MSR DISKS WITH THREE MAGNETIC LAYERS USING IN-PLANE MAGNETIZATION FILMS

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Abstract - Magnetically induced super resolution (MSR) with double masks has been realized without the external magnetic field during readout. This new type of MSR is achieved in disks having three exchange-coupled magnetic layers including in-plane magnetization films. With these disks, a high C/N of 45dB for a mark length of 0.40μm is obtained, making it possible to reduce crosstalk.

KEYWORDS: MAGNETICALLY INDUCED SUPER RESOLUTION (MSR), IN-PLANE MAGNETIZATION FILM, EXCHANGE COUPLING

INTRODUCTION

MSR is one of the promising technologies for achieving high density of magnetooptical disks [1]. Several types of MSR media have already been proposed. Among them, MSR disks with magnetic double layers (D-MSR) using an in-plane magnetization film enables higher linear and track density compared to conventional media without the external magnetic field for readout [2].

We developed MSR disks having the double masks with magnetic triple layers (T-MSR), which results from adding an intermediate layer to D-MSR, and succeeded in improving the MSR characteristics.

This paper first investigates the front mask function consisting of the in-plane magnetization layer. Next, the rear mask formation is analyzed qualitatively. The readout characteristics of T-MSR are then discussed in detail.

EXPERIMENT

Fig.1 shows the structure of the T-MSR prepared on 1.6μm track pitch PC (polycarbonate) substrate. The groove of the substrate is 0.6μm wide and 80nm deep. The readout layer is RE-rich GdFeCo film, and its magnetization direction is in-plane at room temperature (RT) and turn to perpendicular at a higher temperature. The intermediate layer is RE-rich GdFe in-plane magnetization film and its Curie temperature (Tc) is lower than that of the other magnetic layers. The memory layer is TM-rich TbFeCo film.

For C(carrier), N(noise) and crosstalk evaluation, the optical head of A=780 nm, NA = 0.53 was used and no magnetic field was applied during the readout process excluding field dependence measurement. The linear velocity was 9m/s. Crosstalk was measured between land recorded marks of 0.78μm length and its adjacent grooves for which no mark was recorded.

RESULTS AND DISCUSSION

IMPROVEMENT OF FRONT MASK FUNCTION

To analyze the masking effect of in-plane magnetization film, we first evaluated D-MSR having a readout layer of different saturation magnetization (Ms) and a fixed thickness h1 of 50nm (disk D1,D2,D3). All of these readout layers have compensation temperatures between 160°C and 280°C and virtually the same Tc. The memory layer is 30nm thick for all of these disks.

Fig.2 shows the read power dependence of C and N level for a mark length of 0.40μm in these D-MSR disks. C level of disk D1 which has the smallest Ms (100emu/cc) showed almost the same characteristics as the conventional disk, because the readout layer shows perpendicular magnetization at about RT. For disk D3, which has the largest Ms (300emu/cc), the readout layer becomes
perpendicular at the high temperature of 180°C, reducing C level at low power. After Ms of the readout layer was changed from 100emu/cc to 300emu/cc, C level increased for disk D2 which has an Ms of 200emu/cc.

Next, thickness h1 of the readout layer of D-MSR was changed from 40nm to 100nm. C and N measurement of these disks showed that for disk D4 with a readout layer 70nm thick and almost the same composition as that of disk D2, the carrier has a higher value than disk D2, but not high enough for practical use (C/N=35dB).

Kerr loop measurement showed that the readout layer of disk D2 turns completely to perpendicular magnetization at 100°C, but remanent Kerr rotation \( \theta_{kr} \) (Kerr rotation with no magnetic field) appeared at RT. Although \( \theta_{kr} \) of disk D4 was almost zero, the readout layer became completely perpendicular at 120°C, not so high a temperature as in the case of disk D3.

From these results, it is possible to assume that the interface magnetic wall of disk D2 would penetrate significantly to the readout layer which has small effective magnetic anisotropy, and that sufficient masking would not be achieved (Fig.3a). On the contrary, for disk D4 the exchange coupling force between the readout layer and the memory layer becomes weak at the side of light beam, and the magnetization direction of the readout layer becomes sufficiently in-plane to mask the recorded marks in the memory layer (Fig.3b). This can also be achieved without allowing the transition temperature in the perpendicular direction for the readout layer to rise too far, as with disk D3. Therefore, controlling the exchange coupling force or interface magnetic wall is a key point for improving the masking effect of in-plane magnetization film.

We therefore attempted to control the exchange coupling force by using an intermediate layer having a low Tc = 195°C and a larger Ms = 430emu/cc than the readout layer (Fig.1). Fig.4 shows the read power dependence of C and N for T-MSR with reference disks. Although the total thickness of the readout and intermediate layers is 50nm, a large carrier the same as that for disk D4 could be achieved at a low power no higher than 3mW for T-MSR.

The results can be explained in the following manner. For T-MSR, masking effect at low temperature is improved, because the tendency of magnetic alignment toward a perpendicular direction is prevented by the decrease of the exchange coupling force due to the strong effective in-plane magnetic anisotropy of the intermediate layer (Fig.3c). The readout layer also has enough perpendicular magnetization at relatively low power because the Ms of the intermediate layer becomes small for low Tc. Therefore, using the intermediate layer of low Tc and large Ms at RT, C level becomes high without having a thick magnetic layer. This is an advantage especially for high-speed recording.

**MECHANISM OF REAR MASK FORMATION**

In Fig.4, C level strongly increased at low power and steeply increased at 3mW for T-MSR. This shows that in-

![Fig.3 Schematic cross section of the magnetization direction of transition metals at RT for (a) D-MSR (h1=50nm), (b) D-MSR (h1=70nm), (c) T-MSR.](image)

![Fig.4 Carrier and noise level for a mark length of 0.40\( \mu \)m as a function of the readout power for T-MSR (disk A), D-MSR (h1=70nm) and conventional disk.](image)

![Fig.5 Read power dependence of DC level, amplitude of the readout waveform for a 0.78\( \mu \)m mark length and the carrier level for mark lengths of 0.78\( \mu \)m and 0.40\( \mu \)m in T-MSR (disk A).](image)
plane magnetization films function as the front mask, and furthermore, for T-MSR, the rear mask might be created after the temperature reaches \( T_c \) of the intermediate layer, resulting in MSR with double masks\(^1\) being created.

To clarify the magnetic structure of the rear mask of T-MSR, we measured the read power dependence of DC level and amplitude of the readout waveform for a 0.78µm mark length and also C level for mark lengths of 0.78µm and 0.40µm for T-MSR (Fig.5). The DC level of the waveform was measured relative to the center between the signal level when erasing the entire track upward and also, when erasing downward. The erase direction was taken as a positive value.

In Fig.5, up to 3mW of read power, the amplitude of the readout signal increased with the read power because of the increase in light intensity and the formation of the aperture area. DC level also increased gradually, because the erased state remains on both sides of the recorded mark on a land. But at 3.0mW of read power, the rise in amplitude slows, and the DC level suddenly approached sharply the erase level. This coincides with the read power at which C level for 0.40µm steeply increases.

This phenomenon can be explained as the area where magnetization erase direction within the light spot is formed and widened with an increase in power above 3.0mW. From these results, the rear mask might be generated as the copied marks in the readout layer shrink and turn to erase state after that the exchange coupling forces is switched off.

Consequently, the readout state of T-MSR media is considered to have an MSR structure with double masks as shown in Fig.6. In Fig.6, the arrows of each layer indicate the magnetic direction of the transition metals, and the erase state is shifted downward. In the low temperature area (\( T<T_{th1} \)), the readout layer and the intermediate layer have in-plane magnetization and work as the front mask. In the middle temperature area (\( T_{th1}<T<T_{th2} \)), the recorded information in the memory layer is copied onto the readout layer in perpendicular magnetization, forming the aperture. In the high temperature area (\( T_{th2}<T \)), exchange coupling switches off and the magnetic direction of the readout layer shifts to erase state and the rear mask is formed.

Fig.7 shows the possible effective magnetic fields applied to the copied domain in the readout layer after exchange coupling is disconnected. In Fig.7, the open arrows indicate the net magnetic direction of RE-TM atoms of each layer. \( H_{wb} \) is the effective magnetic field caused by the Bloch domain wall. \( H_{leak} \) and \( H_{st} \) are the magneto-static field from the readout layer and the memory layer, respectively.

Shrinking of the written domains copied in the readout layer without applying the external magnetic field is supposed to be promoted by \( H_{wb} \) mainly, and also by \( H_{st} \) which is in the opposite direction of the exchange coupling force between the readout layer and the memory layer. \( H_{leak} \) applied from the adjacent erase state works to expand or stripe the copied domain, although \( H_{leak} \) is weak in the T-MSR because of the compensation temperature of the readout layer. \( H_{st} \) also affects the erase state by reversing the direction of magnetization, but the erase state could
not turn to write state since a large Bloch wall would be formed.

**MAGNETIC FIELD DEPENDENCE OF C AND N DURING READOUT**

Fig.8 shows the magnetic field dependence of C and N for a mark length of 0.40μm in T-MSR during the readout process. When a -40 kA/m external magnetic field (write direction) was applied, C level fell down. That might be caused by that the copying process of the recorded domain from the memory layer to the readout layer being disturbed because of a large Ms intermediate layer interacting with the magnetic field.

The magnetic field of the erase direction might influence the rear mask, because T-MSR is an A-type, but the erasing magnetic field does not exert great impact on C and N level. That was assumed to be due to the Ms of the readout layer having a compensation temperature around 7C of the intermediate layer. The wide margin of ±24 kA/m was achieved with T-MSR for a stable C/N of about 45dB. Therefore T-MSR maintained a stable MSR readout, even with relative fluctuations in the external magnetic field.

**C/N AND CROSSTALK**

Fig.9 shows C/N as a function of the mark length for MSR media and the conventional disk. Read power was set to be 3.5mW for all types of disk. For the optical unit of λ=780nm NA=0.53 used, ideal cut off mark length (λ/4NA) is 0.37μm. Thus, C/N using the conventional detection decreases rapidly at short mark length below about 0.40μm, although the C/N decrease for T-MSR was small. C/N of T-MSR (disk A) was more improved than D-MSR and a high C/N of 45 dB at mark length 0.40μm was obtained.

Fig.10 shows crosstalk measurement results. Crosstalk was improved in comparison to the conventional disk. The other T-MSR (disk B) is shown in Fig.9 and Fig.10. Both the readout layer and the intermediate layer of disk B were set to have an in-plane magnetization of greater strength than disk A at RT. Crosstalk of disk B was less than -30dB at the effective track pitch of 0.8μm, almost the same as D-MSR, and higher C/N, 42dB was obtained compared to that for D-MSR.

**CONCLUSION**

We have investigated the MSR disks using three magnetic layers with in-plane magnetization films. Using the intermediate layer having low Tc and strong in-plane magnetization at RT to control the exchange coupling force, the front masking by in-plane magnetization layer is improved without having a thick magnetic layer. It is also possible to form a new type of rear mask.

With these disks, a high C/N of 45dB for mark length of 0.40μm and less crosstalk can be realized by MSR of double masks without the external magnetic field for readout. These disks hold MSR readout stably under the ±24 kA/m fluctuations of the external magnetic field.

These MSR disks show promise as a next-generation high-density MO disk, because they have a higher linear and track density than conventional disks and can be used in the same type of drives currently in use without the need for additional magnets.

**REFERENCES**