Optical TAMR Head Design for Placing a Heating Spot Close to a Magnetic Pole

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Abstract

A new configuration for optical thermally-assisted magnetic recording (TAMR) is proposed. It has been recognized that, in order to improve writability with TAMR, it is necessary to place the optical heating spot close to the magnetic pole, and with the new configuration, the distance from the optical heating spot to the magnetic pole is shortened. Employed is a Focusing Waveguide (FW), integrated into a flying slider, and a metal plasmon antenna attached to the bottom of the FW. With this configuration, optical near-field intensity peaks when the near-field spot is placed at the clad of the FW. As a result, the optical heating spot locates closer to the magnetic pole. Presented here are the results of simulating optical near-field generation, where the distance between the near-field spot and the magnetic pole is shortened from 450 nm to 120 nm. Using this configuration, the time lag between optical heating and magnetic writing is significantly shortened by a factor of one fourth.

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1 Introduction

In the field of magnetic recording, there has been considerable interest in thermally assisted magnetic recording (TAMR) systems for scaling the recording density beyond 1 Tbit/inch^2. A heating spot with a diameter of less than 25 nm is required in such systems. One method of realizing a small heating spot is to use near-field optics[1)-8)]. Previously, we proposed an optical TAMR head using a "Focusing Waveguide (FW)" (a waveguide-type spot size converter) with a metal plasmon antenna[7)]. In that paper, we demonstrated the possibility of realizing optical near-field generation by using a plasmon antenna mounted on the bottom surface of the FW. One important issue for the TAMR system is to place the heating spot close to the magnetic pole, because a large offset between the heating spot and the magnetic pole may cause a degradation of the writability[1)]. To place the heating spot close to the magnetic pole, one can place the FW core close to the magnetic pole. However, the distance between the FW core and the magnetic pole is limited by the optical absorption of the metal magnetic pole[1)].

In this paper, we propose a new plasmon antenna configuration. The design allows us to position the generation point of the optical near-field outside of the FW core, thus enabling the optical near-field to be placed very close to the magnetic pole. We have considered that the electric field distribution of the FW might cause this phenomenon, and we have demonstrated the new design by means of finite-difference time domain (FDTD) simulation.

2 System design of the TAMR head

Fig.1 presents a schematic of the TAMR head. Light irradiated from an optical fiber is bent at the prism surface and enters the FW, which is integrated into a flying slider. The mode field diameter (MFD)

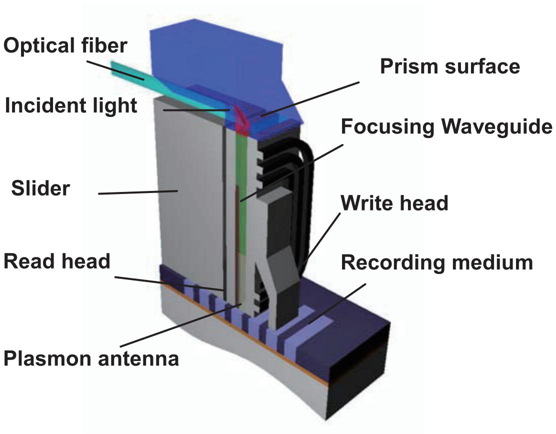

Fig.1 Schematic of the TAMR head with the FW

of the optical fiber is 10 μm at the wavelength of 1.5 μm. The MFD's diameter is far greater than the 25 nm required for an areal density over 1 Tbit/inch^2. In order to generate a small heating spot, we use a FW and a metal plasmon antenna. Fig.2 shows the structure of the FW, which consists of three parts, namely, the silicon core, the SiO_x core, and the clad made of SiO_2. The silicon (Si) core has a tapered shape, whose cross-section is, for example, 300 nm (in x-direction) × 300 nm (in y-direction) at the bottom, and 300 nm × 80 nm at the middle of the FW. The SiO_x core covers the Si core. The cross section of the SiO_x core is 3 μm × 3 μm. The SiO_2 clad covers the SiO_x core. The MFD of the light is reduced to one tenth while the light propagates through the FW from SiO_x core to the Si core because of the mode conversion due to the tapered structure of the Si waveguide. The sufficiently small optical spot then illuminates the plasmon antenna mounted on the bottom surface of the FW. The typical length of the FW is 200 μm, and the propagation loss of the FW is less than 1 dB[9]. The magnetic pole is embedded in the SiO_X core and placed near the Si core. The magnetic pole applies a magnetic field after optical near-field heating and achieves TAMR.

3 Simulation results and discussion

Fig.3 shows a bottom view of the TAMR head. Since Fig.3 represents the bottom surface of the FW, the light propagates only in the Si core. The SiO_x core works as a waveguide clad near the bottom surface. The dimensions of the Si core are assumed to be 300 nm × 300 nm. To place the optical near-field spot close to the magnetic pole, the core must be placed as close as possible to the magnetic pole. However, the propagation loss of the FW will increase when we place the magnetic pole close to the FW core because of the optical absorption of the metal magnetic pole. To avoid a serious propagation loss of the FW, the thickness of the over clad (T_{clad}) is set at 300 nm. In general, the optical near-field spot is generated efficiently around the center of the FW core. Therefore, the distance from the optical near-field spot to the magnetic pole edge (D_o) is 450 nm in this configuration. However, in this case, the D_o is not short enough for the TAMR system to use.

In order to overcome this problem, we designed a new configuration of plasmon antenna by means of FDTD simulation. A plasmon antenna is mounted at the bottom surface of the FW to generate a small optical near-field spot, as shown in Fig.3 (b). The composition of the plasmon antenna is gold, which has a broadband plasmon enhancement factor. The plasmon antenna is triangular, and has a length of 300 nm. The top angle and the thickness of the

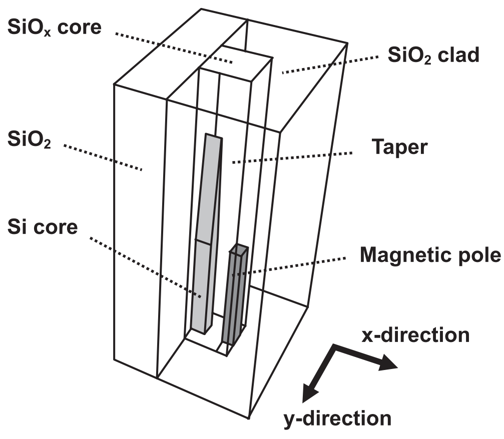

Fig.2 Schematic of the FW

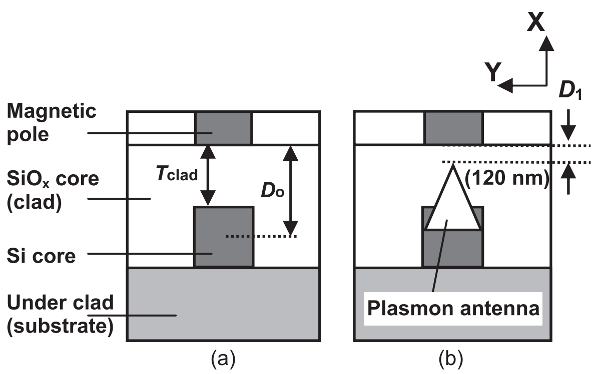

Fig.3 Cross-section of the TAMR head at the bottom of the FW:
(a) Without the plasmon antenna, (b) With the plasmon antenna

structure are 40° and 40 nm, respectively. The direction of the triangle is set to be the same as the polarization direction of the FW in order to generate the optical near-field efficiently. The position of the plasmon antenna is defined by the distance between the apex of the triangle and the magnetic pole edge (D_1). D_1 represents the distance between the heating spot and the magnetic writing spot because the optical near-field spot is generated at the apex of the triangle. Fig.4 shows the intensity of the optical near-field spot as a function of D_1. The intensity of the optical near-field spot is normalized by the intensity, which is calculated without the plasmon antenna. The intensity peaks at D_1 = 120 nm, where the optical near-field spot is generated in the clad region. Therefore, the heating spot approaches within 120 nm of the magnetic pole. Fig.5 shows the electric field intensity when D_1 is 120 nm. Fig.5 (a) shows the distribution of the electric field intensity which was distributed 10 nm from the plasmon antenna in a vacuum. The calculation doesn't include a recording medium. Fig.5 (b) and 5 (c) show a cross-section of the electric field distribution at the peak position. The full-width at half maximum of the spot is 20 nm (in the x-direction) and 30 nm (in the y-direction). The spot size is small enough for a high-density TAMR system.

These phenomena are most likely due to the electric field distribution of the FW at the bottom surface. Fig.6 shows calculated electric field distribution of the FW, where wavelength is 1.5 μm and the polarization is vertical to the substrate (x-polarization).

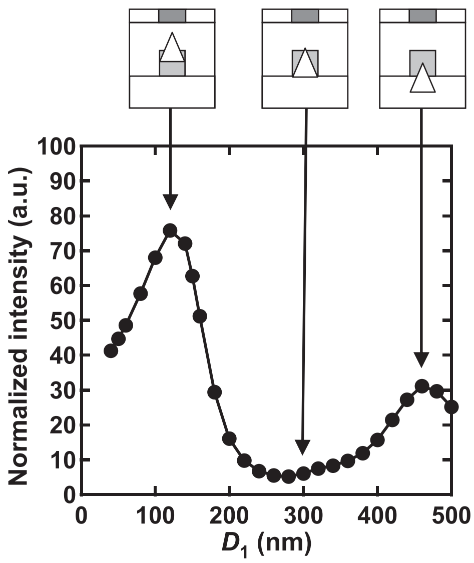

Fig.4 Dependence of the intensity of the optical near-field spot on D_1

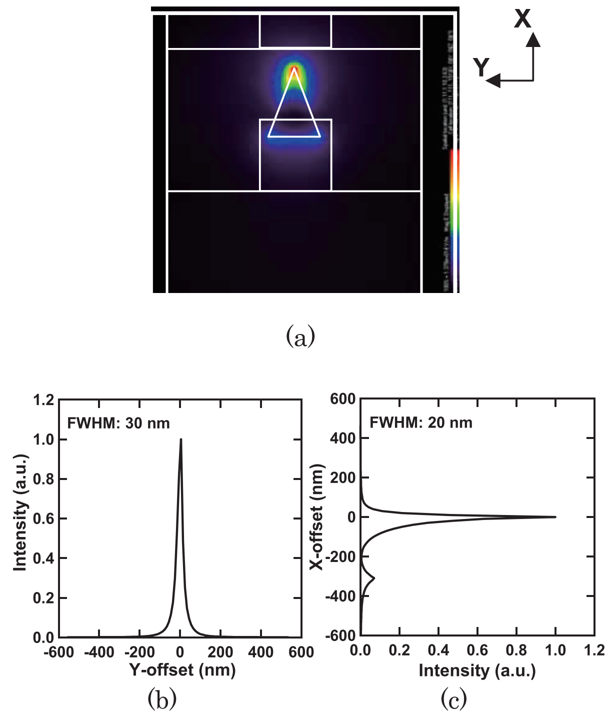

Fig.5 Distribution of the near-field spot: (a) Distribution of electric field intensity, (b) Electric field intensity as a function of y-offset, (c) Electric field intensity as a function of x-offset

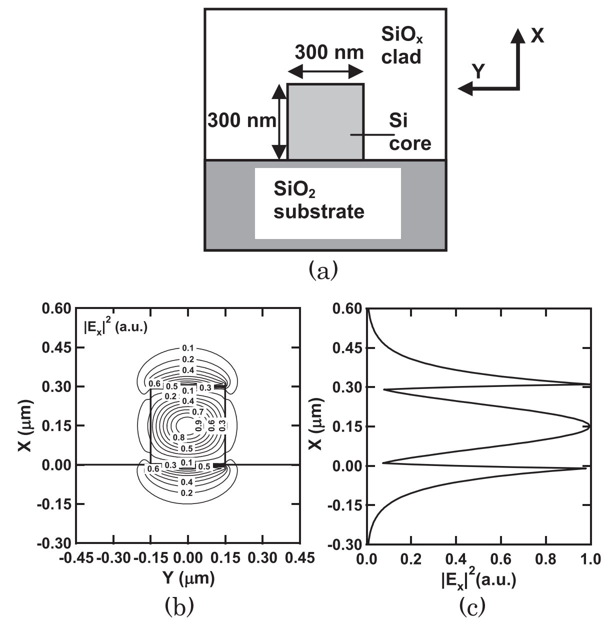

Fig.6 Electric field distribution of the focusing waveguide: (a) Cross-section of the focusing waveguide, (b) Map of the electric field intensity, (c) Cross-sectional view of x-direction at y= 0

The refractive indices of the SiO_2 substrate, Si core, and SiO_x clad are 1.44, 3.48, and 1.47 respectively. It is interesting to note that the peak of the electric field intensity occurs at the boundary of the core and the clad. This is due to the boundary condition of the electric flux density, and this is particular phenomena of the TM-like waveguide mode (x-polarization in the Fig.6). We infer that the plasmon antenna is excited by the strong electric field at the boundary between the core and the clad and that the plasmon antenna generates a strong optical near-field spot.

4 Summary

We have proposed a new configuration of an optical TAMR head in order to place the optical heating spot close to the magnetic pole. Simulations of near-field spot generation have been described. The proposed TAMR head performs to eliminate the time lag between optical heating and magnetic writing. An experimental demonstration is a task for future work.

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References

1) M. A. Seigler, W. A. Challener, E. Gage, N. Gokemeijer, G. Ju, B. Lu, K. Pelhos, C. Peng, R. E. Rottmayer, X. Yang, H. Zhou, and T. Rausch: IEEE Trans. Magn., 44, 119 (2008).
2) W. A. Challener, C. Peng, A. V. Itagi, D. Karns, W. Peng, Y. Peng, X. Yang, X. Zhu, N. J. Gokemeijer, Y. T. Hsia, G. Ju, R. E. Rottmayer, A. Seigler, and E. C. Gage: Nature Photonics, 3, 303 (2009).
3) T. Matsumoto, Y. Anzai, T. Shintani, K. Nakamura, and T. Nishida: Opt. Lett., 31, 259 (2006).
4) M. Hirata, M. Oumi, K. Shibata, K. Nakajima, and T. Ohkubo, IEICE Trans. Electron., E90-C, 102 (2007).
5) S. Miyanishi, K. Innami, T. Naka, T. Kitazawa, M. Yagura, N. Teraguchi, Y. Murakami, and A. Takahashi, IEEE Trans. Magn., 44, 3360 (2008).
6) S. Miyanishi, N. Iketani, K. Takayama, K. Innami, I. Suzuki, T. Kitazawa, Y. Ogimoto, Y. Murakami, K. Kojima, and A. Takahashi: IEEE Trans. Magn., 41, 2817 (2005).
7) N. Nishida, H. Hatano, K. Sekine, K. Konno, M. Saka, and H. Ueda: J. Magn. Soc. Jpn., 32, 174 (2006).
8) F. Tawa, S. Hasegawa, and W. Odajima: J. Appl. Phys., 101, 09H503 (2007).
9) T. Shoji, T. Tsuchizawa, T. Watanabe, K. Yamada, and H. Morita: Electron. Lett., 38, 1670 (2002).

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