Hydrothermally deposited PZT thin film vibration probe sensor

Misato Sasaki*1, Takefumi Kanda2, Minoru Kuribayashi Kurosawa1, Toshiro Higuchi3
1Tokyo Institute of Technology, 4259 Nagatsuda Midori-ku, Yokohama, Japan
2Okayama University, 1-1-1 Tsushimanaka, Okayama-shi, Okayama, Japan
3The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan

Abstract - We have fabricated a touch probe sensor using PZT thin film vibrator. This sensor was designed with the aim of realizing high resolution more than 0.5 nm, low contact force under 100 nN, a wide scanning range in mm scale square and quick scanning surface profile measurement. These features have advantages in measuring nano structure, for example sub micron rule VLSI or micro electro mechanical systems (MEMS). The sensitivity and resolution were 2.0x10⁻² mV/nm and 2.4 nm. The sensor device was installed in AFM. Then an image of surface texture was obtained.

1. INTRODUCTION

A probe sensor was designed with the aim of realizing high resolution more than 0.5 nm, low contact force under 100 nN, a wide scanning range in mm scale square and quick scanning surface texture measurement. These features have advantages in measuring nano structure, for example sub micron rule VLSI or micro electro mechanical systems (MEMS). Some kinds of longitudinally vibrating touch probe sensors[1-4] for surface profile measuring tools or scanning probe microscopes (SPM) have been fabricated. The schematic view of the surface texture measurement by the probe sensor is shown in Fig. 1.

The sensor consists of a part longitudinal vibrating and an exponential horn which enlarges the amplitude at the contact point.

Although bending vibration is used for most AFMs, the longitudinal vibration was used for our sensor in order to maintain high mechanical Q value for high resolution and high resonance frequency. Therefore this sensor is also useful in liquid and can realize the quick scanning.

In order to realize such a measurement, to achieve a sensor which has high sensitivity for detection of the contact is important. It can be considered to miniaturize the sensor vibrator is effective to obtain higher sensitivity.

Fig.1 Schematic view of the surface texture measurement using the probe sensor.
2. SENSOR STRUCTURE AND FEATURES

The sensor was a half wavelength longitudinal vibrator and fixed at the node as shown in Fig.2. The vibrator was made of a titanium plate. The PZT thin film was deposited on it. Electrodes were on each side. One is for driving and the other is for pickup. By approaching the horn tip close to the substrate and measuring the changes of the vibration amplitude we detect the nearby or contact conditions. The length of the vibrator of the sensor was 9.8 mm, the thickness of the Ti substrate is 0.1 mm, PZT was 0.01 mm. Horn’s step up ratio was 3.2. From the measurement, when 3 V was added at the resonance frequency of 304 kHz, the vibration amplitude was 124 nm and the detected voltage was 3.4 V through an amplifier of 20 dB.

Fig.2 Photo of the probe sensor: the length and width of the vibrator were 9.8 mm and 0.1 mm.

3. THE Q CURVE

The Q curve of the sensor is shown in Fig.4. The resonance frequency was 263.0 kHz and the mechanical Q was 845. When the driving voltage was 1.5 Vrms, the pickup voltage was 1.2 Vrms. The set up frequency, used for scanning was fixed little bit lower than the resonance frequency. From the resonance frequency and the mechanical Q, the operation frequency was fixed to be 262.9 kHz. At this condition the pickup voltage was 1.0 Vrms.
4. THE FORCE CURVE

Fig. 5 shows the force curve of the sensor. It shows the changes of the voltage as the sensor approaches the substrate and on the reverse action. First, when the vibrator doesn’t contact the substrate, the pickup voltage did not change around 1.1 Vrms. Then it started tapping the surface and the pickup voltage got lower as it approached. And when it contacted completely, the pickup voltage took constant value which was almost 0 Vrms. Operating point was where the pickup voltage was 0.95 Vrms. From the slope of this graph, the sensitivity was 2.0 x 10^4 V/m. Resolution was calculated from the sensitivity, amplifier noise and amplifier gain. The resolution was 2.4 nm.

\[ R_s = \frac{v_m}{PG} \]

P : Sensitivity  
\( v_m \) : Amp. noise  
G : Amp. gain

5. SURFACE TEXTURE IMAGE

By using the longitudinal vibrator we took the image of surface texture. The object was a diffraction grating glass. The grating period was 500 nm and the depth was 100 nm. First we took an image using AFM (Fig. 6). The grating width was 500 nm and the depth was 100 nm. Then we installed the longitudinal vibrator into the AFM. The image is shown in Fig. 7. The set up frequency and operation point was same as the one from Q curve and force curve. Period of 500 nm grating was obtained and the depth was about 15nm. Compared with the image taken with AFM, the grating depth was shallower, the cross section was not clear and the shape was like a sine wave. This was because, tip was not sharp for high horizontal resolution and could not reach the bottom. So the sensor should have sharp tip for high resolution and for measurement of high aspect ratio texture.
7. ACKNOWLEDGEMENTS

This work was supported by the Grant-in-aid for general scientific research of the Ministry of Education, Culture, Sports, Science and Technology and by the Grant-in-aid for Research Fellowship for Young Scientists of the Japan Society for the Promotion of Science.

8. REFERENCES


6. CONCLUSION

Using the hydrothermally deposited PZT thin film vibration probe sensor, we took an image of surface texture and calculated the resolution. The sensitivity was $2.0 \times 10^4$ V/m and the resolution was 2.4 nm. The resolution, which is from the measurement, has not yet reached the target value of 0.5nm. From now on we will improve the resolution by reducing the noise level, miniaturizing the vibrator and sharpening the tip.