LASER POWER MODULATION DIRECT OVERWRITE ON A Co/Pt MULTILAYER

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Abstract— Laser power modulation direct overwrite (OW) on a Co/Pt multilayer was successful by the magneto-statically coupled OW method. In order to use the Co/Pt multilayer as the storage layer in this method, the magnetization reversal temperature was adjusted by changing the thickness of the Co layer and a small switching field was accomplished by making the total thickness thinner. An OW CNR up to 32 dB with the conventional rare earth-transition metal biasing layer was obtained for the Co/Pt multilayers stacked 2 or 4 times.

KEYWORDS: OVERWRITE, POWER MODULATION, LEAKAGE FIELD, Co/Pt MULTILAYER

INTRODUCTION

Direct overwrite (OW) is the most effective approach for improving the data transfer rate during writing in a magneto-optical (MO) recording system. A new laser power modulation OW method, in which overwriting was carried out by modulating the leakage field generated in the medium, was proposed in a previous work[1]. In this method, the main functional layers, that is, the storage layer (SL) and the biasing layer (BL), were coupled magneto-statically and an initializing process was not necessary before OW. Therefore, an MO recording material which has a low coercivity (H_c) less than 1 kOe can be used for an SL. This is one of the advantages of the magneto-statically coupled OW method.

A thin film Co/Pt multilayer has been studied as a new MO recording material[2,3]. Co/Pt multilayers are thought to be a good candidate for a high density MO recording medium because they have a larger Kerr rotation angle than conventional rear-earth transition metal alloy films at short wavelength. If OW technology is applied to this Co/Pt material, a high speed and high density MO recording system will be realized. For practical use, Co/Pt has a disadvantage of low H_c , but this problem is not so serious for the magneto-statically coupled OW method in principle.

In this paper, an experimental result of laser power modulation OW on a Co/Pt multilayer is shown. Several modifications were required on the magnetic characteristics of Co/Pt when it was applied to the storage layer in the magneto-statically coupled OW medium. The result of these modifications are also presented.

OW PRINCIPLE AND REQUIREMENTS FOR THE SL

The cross-sectional view of the OW medium is shown in Fig.1. It consists of four functional layers; SL, thermal control layer (TCL), BL, and initializing layer (IL). A conceptual view of OW process is shown in Fig.2. In this figure, 2-dimensional profiles of the leakage field (H_l) and the isotherm of the magnetization reversal temperature in SL (assumed as the Curie temperature of SL; T_{cs}) are shown. (a) in the write mode (high power irradiation) and (b) in the erase mode (low power irradiation) are the time when the temperature of SL reaches its maximum value. The medium is cooled from state (a) or (b) to state (d), and H_l at the T_{cs} isotherm increases in time by the thermal diffusion between SL and BL. H_l in the write mode becomes larger than H_l in the erase mode because the difference in temperature between BL and SL becomes small. Therefore, the direction of the magnetic field at the T_{cs} isotherm can be modulated between plus and minus by adding an appropriate external DC field (H_{ex}), and a

Fig.1 Schematic cross-sectional view of overwrite medium

reversed magnetic domain, which is indicated as the hatched area in Fig.2, is created or erased by the laser power level.

The following qualifications are required for SL in order to carry out overwrite successfully.

(1) The magnetization reversal temperature (T_r) is required to be adjusted in order to achieve a large leakage field modulation. It is preferable for T_r to be nearly equal to the Curie temperature of the BL (T_{cB}), typically 200°C [1,4].

(2) Writing and erasing are required to be completed with as small a change in H_{ex} as possible, because the degree of leakage field modulation was evaluated to be about 150 Oe for the OW medium used in a previous work [4]. This H_{ex} change is defined as the switching field ΔH_{sw} in this paper.

(3) The lower limit of H_c is required to be larger than about 200 Oe, because the external field necessary for OW is considered to be within ± 200 Oe [4]. In this paper, the nucleation coercive force, H_{cn} , was investigated for this requirement, because it represents the coercive force to prevent the collapse of the reversed magnetic domain by the external field.

Fig.2 Conceptual view of overwriting process. The drawing like a mountain is the spatial leakage field distribution and the oval is the isotherm of the magnetization reversal temperature of the storage layer. Cooling of the medium progresses as (a), (b), (c), (d).

EXPERIMENTAL

The film structure is shown in Fig.1. All the layers were deposited by RF magnetron sputtering except the Co layer, which was deposited by DC mode, both under the pressure of 5 mTorr. The sputtering gas was Ar+N₂ for Si-N and Ar for the others. The sample was exposed to air after TCL was deposited. A 60 nm sputter-etched Si-N underlayer and a 5 nm Pt buffer layer were stacked preliminarily in order to obtain sufficient H_c for Co/Pt. The number of Co/Pt units, n , was varied from 1 to 7. The magnetic characteristics were measured by a vibrating sample magnetometer using samples on a Si wafer. A recording test was carried out by Nakamichi OMS-2000 using the samples on a pre-grooved 1.2 mm thick glass disk substrate. The wavelength of the laser was 830 nm, and the linear velocity and the pulse width were 9 m/s and 400 ns, respectively.

DESIGN OF Co/Pt MULTILAYERS

Coercivity and the Magnetization Reversal Temperature

The film temperature at which H_c becomes zero was lower than the Curie point for the Co/Pt, as shown later in Fig.5. So, the former temperature was regarded as the magnetization reversal temperature T_r . Assuming magnetization reversal as a magnetic wall motion, this temperature was thought to be a better index for T_r than the Curie point.

It has been found that both T_r and H_{cn} were controlled by the Co thickness. The results are shown in Fig.3 for $n=1$ to 5. T_r and H_{cn} decreased with decreasing the thickness irrespective of n . T_r was found to decrease down to 100°C, and a T_r value of about 200°C was obtained with sufficient H_{cn} for $n=2$ to 5. These T_r values were lower than those reported so far [5]. T_r also decreased by making the Pt layer thicker, but the Co/Pt multilayer became thick to obtain sufficient H_{cn} in this case. A thick SL is not good for a switching field as will be described later. It is interesting that even a single Co layer sample showed a similar Co thickness dependence as a multilayer.

Switching Field

A rewritable-mode write/erase test was carried out for the samples without TCL, BL, and IL. Typical results of the dependence of carrier and noise levels on H_{ex} for samples with $n=3$ and $n=7$ are shown in Fig.4. the write power was 6 mW. Signals written under an external field indicated as "W" could be erased completely by the erase power (PE) and H_{ex}

Fig.3 Co thickness dependence of T_r and H_{cn} for samples with number of Co/Pt units $n=1$ to 5

Fig.4 Hex dependence of carrier level and noise level for $n=3$ and $n=7$.

within the hatched area. The difference in H_{ex} between the threshold and saturation (named as ΔH_{sat}) and the switching field ΔH_{sw} for $n=3$ were found to be smaller than those for $n=7$.

The results of ΔH_{sat} and ΔH_{sw} are summarized in Table 1. It has been found that the thinner the total thickness becomes the smaller ΔH_{sw} becomes. Writing and erasing could be completed by an H_{ex} change of only 80 Oe for the $n=2$ sample. Considering that the demagnetization field is proportional to magnetization and film thickness, the reduction in the demagnetization field in the thinner sample brought a small ΔH_{sat} and resulted in a small ΔH_{sw} . Samples with $n=2$ to 4 were selected for SL according to the qualification (2).

Tab. 1 Result of recording test

n	Thickness (nm)		ΔH_{sw} (Oe)	ΔH_{sat} (Oe)
	Co	Pt		
2	0.45	1.43	80	35
3	0.45	1.43	90	50
4	0.35	1.43	90	70
5	0.31	1.43	150	130

OVERWRITE EXPERIMENT

A 200 nm thick $(Gd_{0.75}Tb_{0.25})_{0.18}(Fe_{0.97}Co_{0.03})_{0.82}$ and a 200 nm thick $(Gd_{0.5}Tb_{0.5})_{0.26}(Fe_{0.5}Co_{0.5})_{0.74}$ were employed for BL and IL, respectively. The change in the magnetization M_s and H_c against temperature for BL and Co/Pt SL are shown in Fig.5. M_s at ambient temperature and the Curie temperature of BL were 90 emu/cc and 220°C, respectively. T_r was somewhat lower than the required value according to the qualification (1). It has been confirmed from other experiments that magnetization reversal in BL is completely suppressed during overwriting by the interfacial wall energy between BL and IL.

The result of a rewritable-mode recording test for the $n=4$ sample is shown in Fig.6. When P_w was high, the leakage field from BL became large and the H_{ex} -CNR curve shifted toward the negative H_{ex} direction. From this result, equi-CNR lines on the H_{ex} - P_w plane can be obtained and the degree of leakage field modulation can be estimated[6]. The degree of leakage field modulation was found to be about 80 Oe in this case. This value agrees well with the evaluation from numerical calculation[4], 90 Oe. It has been found that ΔH_{sat} becomes larger than that of SL alone by stacking BL and IL, compared with Fig.4. A large ΔH_{sat} was also observed for the same medium but using a non-magnetic pseudo biasing layer[6]. The change in thermal response of SL is thought to

Fig.5 Temperature dependence of magnetization of BL and of magnetization and coercivity of SL

Fig.6 Hex dependence of CNR of $n=4$ sample as a function of writing power

Fig.7 Spectra of overwritten signals of $n=4$ sample. Peak power was 13 mW, bottom power was 9.4 mW and Hex was -30 Oe.

make ΔH_{sat} larger.

The spectra of overwritten signals for the $n=4$ sample are shown in Fig.7. The recording conditions are as follows; peak power:13 mW, bottom power:9.4 mW and Hex:-30 Oe. These conditions were selected so that the thermal interference between the written marks was reduced in order to confirm the capability of overwrite. Overwrite between 1 MHz and 1.25 MHz was carried out successfully with CNR 32 dB. OW was also possible for all the other samples with over 30 dB. The OW CNR and the Kerr rotation θ_k of these samples are listed in Table 2. A large OW CNR was expected for the thinner samples which had small ΔH_{sw} values, but the decrease in θ_k , which was due

Tab. 2 Result of overwriting test

n	OW CNR (dB)	Kerr Rotation θ_k (deg.)	$\sqrt{R\theta_k}$ (deg.)
2	30	0.14	0.10
3	32	0.18	0.14
4	32	0.24	0.17

to the thin Co layer, reduced the CNR of SL and the OW CNR.

In the present study, the OW CNR was lower than the saturated CNR shown in Fig.6, but it is expected to be improved by the following modifications. Leakage field modulation is thought to be improved by using a biasing layer with a larger M_s than that in this paper. Such a BL is available as used in a previous study[6]. T_r seems to be somewhat low for overwrite as mentioned above. The leakage field will be used more effectively with a proper adjustment of T_r .

CONCLUSION

Laser power modulation overwrite on a Co/Pt multilayer was successful by the magneto-statically coupled method. The magnetization reversal temperature and the switching field were modified by changing the Co layer thickness and the number of Co/Pt units, respectively, in order to apply Co/Pt to OW medium. An overwrite CNR up to 32 dB was achieved for thin Co/Pt films stacked 2 to 4 times. The OW CNR is expected to increase by some modifications of the medium. The advantages and the capability in the future development of the magneto-statically coupled overwriting method has been demonstrated.

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