A Newly Developed AFM-based Three Dimensional Profile Measuring System

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Abstract

An atomic force microscope (AFM) based three dimensional profile measuring system was developed. This system enables a dimensional metrology with a nanometer spatial resolution and has a large measuring area of 18 mm × 18 mm × 10 mm. This system is composed of a planar nano-motion table system driven by voice coil motors, a vertical nano-motion system driven by a hybrid actuator and an AFM probing system. Performance evaluation results confirm that the measuring system has 10 nm resolution and a large measuring area.

1 Introduction

Demands for precision measurement of three dimensional (3D) micro-geometries over a large area have recently increased in a variety of industries [1]. In order to meet such demands, a three dimensional profile measuring system with high measuring resolution and large measuring area is required. This study presents a newly developed atomic force microscope (AFM) based 3D profile measuring system.

2 AFM-based 3D profile measuring system

Figure 1 shows a proposed design concept of an AFM-based 3D profile measuring system. The proposed system is composed of a planar nano-motion table system (Fig.2), a Z axis nano-motion system and a probing system. A 3D profile can be measured by controlling the position of a probing system to keep the distance constant between a probe and a specimen surface during an XY scanning as shown in Fig.3.

The planar nano-motion table levitated with four porous air bearings can be driven by eight voice coil motors (VCMs). The table position on the XY plane is measured by a laser interferometer and two plane mirrors fixed on the table. In order to enlarge the limited stroke of a piezoelectric actuator (PZT) for the Z axis drive, a main body is driven by the VCM with a millimeter stroke. By a through-hole at the center of the vertical moving body, the position of the probe can be measured directly. In addition, the Z axis nano-motion system has a gravity compensator equipped with a vacuum cylinder. The planar nano-motion table and the Z axis nano-motion system are guided by aerostatic bearings. Therefore, these nano-motion systems are guided and driven in a perfect noncontact condition, and various nonlinear phenomena can be reduced [2].

In order to improve stability, the overall 3D profile measuring system was installed in a temperature-controlled enclosure and the machine base is supported by an active vibration isolation system.

Figure 4 shows the appearance of the 3D profile measuring system developed.

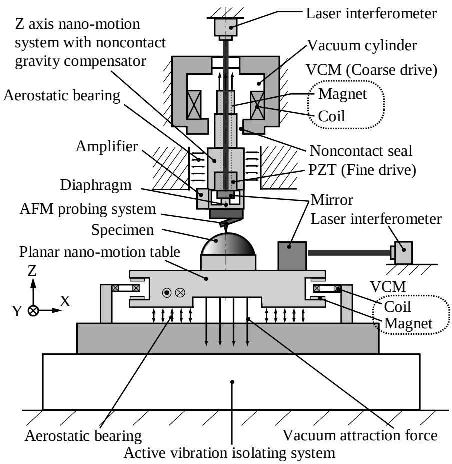


Figure 1: Design concept of an AFM based 3D profile measuring system

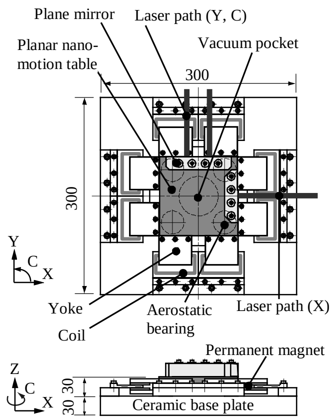


Figure 2: Concept of a planar nano-motion table system

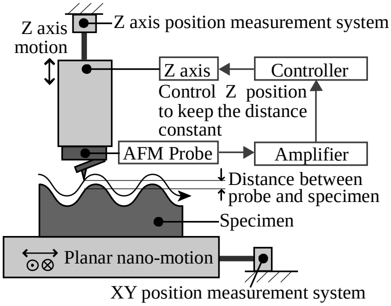


Figure 3: Probe control system

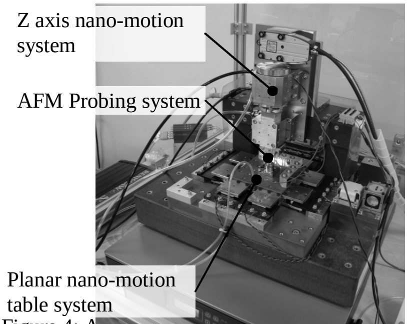


Figure 4: Appearance of the measuring system

3 Performance evaluation of the 3D profile measuring system

Atomic force detecting experiments were conducted to evaluate the measuring resolution of the 3D profile measuring system. The Z axis was controlled for 10 nm stepwise positioning without XY scanning and without atomic force feedback. The Z position data measured by the internal interferometer was compared with the output signal obtained from the AFM probing system. As shown in Fig.5, clear stepwise responses of both the Z position and the output signal could be observed. These results confirmed that the system has 10 nm measuring resolution.

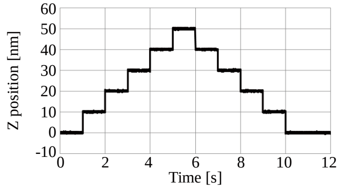
In order to evaluate the measuring performance, actual measurement experiments were conducted. A spherical lens with a diameter of 15 mm as shown in Fig.6 was used as a specimen. Fig.7 shows the 3D profile of the specimen measured with measuring conditions shown in Table 1. The temperature at the measuring point was controlled so as to maintain at 26.2 ºC ± 0.3 ºC. Fig. 8 shows the cross sectional profile of the specimen measured with measuring conditions shown in Table 2. For a comparison, the profile curve measured by a contact type surface profile measuring instrument (Taylor Hobson, Form Talysurf PGI820) is also shown in Fig.8. In this instrument, a surface profile is obtained by pressing a contact probe against a specimen with a constant force and measuring the displacement of the probe, while in an AFM, a surface profile is obtained by measuring an atomic force. Fig.9 shows the difference between the profiles measured by the measuring system and by the surface profile measuring instrument. The difference was approximately ± 1.0 μm.

Table 1 Measuring conditions for the 3D profile measurement

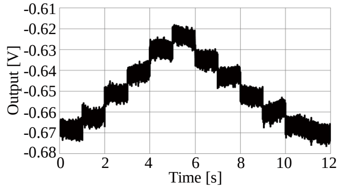
Scanning range	2 mm × 2 mm
Sampling length (X)	20 μm
Sampling length (Y)	1 μm
Scanning speed	1 mm/s
Measuring time	75 min.

Table 2 Measuring conditions for the cross sectional profile measurement

Scanning range	6 mm
Sampling length (X)	0.25 μm
Scanning speed	1 mm/s



(a) Z position



(b) Probing system output

Figure 5: Results of 10 nm stepwise positioning experiments

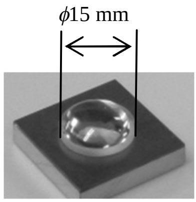


Figure 6: Spherical lens

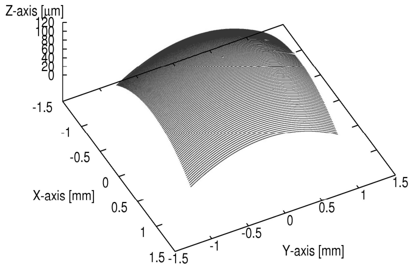


Figure 7: 3D profile of the spherical lens

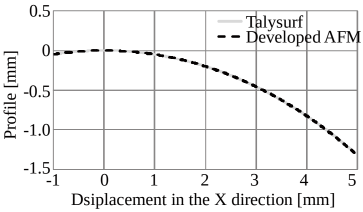


Figure 8: Cross sectional profile of the spherical lens

Figure 9: Difference between the profiles measured by the measuring system and by Form Talysurf

4 Conclusions

This paper presented a newly developed AFM-based 3D profile measuring system with a nanometer spatial resolution. As a result, the following conclusions could be drawn:

(1) The design concept of an AFM-based 3D profile measuring system was proposed to provide a large measuring range and a measuring resolution of nm order.

(2) The performance evaluation results confirmed that the measuring system developed achieves a measuring resolution of 10 nm and a measuring range of 18 mm × 18 mm × 10 mm.

Acknowledgement

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References

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