Development of Nano-Probe System for Nano-CMM (Coordinate Measuring Machine with Nanometer Resolution)

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1. Introduction

When developing micromachines and small optical elements, it is necessary to perform traceable 3D measurements of the micromachine and its parts or the optical element in nanometer resolution. While practical technologies for traceable measurements of surface shapes on a nanometer scale have been made achieved with scanning tunneling microscopes and atomic force microscopes, a measuring machine for measuring three-dimensional sizes and positions has yet to be adequately developed. Thus, it is necessary to develop a 3D measuring machine with nanometer resolution, that is, a nanometer coordinate measuring machine (nano-CMM). The probe system in this nano-CMM has been deemed the most difficult to develop. In this study, a nano-probe system was developed by combining mechanical contact with optical sensing of that contact.

2. Development of the Nano-Probe System

As shown in Fig. 1, the nano-probe system has a mechanically supported stylus ball that contacts the object to be measured and employs an optical system for directly sensing displacement of the ball. With this method, it is possible to construct a 2D or 3D sensing system with stable nanometer resolution for measuring objects having various surface aspects. Fig. 2 shows the construction of the nano-probe system and its prototype. A small ball having a diameter of 0.5 mm or less contacts the object, while an optical sensor comprising a laser and a quadrant photodiode detects the movement of the ball during contact. The overall size of the apparatus is approximately 100 x 30 x 30 mm, enabling the apparatus to be mounted in the Nano-CMM. The resolution of the prototype nano-probe system was evaluated and determined to be capable of achieving 10 nm or less resolution. Further, when performing 2D measurements, crosstalk and the like occurred between the X and Y axes. However, having achieved a resolution of about 10 nm, the probe system can be applied for the Nano-CMM.

3. Conclusion

As described above, we developed a nano-CMM and a nano-probe as basic tools for developing future micromachines. However, there are many issues that remain unresolved before these devices can be actually used, such as establishing a method for calibrating the measuring machine, improving reliablity of measurements, and evaluating the device's aging.

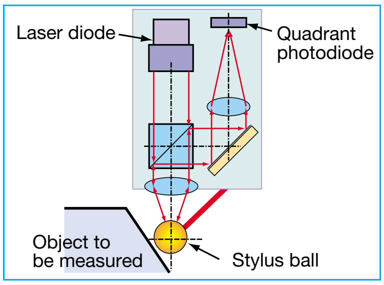

Fig. 1 Basic principles of the nanoprobe system

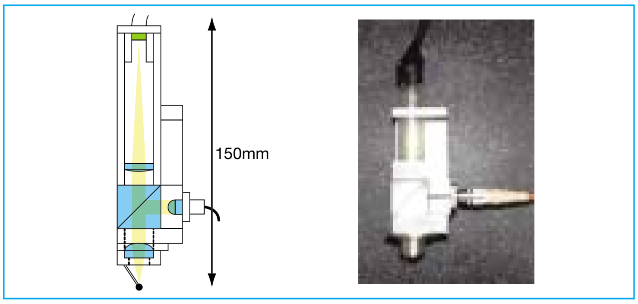

Fig. 2 Construction of a nano-probe and its prototype

Micro Hand System Capable of 3-D Tracking

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1. Introduction

We have been developing an automated micromanipulation system for handling and machining micro-objects under a microscope. In order to perform such auto-micromanipulations, we have developed a system for automatically focusing the target object, a system for recognizing the object in the focal plane and detecting its position, and a micro hand system that integrates these two systems in order to control a two-fingered micro hand to pick up objects while automatically tracking the movement of the object.

2. Auto-focusing system

A characteristic quantity for determining the vertical relationship between the object and the focal plane of an optical microscope is found based on RB data of an image around the object near the focal plane. Accordingly, we developed a system for automatically tracking the focal point of the microscope on the micro-object by deriving an algorithm for focusing the object based on this condition. We configured a system that applies the same principle of controlling the micro hand in the direction of height for tracking the fingertips of the hand at the focal plane. We achieved a tracking speed of 0.1 Hz (12 μm p-p).

3. Auto-handling a moving micro-object with the micro hand

Using template matching, the positions of the fingers and the object in the focal plane are automatically detected. Sufficient tracking accuracy for moving objects in the focal plane was achieved using a 60 x 60 pixel template. We achieved auto-calibration required for accurately positioning the micro hand by combining the auto-focusing with position detection in the focal plane. Fig. 2 shows the absolute positioning accuracy achieved through the calibration, which ensured within about 2 μm.

By integrating the above functions, objects could be picked up automatically with the micro hand. Fig. 3 shows the micro hand performing a high-speed process to automatically pick up a glass particle 5 μm in diameter.

In the future, we will apply these achievements in automanipulations targeting such moving micro-objects as active cells.

Fig. 1 Overview of the system

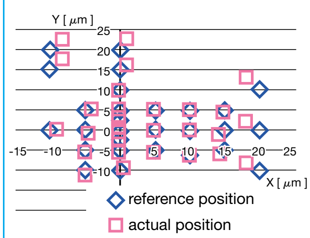

Fig. 2 Positioning accuracy with calibration

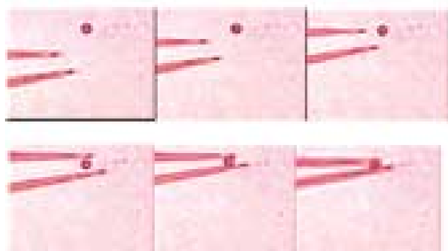

Fig. 3 Automated object handling