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Simultaneous Reflection and Transmission Modes Near-field Scanning Optical Microscope

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Near-field optical scanning microscopy (NSOM) has the capability of the conventional optical microscope as well as the high resolution comparable to the scanning electron microscope. In NSOM, a probe with sub-wavelength tip size scans the sample surface with sample/tip separation in 100A length scale. During the scanning period, light emitted by the probe is modulated in accordance with the optical properties of the sample surface. Two configurations can be used to record the light intensity changes, one is to detect the backward scattering light from the surface, the other is to collect the transmission power through the sample. These two images are in opposite contrary and known to be the reflection and transmission mode near-field optical images, respectively. However, due to the configuration, previous NSOM4-7 did not deal with these two images simultaneously. In this paper, we present our new NSOM system that can obtain simultaneous reflection and transmission mode images.

Figure 1 sketches the setup of our NSOM. The system can be divided into two different branches. At the heart of the system is a glass fiber, pulled to form a tapered shape with about 80nm tip size. Some 75nm of alumni are deposited on the tapered fiber's sides to prevent linkage of light. The fiber probe is fixed on a piezoelectric plate, and set into vibration near its resonance. Upon approaching the probe to the sample within 100A scale separation, the distance between sample and probe tip causes an attractive Van-der Waals force. This results in the damping of the tip's vibrational amplitude. The amplitude is recorded and is compared to a preset value. The resulting difference feeds back to the z piezo and maintains the sample/tip separation.

In the above feedback system, how to measure the tip's vibrational amplitude is important. We have used a simple method to measure it. First, an Ne-He laser (15mW at 633nm) is focused near the tip end, then the intensity of the scattered light is detected by a photodetector. By using a lockin instrument, the small AC component in the scattered light is measured. The AC signal contains the message of the vibrational amplitude and can be explained by a simple ray-optics model. The principle of the model is following: Suppose the fiber tip is located at x, part of the incident light (form x to x+a) is scattered to the detector. After probe vibrates with a small amplitude Dx, the incident light which scattered to the detector is little changed. the intensity change can be represented as

$$I_{AC}(x)=\frac{\Delta x}{a}\left|I_{DC}(x+a)-I_{DC}(x)\right| \quad (1)$$

were I_{AC} is the AC component and I_{DC} is the DC component of detected scattered light. Because only small part of scattered light can reach to the detector, the resultant relation between the amplitude and measured AC component is then represented as

$$I_{AC}(x)=\Delta x\cdot I_{DC}(x) \quad (2)$$

Above result shows that the measured AC component is the derivative of the DC component, and the vibrational amplitude can be easily obtained by only comparing the DC and AC values. Fig. 2 shows the measured results of the IDC and IAC signals when the vibrational probe moves along x-axis. As shown in Fig. 2, the AC signal is clearly in proportional to the derivative of DC intensity distribution and the vibrational amplitude is calculated to be about 50A.

In the optical branch, another Ne-He laser with green light is coupling to the fiber probe to excite the near-field optical source. It is necessary to use

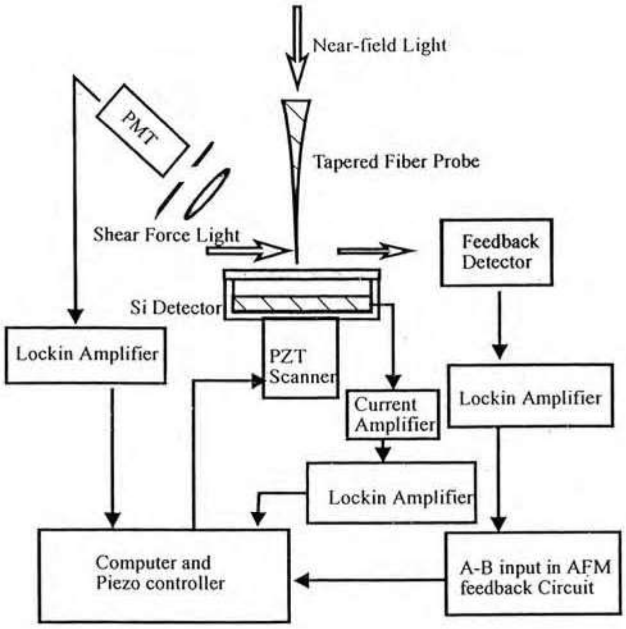

Fig. 1. The schematic of the transmission/reflection near-field optical microsope.

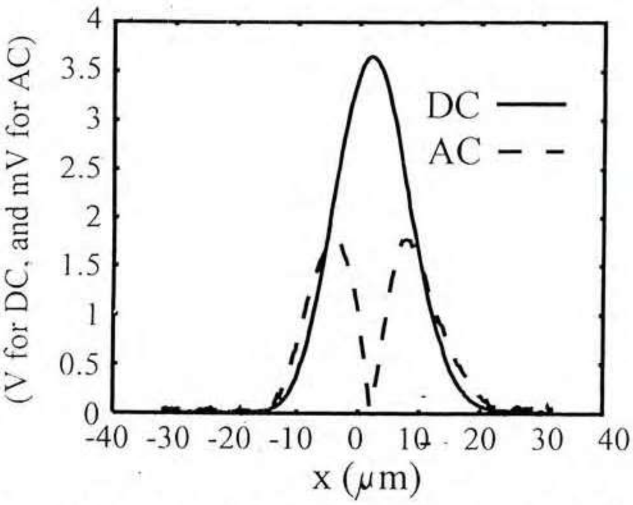

Fig. 2. Measured results of the DC and AC signals of a vibrational probe moving along x-axis.

another wavelength laser because the feedback laser is focused very near onto the tip position that will affect the detection of the near-field power. With another wavelength, we can use a filter to reduce such effect. In the recording of transmission mode image, a planar silicon detector is placed directed below the sample. When near-field light transmitted through the sample, it is collected by the detector.

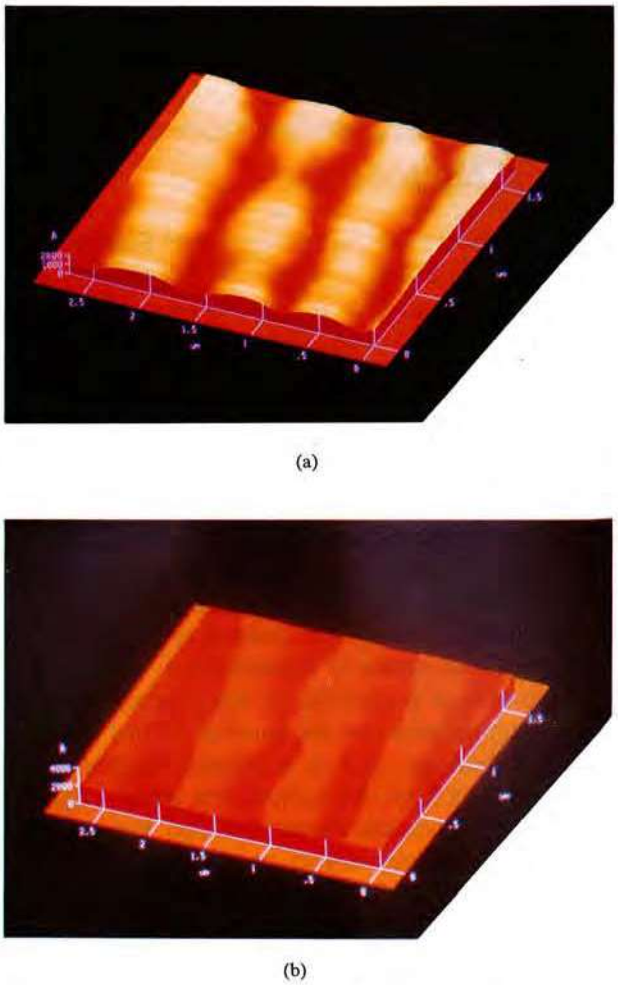

Fig. 3. Simultaneous transmission(a) and reflection(b) near-field optical images of gold gratings on glass.

At the same time, the scattered near-field power by the sample is focused by an objective lens and then directed on to a photo multiplier tube (PMT). The output of the PMT contains the reflection mode image, and a lockin instrument is used to readout the signal variations.

We have used the system to scan a number of samples of different compositions and structures. In our experiments, the resonance frequency of the fiber probe was 62.5 kHz, the driven voltage to the planar PZT was 0.01V. The NSOM light source was 0.5mW unpolarized He-Ne laser at 540 nm wavelength and optical power from the tip end was measured to be about 1 nW. The preset value was set to maintain the distance between the tip and sample to be about 200nm. To demonstrate our NSOM system with simultaneous reflection and transmission images, a sample of gold grating on glass was tested. The grating had a period of 1mm, and 2000nm thickness of gold. Fig. 3 shows the simultaneous transmission(a), and reflection (b) NSOM images. These images show good agreement with the sample.

In conclusion, we have presented a scanning probe microscope using attractive-mode force signal to regulate the tip/sample separation, and provided three images of one topographic and two optical images. We believe the system is the first NSOM that can deal these three images simultaneously. Also, we present a new method to measure the small tip's vibrational amplitude for the feedback system. The method is much simpler than others. A simple ray-optics theory can illustrate the mea-surement of vibrational amplitude.

REFERENCES

Betzig E, JK Trautman. 1992. Science **257:** 189.

Betzig E, A Lewis, A Harootunian, M Isaacson, and Kratshmer. 1986. J. Biophys. **49:** 269.

Betzig E, JK Trautman, R Wolfe, EM Gyorgy, PL Finn, MH Kryder, C-H Chang. 1992. Appl. Phys. Lett. **61:** 142.

Fischer UCh. 1986. J Vac. Sci. Technol. **B 3:** 386.

Durig U, DW Phol, F Rohner. 1986. J. Appl. Phys. **59:** 3318.

Betzig E, JK Truman, TD Harris, JS Weiner, and RL Kostelak. 1991. Science **251:** 1468.

Roberts A. 1991. J. Appl. Phys. **70:** 4045.