SNOM INVESTIGATION OF A HIGH DENSITY OPTICAL DISC AFTER RECORDING

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Recording mechanism of an organic thin film as the recording medium in high density data storage, digital versatile disc-recordable(DVD-R), is studied by a scanning near-field optical microscope(SNOM) and an atomic force microscope(AFM). Physical deformations as recorded pits have been produced in the organic recording layer during recording process. Dynamic recording performance of the disc is closely related to its microscopic properties as revealed by topographic observation.

1 Introduction

Organic thin films as optical recording media have been commercialized such as write-once read-many(WORM) optical disc, compact disc-recordable(CD-R), and more recently, digital versatile disc-recordable (DVD-R) [1-3]. By adopting a short-wavelength recording laser and a narrow track pitch in the pregrooved disc, higher recording density has been achieved in DVD-R than in CD-R. Despite their wide applications nowadays, the recording mechanisms of the organic recording media have not been fully understood. After the emergence of DVD-R within the last two years, no detailed report on its recording mechanism has been revealed so far. In the previous study, various kinds of techniques have been suggested for the study of the recording mechanisms of organic thin films including scanning electron microscope(SEM), AFM and scanning tunneling microscope(STM) [4-6]. However, several disadvantages appear, for example, electron charging effect or lack of height information in SEM and the requirement of conductive sample surface in STM. In this study, SNOM and AFM are used for the topographic observation.

2 Experimental details

The multilayer structure of the commercialized disc (Mitsubishi Chemical Co.) used in this study is illustrated in figure 1. A disc drive with a 635 nm pickup head and NA=0.60 was used for both recording and retrieving (figure 2). The recording process was carried out at 7 MHz and 6 m/s of the disc rotation speed with laser power ranging from 2.0 to 7.0 mW. The data were recorded in the grooves of the pregrooved disc. After recording, the protective and reflective layers were removed from the organic thin film.

The system used in this study for topographic observation was SPI3800 (Seiko Instruments, Inc.), which carried out SNOM and AFM measurement separately. In the SNOM measurement (figure 3), a commercialized tapered, chromium/aluminium coated optical fiber with an aperture of about 50 nm (Nanonics, Germany) was used to illuminate the sample. A diode laser pumped crystal laser operating at a wavelength of about 530 nm was adopted as the light source. The sample was scanned underneath the fiber and the transmitted light from the sample was collected with an objective lens and directed to a photo counting avalanche photo-detector as topographic information or a CCD camera for monitoring. Shear force feedback was used to maintain a constant tip-sample separation and to generate high-resolution topographic images. A personal computer controlled the raster scanning of the sample and collected the counts per pixel for the detector. For AFM measurement, contact-mode was adopted.

3 Results and discussion

Figure 4 shows simultaneously obtained shear-force and SNOM images of the organic thin film after 7.0 mW laser recording. From these images, it can be found that pits were produced in the recording layer. Even after removing the organic thin film, it was possible to find out bumps on the polycarbonate substrate. Further observation showed that obvious marks can be identified only in regions after larger than 5 mW laser recording. As from our investigation, contact-mode AFM was a quite convenient technique for the study of the topography of the recorded marks, however, misleading information was produced sometimes due to the roughness and tilt of the sample surface. In contrast, from simultaneously obtained SNOM and shear-force image, reliable information can be obtained from the non-destructive optical image which can serve as a reference to assess the shear-force or AFM images. Considering their respective merits, combination of SNOM and AFM techniques in this study is advantageous to ensure reliability, ease adjustment difficulty, and improve efficiency.

In the dynamic test measured by the disc drive, the carrier to noise ratio (CNR) of the disc increased steadily with the increase of the write laser power from about 1.3 dB at 2 mW and reached 53.9 dB at 7 mW. The noise level was about -62.1 dBm for write laser power less than 5 mW. Abrupt increase was found at the write power of 5 mW and the noise level was measured to be -59.9 dBm for write laser power from 5 to 7 mW. In the dynamic test, it is also possible to evaluate the modulation of the readout signals from the recorded marks. The modulation M is defined as

$$M=(I_{max}- I_{min})/ I_{max} \tag{1}$$

in which I_{max} and I_{min} are the maximal and minimal readout signal, respectively.

A close correlation has been found between the deformation and the modulation, as shown in figure 5. It can be found that the deformations on the organic thin film and polycarbonate substrate increase with the increase of the modulation. After laser irradiation, the organic thin film decomposed and generated gas which resulted in the pit formation on the thin film. The deformation on the substrate was caused by the stress release of polycarbonate which received thermal energy from the organic thin film upon laser irradiation through thermal diffusion.

4 Conclusions

Physical deformations have been found in the organic recording layer and polycarbonate substrate of DVD-R after recording process. The deformations are ascribed to the decomposition of the organic thin film and stress release of the polycarbonation substrate. Combination of SNOM and AFM techniques in the topographic study is advantageous to ensure reliability, ease adjustment difficulty, and improve efficiency.

References

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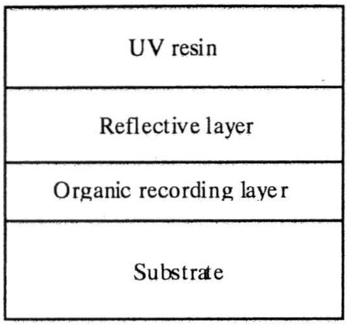

Figure 1 Schematic representation of a DVD-R

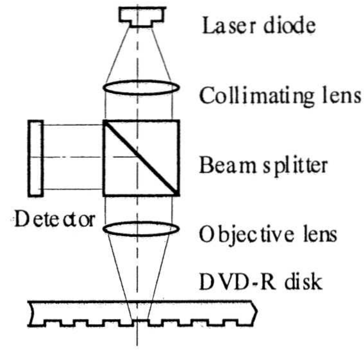

Figure 2 Schematic illustration of the optical recording system

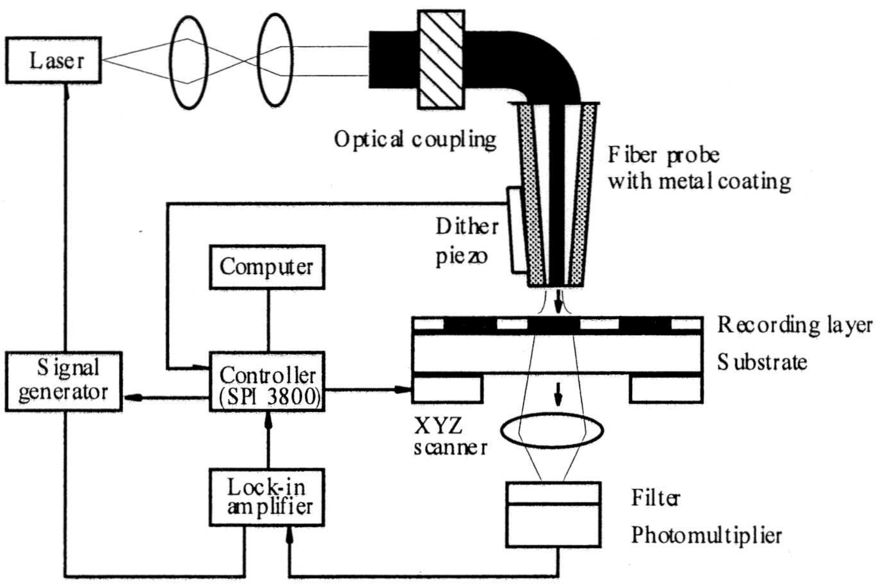

Figure 3 Schematic diagram of the SNOM system

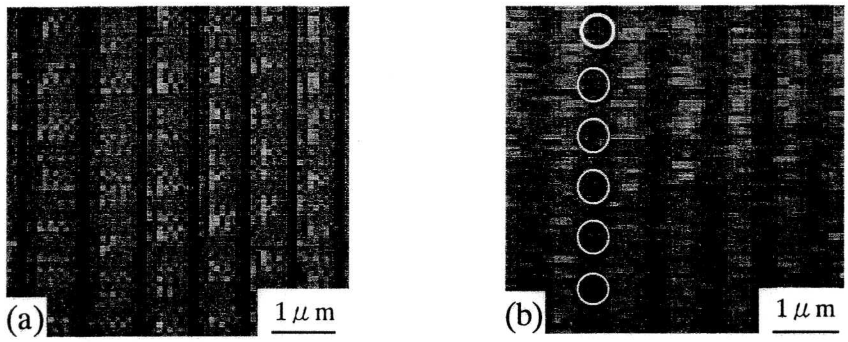

Figure 4 Shear-force image (a) and SNOM image (b) of recorded marks on organic layer.

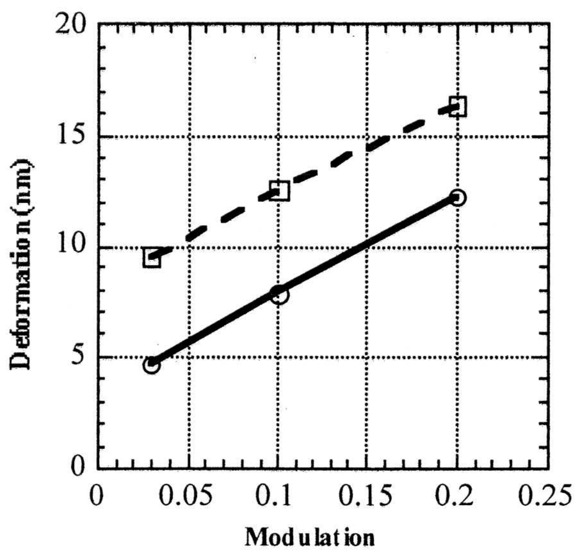

Figure 5 Relationship between deformation of the recorded mark and modulation: □, on the recording layer; ○, on the polycarbonate substrate