Incident Angle Auto-Alignment of Ellipsometer using Precision 3-Axis Stage with Kinematic Coupling

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Introduction

The demand for high precision stage is increasing to obtain more accurate and precise results in many areas especially in the optical measurement systems and thin-film measurement systems. Ellipsometer is an optical measuring instrument for the characterization of, and observation of evens at, an interface or film between two media and is based on exploiting the polarization transformation that occurs as a beam of polarized light is reflected from or transmitted through the interface or film. It is known as a useful one for determining optical indices and thickness of thin films.

In ellipsometer the resulting polarization state of the reflected light is measured and the changes in amplitude and phase occurring upon reflection are determined. It is notable that the ellipsometry parameters ψ and Δ, not the physical quantity, are measured by an ellipsometer. Ellipsometry parameters are functions of the incidence angle and depend strongly on the incidence angle factor. So precise incident angle alignment is an important process and has influence on the accuracy of ellipsometry measurement.

In this paper, we propose a novel design of 3-axis (z-axis, pitch, roll) motion stage [1] and it is utilized for incident angle auto-alignment of ellipsometer. To develop several properties of stage, the kinematic coupling [2] is applied. The kinematic coupling has many advantages, such as closed form motion solution, high repeatability, low construction cost, and no play between mating parts. This novel device could have much influence on not only ellipsometer but also other precision and automation systems, such as, optical microscopes, scanning prove microscopes, reflection measurement systems and etc, where the device tilts and translates specimen or component. The incident angle auto-alignment of ellipsometer[3] consists of two steps, searching the spot and aligning to the center of detector. It is possible to align the incident angle automatically without additional apparatus by this algorithm.

Stage Design

Figure 1 shows the designed overall structure of the stage. Figure 2 presents the bottom of upper plate.

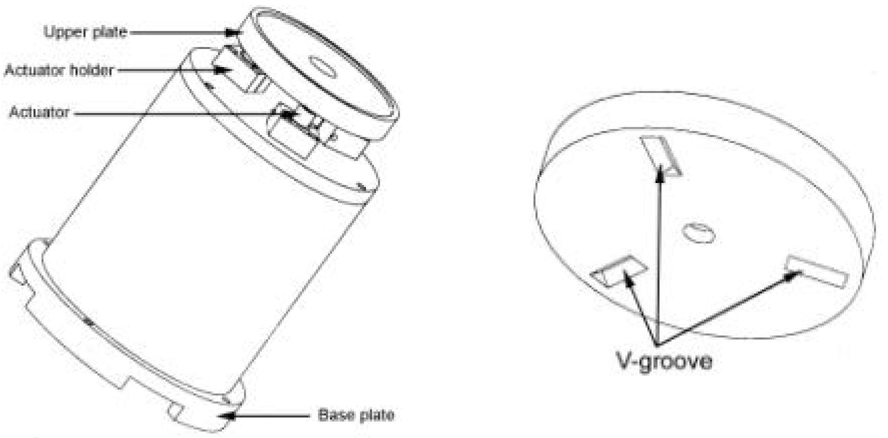

Fig. 1 Structure of 3-axis stage

This stage is composed of an upper plate, three actuators, and a base plate. There are three V-grooves symmetrically in the bottom of the upper plate. The specimen is fixed on the top of the upper plate. The end of each actuator is a ball that contacts with each V-groove. This configuration makes 6 points contact and gives us 6 independent constraints between upper plate and actuators. Generally speaking an object that is rigid requires 6 independent constraints to exactly constrain 6 degrees of freedom. So we can say that the degree of freedom of the upper plate relative to the actuators is zero. This kinematic coupling provides closed form motion solution, high repeatability, no play between mating parts, and several properties of kinematic design. We use ultrahigh resolution linear DC Motors made by PI instrument. These motors travel 25mm range with 0.06μm resolutions and have ball tips. Three actuators are controlled independently. The position and tilting angles of the upper plate are determined by the positions of actuators. So we can get 3-axis motions (z-axis, pitch, roll) of upper plate by controlling the positions of actuators. If we make actuators move with 0.06 μm resolutions, the stage provides 0.18 arcsec resolution over total range of 19.84 degrees in pitch and roll motion.

Auto-alignment algorithm

The incident angle alignment of ellipsometer is a process of centering the spot on the detector. If the alignment is carried out, we can have exact information about incident angle and have maximum intensity, in other words, we can get a large SNR. Incident angle and noise signals are sensitive factors to ellipsometric parameters, ψ and Δ. Most existing approaches have additional apparatus for alignment. But we would like to do this work automatically by using specimen stage only.

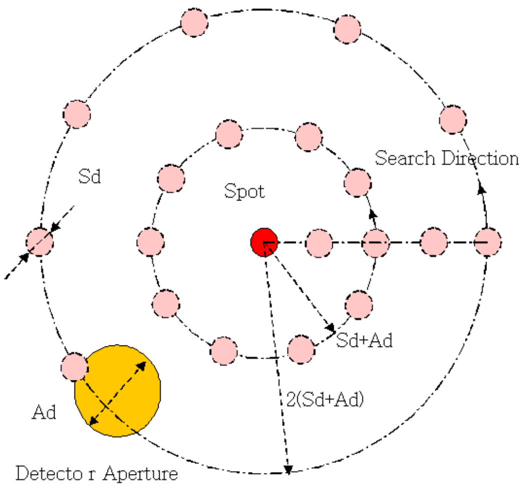

Fig. 3 Step 1 (Accessing)

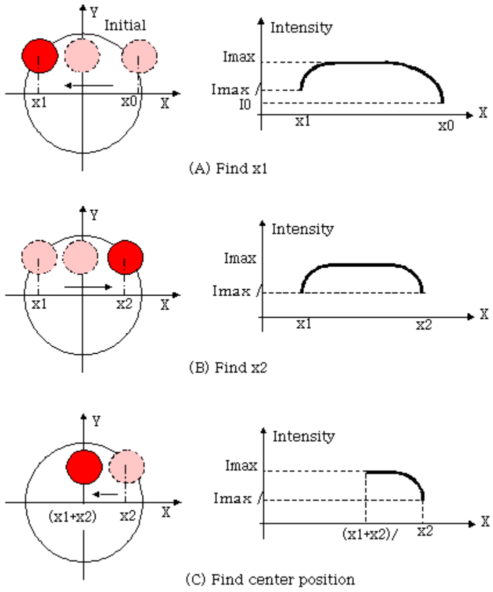

Fig. 4 Step 2 (Centering)

Incident auto-alignment algorithm consists of two steps. Fig ure 3 shows the schematic figure of the first step that is positioning the spot to detector aperture. The spot and detector aperture (photo diode) are on the detector plane in figure 3. Let' s assume that initial position of the spot is the center of plane and the detector aperture is in the bottom of the plane. There isn' t any overlapped area between spot and detector aperture, so there is no output intensity. And then we make the spot circle round through actuating the stage properly. If we don' t detect any intensity, we increase the radius of circular motion. The incremental amount of radius is the sum of Sd and Ad, where Sd is a diameter of the spot and Ad is a diameter of the detector aperture. The circular motion of spot stops when there is some output signals and the first step is finished

Figure 4 presents the second step that is centering process. The intensity will be proportional to overlapped area. If we make the spot move along X-axis, the intensity varies just like figure 4-(A). We can know the maximum intensity value and stop the stage when the intensity is the half of maximum value. Then the position of the stage will be x1, we remember this. Next, we make the spot move along reverse X-axis, and find x2 position. Finally if we move the stage to middle position of x1 and x2, (x1+x2)/2, the alignment along X-axis is end. The aligning process along Y-axis is the same.

General incident angle alignment includes Z-axis alignment. However, this algorithm is related to 2-axis alignment only, pitch and roll.

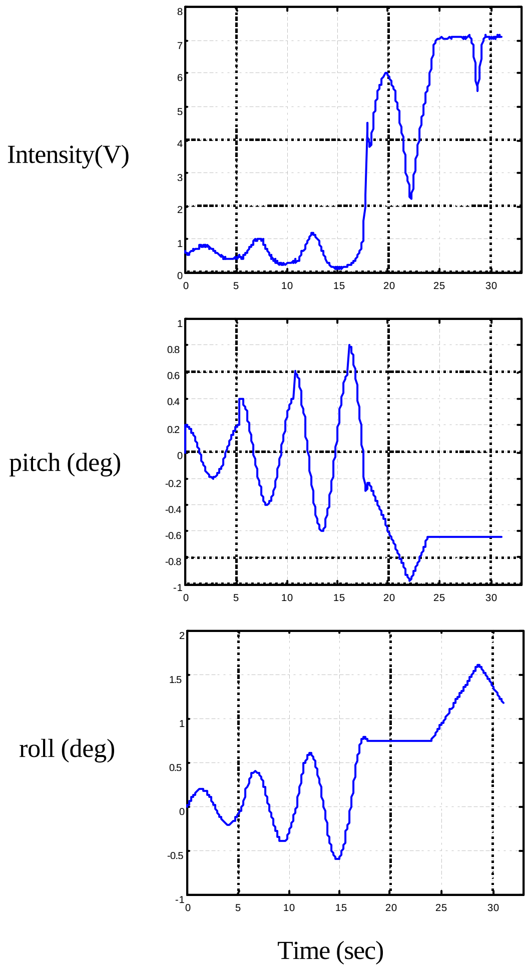

Fig. 5 Experimental result

Result and discussion

Figure 5 shows the experimental result. The configuration of experiment was very simple. The light of laser diode was reflected by mirror on the stage and reflected light was detected by photo diode. The top figure of result is the intensity variation during incident angle auto-alignment process. The second and third figures are the angle variations of stage, pitch and roll. The incremental angle of stage is 0.01 degree. The intensity is vibrating until 17 seconds because of the circular motion of spot, step 1. Next only pitch angle is varied to find center position along X-axis. Finally only roll angle is varied and the spot is aligned along Y-axis. The total elapsed time is 31 seconds.

In this paper we propose a novel 3-axis precision stage and incident angle auto-alignment algorithm without using additional apparatus. We expect that this work can have much influence on the precision and automation of system.

Acknowledgement

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