Plasmonic near-field phase change recording

Din Ping Tsai
Center of Nanostorage Research and Department of Physics,
National Taiwan University, Taipei 10617, Taiwan
Tel: 886-2-3366-5100 Fax: 886-2-2363-9928 E-mail: dptsai@phys.nt u.edu.tw

ABSTRACT

We investigate the plasmonic near- field phase-change recording on a sandwich phase change recording thin film, $ZnS-SiO_2$ /$Ge_2Sb_2Te_5$ /$ZnS-SiO_2$. Because the optical response of the local plasmonic structures is the key of understanding the near- field optical recording process, we use near-field scanning optical microscopy, Z-scan and optical pump-probe system to explore the optical interactions of various plasmonic near- field structures. The direct near- field optical images of the focused laser spot through various plasmonic structures in the transmission mode can be acquired by using a tapping-mode near- field scanning optical microscope (NSOM). The local near- field optical interactions of the transmitted laser spots give important plasmonic information. The nonlinear absorption and refraction of the samples can be disclosed by the experiments of Z-scan. Measurements of transmission and reflectance indicate complicate transition process of the optical interactions and couplings of the plasmonic structures. Both reverse saturable absorption and saturable absorption happened at different range of input power. The results of the optical pump-probe experiments show the temporal dynamic optical response that is closely related to the response time and recording rate of near-field optical recording. The interactions of the localized surface plasmon depended on the properties of the plasmonic materials and their local structures in nanometer scale. The effects of the localized surface plasmon are considered to be the key issue in super-resolution near- field phase-change optical recording.

Keywords: Plasmonic recording, phase-change recording, near-field recording, super-resolution recording.

Near-field optical recording was first proposed and demonstrated by Betzig et al. [1] on multilayered Pt/Co magneto-optical thin films using a near-field scanning optical microscope (NSOM). The most important advantage for near-field optical recording is the superior spatial resolution with no diffraction limit. To realize near-field optical recording in practice, Terris et al. [2] used a solid immersion lens (SIL) to reduce the mechanical damage caused by the near-field optical fiber probe and to achieve a higher recording speed. However, the control of the near-field distance between the SIL recording head and the recording medium, and the near-field aperture size of the SIL, are the major hurdles for commercial applications.

Tominaga et al. [3-6] suggested and demonstrated that a 15 nm Sb thin film on the top of the phase-change (PC) recording layer (GeSbTe) within the near-field distance can produce similar results to a local near-field SIL. In 1998, they have successfully shown that a multilayered structure of polycarbonate/SiN (170 nm)/Sb (15 nm)/SiN (20 nm)/GeSbTe (15 nm)/SiN (20 nm) on a digital versatile disk (DVD) gives the estimated recorded marks of 90 nm at a constant linear velocity of 2.0 m/s. The carrier-to-noise ratio (CNR) can be more than 10 dB. They named this multilayered structure, SiN (170 nm)/Sb (15 nm)/SiN (20 nm), a super-resolution near-field structure (super-RENS), and considered the 15nm Sb thin film as a nonlinear optical layer which controls the near-field optical aperture. Because the near-field distance can be easily controlled by the fixed spacing layer (20nm SiN) between the non-linear optical layer (15nm Sb) and the recording layer (15 nm GeSbTe), the super-RENS is considered a more feasible way of achieving near-field optical recording with a simpler recording head design, less mechanical damage, and higher recording speed. In 2000, Tominaga et at. [7,8] showed another type of super-RENS using a 15 nm AgO_X thin film as the nonlinear optical layer, and found the better results on the measurements of CNR with less laser powers of the recording and readout process.

The near-field optical interaction of either the 15 nm Sb or AgO_X thin film is obviously the key subject of the super-RENS. The working mechanism of the super-RENS is definitely an important foundation for various potential applications of the super-RENS. In particular, the function of the 15nm Sb or AgO_X thin film at the focused laser spot is a very interesting issue for the super-RENS. Although Fukaya et al. [9] and our group [10] have studied the optical switching property of a light–induced pinhole or scatter in the Sb or AgO_X thin film, respectively. We have also investigated the near-field measurements of either the Sb or the AgO_X type of super-RENS using a near-field scanning optical microscope (NSOM) for the understanding of their near-field optical properties [11-14]. Recently, reports of either a PtO2 , PdOx or WOx thin film super-RENS have been published for the write-once-read-many (WORM) disk with good CNR values for the mark sizes of 100-nm or 150 nm.[15-17] Our group showed a super-resolution optical structure of polycarbonate /ZnS-SiO_2 /ZnO /ZnS-SiO_2 /$Ge_2Sb_2Te_5$ /ZnS-SiO_2 can also obtain high stability and CNR[18]. Because the optical response of the local structures of the super-resolution near-field optical structures is obviously the key of understanding the near-field optical recording process, we use near-field scanning optical microscopy[19, 20], Z-scan experiments [10, 21] and optical pump-probe system[22] to explore the optical interactions of various super-resolution near-field optical structures. In this paper, we report the experimental study of the focused laser spot through various super-RENS samples in the transmission mode by using a tapping-mode NSOM. The direct near-field optical imaging of the transmitted laser spots through these nonlinear optical layers can provide much important information, and reveal the local near-field optical interactions of the super-RENS. The nonlinear absorption and refraction of the super-RENS thin film can be disclosed by the experiments of Z-scan. Many interesting local interactions were found. Measurements of transmission and reflectance indicate complicate transition process of the optical interactions of the super-resolution near-field optical structures. Both reverse saturable absorption and saturable absorption happened at different range of input power. Negative nonlinear refraction coefficients were found for AgOx super-RENS nano thin film. The results of the optical pump-probe are able to show the temporal dynamic optical response of the super-RENS thin films which is closely related to the response time and recording rate of near-field optical recording.

Based on all the various local optical responses observed, interactions of localized surface plasmon[23, 24] is proposed and used to explain and analyze the super-RENS. We found that the developments of the super-resolution near-field optical structures are closely related to the basic principle of near-field optics on the surface plasmonic structures. The connections of the near-field and far-field optical interactions of the local plasmonic structures of super-RENS play an important role. The interactions of the localized surface plasmon depended on the properties of the conductive materials and their local structures in nanometer scale. The effects of the localized surface plasmon are considered to be the key issue in many aspects of super-resolution near-field optical storage.

Acknowledgement

We thank the financial supports from National Science Council, Taiwan, R.O.C. under the grand number NSC-92-2120-M-002-008, and the Ministry of Economic Affairs of Taiwan, R.O.C. under the grand number 92-EC-17-A-08-S1-0006.

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