SCANNING TUNNELING MICROSCOPY STUDIES ON OPTICAL DISC

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ABSTRACT

Scanning tunneling microscope (STM) is used to investigate the optical disc. The areas with and without data stampers are all observed carefully. Three-dimensional images of the disc surface clearly demonstrate the period, depth of the grooves and the shape of data stampers. Some phenomena of STM imaging are also discussed.
Keywords STM, Topography, Optical disc

Compared with scanning electron microscopy (SEM), STM can give 3-dimensional information of the surface. This advantage makes it be widely used to investigate the materials such as optical disc[1,2]. In this work, STM is used to study a kind of optical disc, and the some phenomena of imaging are discussed.

The optical disc studied consists of a substrate, a photo-absorption layer and a conductive layer. The pregrooved substrate was formed using polycarbonate. The photoabsorption layer composed of phthalocyanine was formed by physical vapour deposition at a pressure of 2.0×10^{-3} Pa (about 40 nm in thickness). Then Ag was deposited on to make the conductive layer (about 20 nm in thickness). Finally, recording was carried out by the focused laser beam absorbed by the photoabsorption layer, and the heat made the struck point expand to form a data stamper.

Our results were collected on a STAR-1 STM (Shanghai Nanometer High Technology Company) at the constant current mode. The typical imaging bias was 0.4V, and tunneling current was 0.5~1 nA. The tips were etched from W wire.

First, the area of an original disc was imaged. The typical image is shown in Fig.1, in which the period of groove is 1.6μm. The gray scale represents the sample height with the lighter features being taller. From the SEM results the width of the groove is about 0.6μm. The apparent width in STM images may vary with the shape of tips, ranging from 0.4 to 0.6μm. The apparent depth also changes from one image to others. The largest corrugation is found to be 100nm.

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Then the attention was paid to the recorded area on the disc. Two typical images are shown in Figs.2 and 3. The data marks can be clearly seen in the images. It is found that the data stampers may be divided into two kinds: One is like a round island with a diameter about 0.9μm and height about 150nm (see Fig.2). The other has a hole in the center of island with a lower height about 60nm (see Fig.3). The difference between the two comes from the difference of recording conditions. It has been known that the stampers are pumped up by a focused laser beam on the hollows. When the struck regions of phthalocyanine layer absorb the heat of laser, the blisters appear like a round island. If the energy of laser increases to a limit, the blisters may break, and form holes in their centers.

From SEM images, one may find that most of the data stampers have holes in their centers. This is different from the STM results which have shown a large part of data stampers is in round shape. It can be understood that the electrons with high energy may modify the stamper shape during SEM scanning. These effects have been found after one image compared with another. The striking of the electrons with energy as high as 20keV can lead the round stampers to collapse on their tops, resulting in the round stampers to be uncommon. In contrast, STM images are rather stable in our experimental conditions. Since the effects of tunneling electrons (typically with energy less than 1eV) on the sample is negligible small, the only one to be considered is the forces of STM tip on the sample. If the interaction of the tip with sample is strong (this condition may be achieved by low bias and high tunneling current), the modification of the stampers may also be found in STM images, but it is very limited.

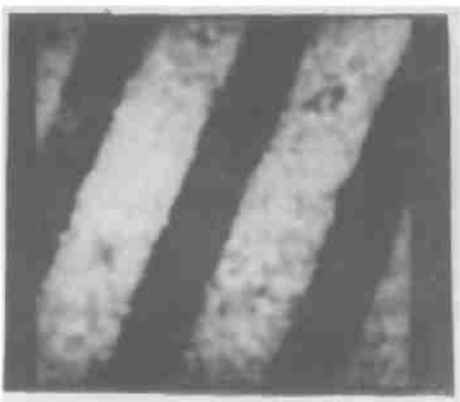

Fig.1 A STM image of optical disc which has not been recorded

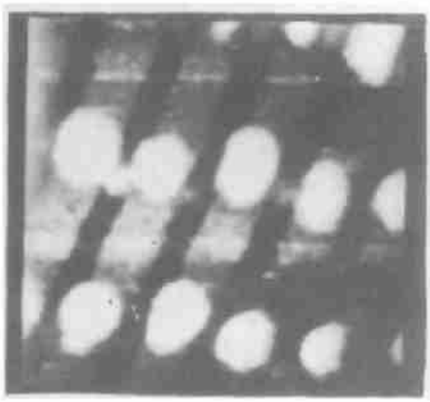

Fig.2 A STM image of recorded area on the disc

During the experiments, it was found that the status of the tip was crucial in order to obtain true topography, especially for such a sample as optical disc with large corrugation. Obviously, it is necessary to use a tip with as sharp as possible. This can be gotten through W wire being etched. A long and thin tip, however, will be relatively unstable. Here is an interesting phenomènon presented in Fig.4. Three different areas can be clearly seen at the picture. In the middle, the grooves are the deepest (about

50nm), and the depth at the upper and the lower part is only about 20 nm. It may be understood as follows: At first, the tip front is relatively blunt, resulting in the depth of groove appeared small. During the scanning, the tip adsorbs a cluster of atoms from the sample, or a part of the front of the tip is removed due to the interaction with the sample, and accidentally a very sharp tip is obtained. Consequently, the largest corrugation appears, and at the same time because the position of the effective tiny tunneling tip changes, the phase-shift of the images would occur, which is shown clearly. But the topmost atoms are unstable, and finally they are removed, and the tip becomes blunt again, leading to the rest of the image. On the other hand, an asymetry tip will produce a distorted image. If the tip is not etched very well, its front may not be a sphere. As a result, the data stamper seems to have a tail in one direction in some of the experimental results. We have to carefully choose the etched tips to obtain satisfied results, and the results can be sure only by the reproduction of the images with many etched tips. The mechanical cut tips can not produce valuable information here. Anyway, the results presented in this paper show that the instrument is suitable to investigate the disc without much distortion. Also, the disc can be used as a standard to calibrate horizontal range of STM.

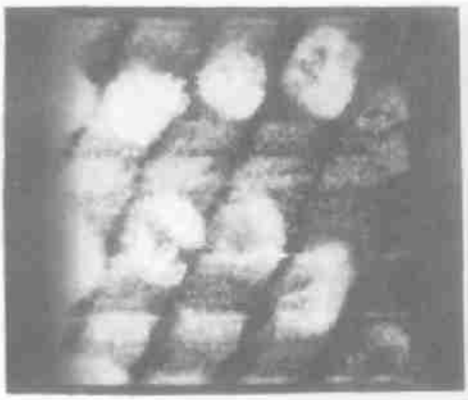

Fig.3 A STM image of recorded area on the disc where the data stamper has a hole in its center

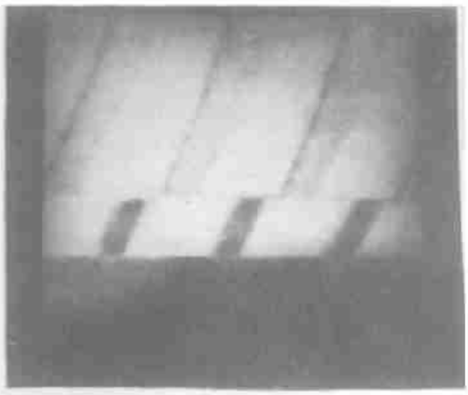

Fig.4 STM image showing the effects of the tip shape on the STM results

In conclusion, the results show that STM may not only give high resolution of the surface, but also the morphological information of the disc more truly, which is very important in the study of recording condition on optical disc. In future, it will be worth studying the dependence of the shape of the data stampers on the recording energy of the laser to find the optimum condition of recording.

REFERENCES

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