaxation in this type of disk.

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