Long Scan Stage for the Metrological Atomic Force Microscope

TaeBong Eom, JaeYun Lee and JongAhn Kim
Korea Research Institute of Standards and Science, Youseong, Daejeon 305-666, Korea

Abstract
This paper presents the design and fabrication of a long scan stage for metrological atomic force microscope. On designing the system, we mainly consider a simple structure with low vibration and high accuracy. Instead of the traditional two-level stages, we used a surface plate as the reference of the main stage. Therefore, it has low profile and simple structure. Surface plate was made of ceramic glass with very low thermal expansion. The stage is positioned on the surface plate of 800 mm x 800 mm. It is guided horizontally by a cross structure with two precision bars perpendicularly linked and vertically by the surface plate. The sliding pads of PTFE are used at X- and Y-axes, and also used for vertically supporting the stage. The X-axis guide bar with a moving plate is glued on the surface plate. The Y-axis guide bar is attached to the X-axis moving plate and moved to the Y-direction. Finally the Y-axis guide bar guides the XY-stage plate, so the XY-stage plate can be moved to two directions. This global stage also has the two-axis flexure structure machined by the precision wire-cutting machine. By combining global stage and micro-stage, the fast and long movement and the fine positioning can be provided. A two-axis tilt stage for adjusting the pitch motions of the stage and a L-shaped mirror for laser interferometer is positioned on the tilt stage.

Introduction
Atomic force microscopes (AFMs) have been used frequently to observe the surface texture. With the development of nanotechnology, there has been growing demand for measuring the dimension of the very small structure. For this purpose, several metrological AFMs have been developed. Most of them have the precision flexure stages and displacement measuring systems such as capacitance type sensor or laser interferometer [1, 2]. These metrological AFMs are used mainly for measuring the pitch and step-height. However, these measuring systems have the short measuring range of a few ten µm. For measuring the image placement of the photomask and wafer, a special metrological system having long measuring range is required. National Institute of Standards and Technology is developing a STM based Molecular Measuring Machine having an accuracy of 1 nm and a measuring range of 50 mm x 50 mm x 0.1 mm [3]. PTB also developed a SEM-based Electron-Optical Metrological System with a measuring range of 300 mm x 300 mm [4]. Recently PTB reported a large range scanning probe microscope (LR-SPM). It has a large measuring volume of 25 mm x 25 mm x 5 mm and is applicable to topography
measurements. At present, we are also constructing a metrological AFM with a large scanning range. The aim of the project is to develop a nano-measuring system presenting a resolution of sub-nanometer with a measuring range of 250 mm x 250 mm x 20 µm.

**Design and construction of the stages**

Two years ago, we had designed and fabricated a long scanning stage for test purpose. The main structure of the present system is similar to the old version. Fig.1 shows two-axis translation system. On designing the system, we mainly consider an Abbe’s offset free arrangement and a simple structure with low vibration and deformation. In stead of the traditional two-level X and Y stages, we used one level X-Y stage. The surface plate is used as the reference of the stage. Therefore, it has low profile and simple structure. Surface plate was made of the ceramic glass with low thermal expansion coefficient and its flatness is below 1.3 micrometer over the size of 800 mm x 800 mm. The X-Y stage is positioned on the surface plate. It is guided horizontally by a cross structure with two precision parallel bars rectangularly linked and vertically by the surface plate. The X-axis guide bar, which is made of aluminum alloy and grinded precisely, is glued on the surface plate. It carries a X-axis moving plate. A Y-axis guide bar is fixed to the X-axis moving plate and moved to the X direction by motion of the X stage. Finally the Y-axis guide bar guides the Y-axis moving plate on which the X-Y moving plate with flexure hinge structure is mounted, so it can be moved to two directions. The sliding pads, which are made of PTFE, are used as bearings of X-Y translation system. X- and Y-axis moving plates are vertically guided by four sliding pads respectively. One sliding pad is rigidly fixed to the moving plate and three sliding pads are fixed to flexure mechanism for adjusting the contact force with guide bar and the...
squareness between two guide bars. The X-axis moving plate and the X-Y moving plate are vertically guided with the surface plate by 3 sliding pads respectively. X- and Y-axis moving plates are driven by the lead screws with the geared DC servo motors and have the moving range of 250 mm and 250 mm. The X-Y moving plate, which is made of a single aluminum block, has the two-axis flexure hinge structure machined by the precision wire-cutting machine. This flexure stage (micro-stage) consists of two micro-stages which are decoupled avoiding the cross-talk effect. The X micro-stage and Y micro-stage are driven by two PZTs and one PZT respectively. The micro-stage provides a linear translation of 40 µm x 40 µm and angular motion of about 1 minute for adjusting yaw motion (see Fig. 3). By both global stage and micro-stage, the fast and long movement, and the fine positioning are provided. The tilt stage, on which L-shaped mirror and specimen to be measured are mounted, is kinematically coupled to the inner moving part (equivalent to Y micro-stage) of the micro-stage. Two pitch motions of the tilt stage are provided by two PZTs of the micro-stage. To measure the displacement of the X-Y stage, we use a heterodyne type laser interferometer. The Agilent 5517 He-Ne laser, of which beat frequency is about 1.8 MHz, is used as a light source. At X-axis, three plane-mirror type interferometers are used for 1 displacement and 2 angular measurements. At Y-axis, one plane-mirror interferometer is used for only displacement. In order to encode the phase difference between reference signal and measurement signal of the heterodyne interferometer, the phase-quadrature mixing technique is used. Two outputs of phase demodulating electronics become sinusoidal signals with phase quadrature.

![Fig. 3 Flexure hinge type micro-stage.](bottom view)

A compact flexure with PZT is used for actuation of AFM tip and a capacitive sensor reads the displacement of the tip. The PZT actuator with cantilever and capacitive sensor is mounted on a
stage driven by Pico-motor, which is used for coarse adjustment of the AFM tip relative to sample surface. In order to view the sample surface and the AFM tip, an optical microscope with CCD camera is also used.

**Further works**

Now we are constructing the large range nano-measuring machine for semiconductor metrology applications. For this, a long scan stage with a measuring range of 250 mm x 250 mm x 20 μm is fabricated. The preliminary test shows that the long range stage works well. Further study is to combine the stage with laser interferometer and develop the control algorithm.

![Nano-measuring machine under construction.](image)

**Fig. 5** Nano-measuring machine under construction.

**References**


