REAR APERTURE DETECTION OF EXCHANGE-COUPLED TRILAYER FILM WITHOUT INITIALIZING MAGNETIC FIELD

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Abstract- We propose an exchange-coupled magnetic trilayer film, which is composed of a readout layer, an intermediate layer, and a writing layer, to achieve magnetically induced super resolution (MSR) by rear aperture detection (RAD). The film doesn't require several kilo oersteds of magnetic field to align the magnetization direction of a readout layer. We obtained a carrier-to-noise ratio (CNR) of over 40 dB for a 0.4 µm mark length (0.8 µm mark pitch) and cross-talk of under -40 dB for a 0.78 µm mark length on 0.81 µm effective track pitch.

KEYWORDS: MSR, RAD, TRILAYER, INITIALIZING MAGNET

INTRODUCTION

Several detection methods, such as front aperture detection (FAD) [1], center aperture detection (CAD) [2], and rear aperture detection (RAD) [3], have been proposed for magnetically induced super resolution (MSR) readouts, in order to achieve higher density magneto-optical (MO) storage. In these detection methods, exchange-coupled magnetic multilayer films are adopted. A focal spot at the surface of a film is narrowed by partially forming an optical mask inside it and then enabling it to accurately resolve a recorded mark which is smaller than the diffractive limit. FAD and RAD disks employing a readout layer with perpendicular magnetic anisotropy exhibit high carrier-to-noise ratios (CNR) for short mark lengths. Although a FAD disk can consist of a simple magnetic multilayer film, it can't suppress cross-talk from adjacent tracks. On the contrary, an RAD disk using a quadrilayer film [3] is more efficient because it has a high CNR, and it also suppresses cross-talk from adjacent tracks, even for a narrow track pitch. It does, however, restrict the magnetic properties and thicknesses of each layer in medium design. In addition, an RAD disk requires an external initializing magnet with several kilo oersteds of magnetic field to align the magnetization direction of the readout layer. Such a magnet is too large to insert into a modern downsized drive.

Thus, we propose a new RAD disk with the following features.

1) Triple layer film utilizing an intermediate layer with functionally sophisticated magnetic properties.
2) No large initializing magnet. Alignment of the readout layer by a readout magnet, a substitute for a writing and/or an erasing magnet.

We present the magnetic properties and the readout characteristics of MSR by RAD using an exchange-coupled trilayer film.

READOUT MECHANISM

The trilayer film is composed of a readout layer, an intermediate layer, and a writing layer. The intermediate layer is sandwiched between the readout and writing layers and controls the exchange coupling force. The magnetization of the readout and writing layers is oriented normal to the film plane at from room temperature (Troom) to Curie temperatures (Tc) in each layer. The magnetization of the intermediate layer has to be parallel to the film plane at Troom and is perpendicular to the film plane at about 80 °C.

Figure 1 shows the magnetization state for each layer in our RAD disk, where the disk moves from right to left. Under the absence of a magnetic field, this RAD permits the readout
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Table 1 Trilayer film structure

<table>
<thead>
<tr>
<th>Layer</th>
<th>Composition</th>
<th>( T_c (\text{°C}) )</th>
<th>Dominant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Readout</td>
<td>GdFeCo</td>
<td>290</td>
<td>RE</td>
</tr>
<tr>
<td>Intermediate</td>
<td>GdFeCo</td>
<td>270</td>
<td>RE</td>
</tr>
<tr>
<td>Recording</td>
<td>TbFeCo</td>
<td>260</td>
<td>TM</td>
</tr>
</tbody>
</table>

![Graph](https://via.placeholder.com/150)

**Fig. 2** The dependence of the minor loop shift of the readout layer, \( H_s \), on the thickness of the intermediate layer (\( h_2 \)).

layer to align the magnetization parallel to the writing layer by an exchange coupling force, as shown in the region to the right of (a). After passing point (a), under the presence of a magnetic field of 500 Oe, the recorded marks on the readout layer are erased at Troom before the readout, as shown at the region between (a) and (b), where a writing magnet (\( H_w \)) substitutes for the readout magnet (\( H_r \)). A readout laser heats the rear side of a focal spot more than the front due to the revolution of the disk [4]. Even if the readout layer is irradiated by a readout laser, it remains in an initializing state because of the weak exchange coupling force, as shown at the region between (b) and (c). Here, the magnetization direction of the intermediate layer is still in-plane. This region works as an optical mask for the focal spot. When the focal spot temperature partially rises above \( T_{copy} \), as shown at the region between (c) and (e), RAD is performed. The mask and aperture regions are then formed in a focal spot. The \( H_r \) and the exchange coupling force must satisfy the following.

\[
H_r > \sigma_1/(2M_{s1}h_1) + H_{c1}, \quad T = \text{Troom} \quad (1),
\]

\[
H_r < \sigma_1/(2M_{s1}h_1) - H_{c1}, \quad T > \text{Tcopy} \quad (2).
\]

\( \sigma_1 \) is the interface wall energy between the readout layer and the writing layer. \( H_{c1} \) is the coercive force, \( M_{s1} \) is the saturation magnetization, and \( h_1 \) is the thickness of the readout layer.

**EXPERIMENTAL**

 Fundamental Properties

Table 1 lists the structure and layer properties of the exchange-coupled trilayer film for MSR by RAD. The GdFeCo film with perpendicular magnetization is preferable as a readout layer because of its small coercivity and large Kerr rotation angle. A GdFeCo film with in-plane magnetization is suitable for an intermediate layer, because the temperature at which the magnetic easy axis begins to change from in-plane to perpendicular is controllable by changing the Gd content. We fabricated the multilayer film on a pre-grooved 2p (photo-polymer) glass substrate with a track pitch of 1.6 \( \mu \text{m} \) by successively dc-magnetron sputtering each layer. Figure 2 shows the effect of the thickness of an intermediate layer (\( h_2 \)) on the shift of the minor loop of the readout layer (\( H_s \)). Measurement was carried out at Troom to clarify whether the readout layer is initialized by the small magnetic

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Fig. 4 The dependence of $H_{c1+}$ and $H_{c1-}$ on the readout layer.

Fig. 5 The dependence of C, N level on readout power for the film with $h_2=30\text{nm}$, where recording was done at linear velocity of 7m/s and readout was done under Hr of 400 Oe.

field at Troom. We see that $H_s$ is inversely proportional to the thickness of the intermediate layer and is small enough (about 200 Oe) for initialization, in the case of $h_2 < 20$ nm. The variation of $H_s$ according to the temperature is also an important condition. We studied the dependence of the readout layer $H_{c1+}$ and $H_{c1-}$ on the temperature, where $h_2 = 30$ nm. The minor loops of the readout layer at each temperature are shown in the inset figures (a) and (b) in Fig. 4. $H_{c1+}$ is smaller than Hr at Troom and $H_{c1-}$ is larger than Hr at above 80 °C. This indicates that the readout layer is initialized at Troom and is aligned to the writing layer at above 80 °C, where Hr = 300 Oe. Thus, we can obtain MSR by RAD using only the readout magnet. This means that an initializing magnet is not required.

**Dynamic Properties**

Here, we describe readout characteristics of the film when $h_2 = 30$ nm. Figure 5 shows the dependence of the carrier (C) and noise (N) levels on readout power (Pr) for a 0.4 µm mark length (0.8 µm mark pitch), for a recording at a linear velocity of 7 m/s. For readout, Hr = 400 Oe is a sufficiently large magnetic field to initialize the readout layer from Fig. 4. The C level gradually increases by strengthening the Pr up to 1.4 mW, and it rapidly increases at 1.6 mW by the formation of aperture. This means that the effective focal spot narrows and MSR is carried out at this Pr value. We obtained a CNR of 41dB at Pr = 2.2 mW. In order to confirm the RAD readout, we observed the reproduced waveform for 0.8 µm marks, shown in Fig. 6, where Pr = 2.2 mW and Hr = 400 Oe. From this figure, a steep rise occurs before reaching the maximum amplitude of the signal (to the left of the maximum point), reflecting that fast switching causes from the front mask area to the aperture area [3], and showing that this MSR readout is RAD. Figure 7 shows the dependence of the C

Fig. 6 The reproduced waveform for isolated 0.8 µm marks, where Pr=2.2mW and Hr=400 Oe.
level and the N level on Hr for a 0.4 μm mark length, where Pr is 2.4 mW. When Hr is smaller that 150 Oe, only a conventional readout is performed. By increasing the magnitude of Hr, the C level rapidly increases at Hr = 250 Oe and approaches a constant value, but the N level gradually decreases at an Hr of over 300 Oe. This means that our exchange-coupled trilayer film enables a RAD readout without a large initializing magnet, which can be substituted by writing and/or erasing magnets used in present conventional drives for magneto-optical recording. We also measured cross-talk signal. It was carried out at a groove adjacent to a land with recorded marks of 0.78 μm mark length as shown in Fig. 8. Conventional readout was done with an Hr = 0 Oe and MSR readout was done with an Hr = 400 Oe. In spite of a narrow track pitch (effective track pitch = 0.8 μm), this disk can suppress cross talk down to -42 dB.

CONCLUSION

For an RAD disk without a large initializing magnet, we proposed a trilayer film composed of readout, intermediate and writing layers. We confirmed that RAD readout is performed by applying a magnetic field as small as 300 Oe, which is small enough to substitute writing and/or erasing magnets for an initializing magnet during reading. We obtained a CNR of over 40 dB for a 0.4 μm mark length and cross-talk of under -40 dB for a 0.78 μm mark length on 0.8 μm effective track pitch.

REFERENCES