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Holographic Nanometer Alignment for a Wafer Stepper

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To achieve higher overlay accuracy, we propose a new interferometric wafer alignment method called holographic nanometer alignment for a wafter stepper with submicron resolution. The response sensitivity of alignment signal is estimated to be 5 nanometer for the step movement of the wafer having various surfaces including Aℓ deposition. The resultant overlay accuracy has been improved to 0.1 μm/3 sigma.

1. Introduction

Recently, the feature size of VLSIs has been going into the submicron region. The decrease in the feature size of VLSIs requires an increased overlay accuracy and a higher resolution as well. The registration accuracy in a half-micron lithography, for instance, requires an order of tens of nanometer.

Many studies have been carried out to achieve a higher accuracy.1)2) Current reticle/wafer alignment of a wafer stepper relies on detecting an objective image of an alignment mark through a projection lens. The detected signal of a wafer alignment depends on the edge contrast of the alignment mark through the projection lens. Since there are changes in the contrast, depending on the Aℓ-deposited wafer surfaces and the chemical vapor deposited wafer surfaces, it is difficult for the conventional methods to have an overlay accuracy better than 0.1 μm/3 sigma.

The superimposed dual grating method2) introduced to the reticle/wafer alignment of a wafer stepper had an overlay accuracy of 0.08 μm/3 sigma on silicon. In this case, the detected light intensity seems to consist of more than three diffracted beams, and the response of the light intensity is considered to be affected by the topography of the alignment marks.

This report presents a new interferometric wafer alignment method for the wafer stepper, which works as an ideal interferometer. The performance of holographic nanometer alignment was investigated for various surfaces including Aℓ deposited wafer.

2. Principle of holographic nanometer alignment

The schematic configuration of Holographic Nanometer Alignment (HNA) system is shown in Fig. 1. The HNA system is mainly composed of a reticle with a reticle alignment grating, a pair of Fourier Transform (FT) lenses, a spatial filter disposed between the FT lenses, a Mx reduction lens, a wafer with a wafer alignment grating and a photo detector.

A laser beam used as the alignment light is incident on the reticle alignment grating with a pitch P. A number of the diffracted beams pass through the first FT lens and are converged at the FT plane. The spatial filter at the FT plane accepts only ± 1st order beams to pass through the second FT lens. Thereafter, two beams intersect and interfere with each other at the image plane of the second FT lens, and a fringe is generated. The fringe pitch is a half pitch of the image of the reticle alignment grating. After that, the fringe is projected by the projection reduction lens and the fringe is reproduced by the projection reduction lens and the fringe is reproduced again by interference

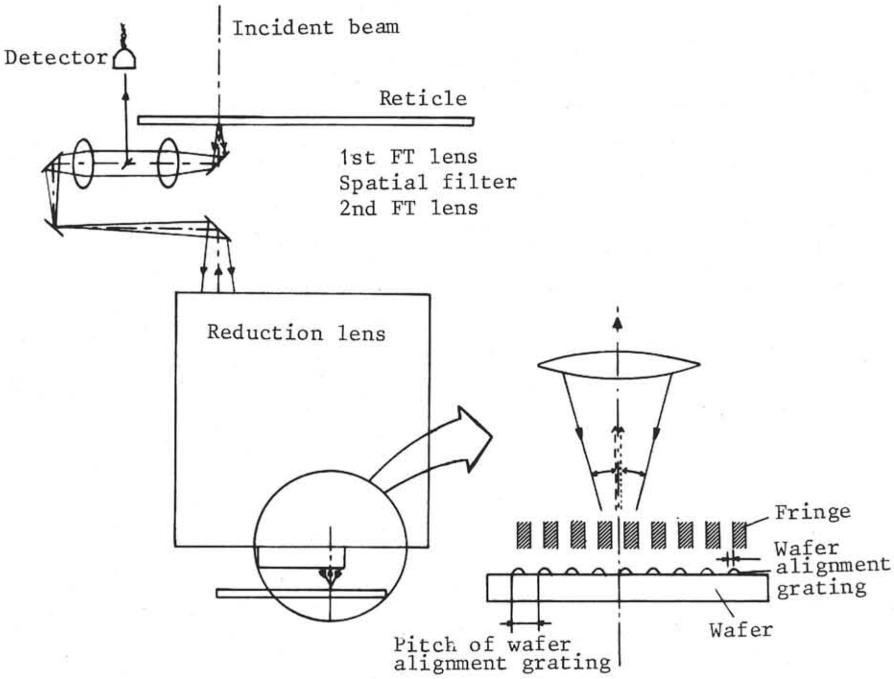

Fig.1 Schematic configuration of the holographic nanometer alignment system and the principle of HNA

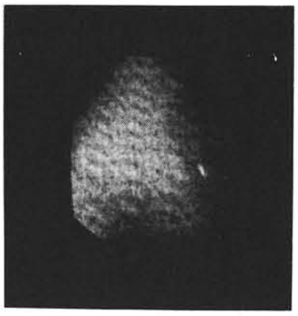

Fig.2 Moirè image at the detector position

between two conjugate beams at the surface of the wafer. The fringe pitch becomes P/2M when the reduction rate of the reduction lens is M.

Two beams, which are incident on the wafer, are rediffracted by the wafer alignment grating to the same direction. Two perpendicularly rediffracted beams go back-through the projection lens and 2nd FT lens and are reflected by the mirror at the center of the FT plane of FT lenses. Two diffracted beams interfere with each other and generate a moirè image. The light intensity of the moirè image indicates a relative position between the fringe and the wafer.

Figure 2 shows the moirè image at the photo detector position. A stripe pattern will appear in the moirè image when there is an azimuthal displacement between the wafer alignment grating and the reticle alignment grating. In this photograph no stripe pattern appears, that means the azimuthal displacement between them is within 1 sec.$^{3)}$

3. Experimental procedure and results

In the experiment, a 488-nm Ar laser is chosen for the alignment light as it does not expose the resist on the wafer. Prepared things included a 10 μm-pitch reticle alignment grating, and a 5× reduction lens projected a 0.5 μm L/S fringe on the wafer, which was generated by the first order diffracted beams. Also, various surfaces of the wafer alignment grating (eg. 1 μm-thick Aℓ deposition) were prepared. The pitch of the wafer alignment grating was 2 μm, double that of the fringe.$^{3)}$

Figure 3 shows the displacement versus the moirè light intensity curve. The measurement was made by positioning alignment grating of the wafer to corresponding alignment grating of the reticle. The observed light intensity was varied sinusoidally with the displacement, and the pitch of the light intensity signal was 1 μm, which was equal to the fringe pitch. A magnified graph is also shown in Fig.3. The notches in Fig.3, caused by step movements, correspond to 5 nm and 10 nm, respectively. The step movements were measured by a capacitance metering. The response sensitivity to a step movement of 5 nm was clearly obtained with minor fluctuations, that was caused due to the irregularity of the step movements of the stage. Although the moirè light intensity varied, the response sensitivity remained unchanged at 5 nm for various surfaces including Aℓ deposited wafer. This result confirms that the response sensitivity of HNA was better than 5 nm for various surfaces.

Figure 4 shows the signal output of the moirè

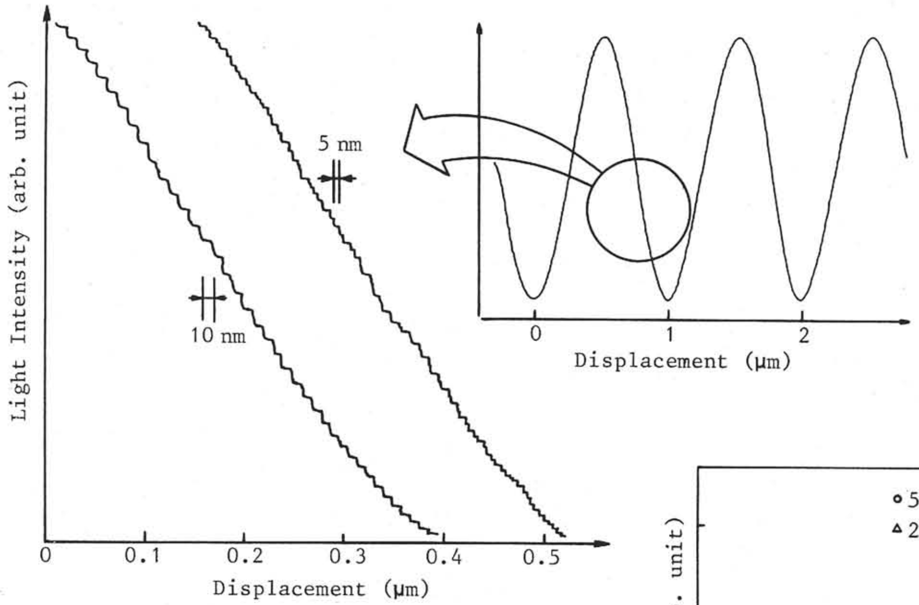

Fig. 3 The displacement versus moirè light intensity curve

light intensity versus alignment grating area. The moirè light intensity signal was proportional to alignment grating area. Figure 5 shows the moirè light intensity signal when the wafer alignment grating was 25 μm × 25 μm square. The shape of the signal represents almost cosine curve. This consists with the fact that the divergence of the diffracted beams by the grating is very small until the grating width becomes under 20 μm. So it affects little on the signal to noise ratio of the moirè light intensity signal. As a result, the wafer alignment grating for the HNA is not bigger than conventional wafer alignment marks.

Figure 6 shows the SEM photograph of the test pattern to examine the overlay accuracy. The wide pattern is the 1st wafer pattern and the narrow pattern is the overlaid 2nd resist pattern. The 1st wafer pattern was fabricated on SiO_2 substrates by a 10× wafer stepper and reactive ion etching. The 1 μm L/S wafer alignment grating was engraved at the same time. The etching depth was 500 nm. For the overlay on the Aℓ surfaces, 500 nm thick Aℓ film was deposited on etched SiO_2 samples.

The 2nd resist patterns were prepared as follows: On top of the 1st wafer patterns, 1 μm thick resist was spin-coated. By means of a microscope, the overlay prealignment was roughly made within the precision of 1 μm using the conventional cross alignment marks. Then the stage was moved until the light intensity signal indicated the peak and was stopped (peak alignment). Thereafter the resist on the wafer was subjected to a successive exposure and development. 1 %

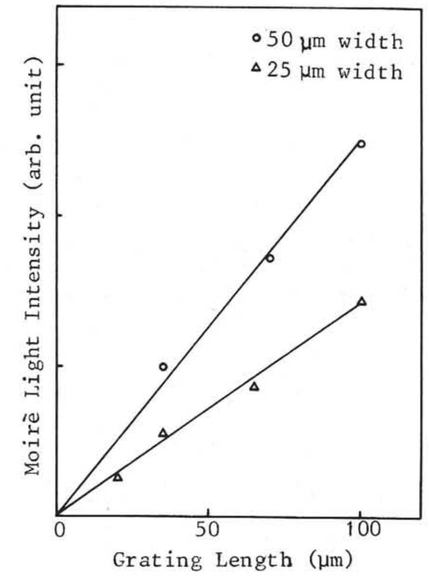

Fig. 4 The signal output (peak to peak) of the moirè light intensity versus alignment grating area.

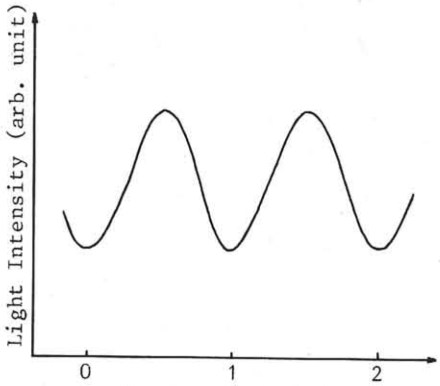

Fig. 5 The moirè light intensity signal when the wafer alignment grating size was 25 μm × 25 μm square.

deviation of the signal at the peak is equal to 20 nm misalignment. The overlay accuracy measurement which was given as the difference of the edge positions on the 1st wafer pattern to the overlaid resist pattern shown in Fig.6 was made by Electron Beam Line width measurement system. The measurement accuracy of E.B.L system was 30 nm.

Figure 7 shows the histogram of the overlay accuracy. We have observed that overlay accuracy of HNA is maintained within 98 nm/3 sigma both on the SiO_2 and Aℓ deposited surfaces by the peak alignment, which is consistent with the fact that the shape of the HNA signal did not depend on the topography of a wafer alignment grating since the HNA detector worked as an ideal interferometer. As a result, the same overlay accuracy was obtained with both SiO_2 and Aℓ deposited wafers.

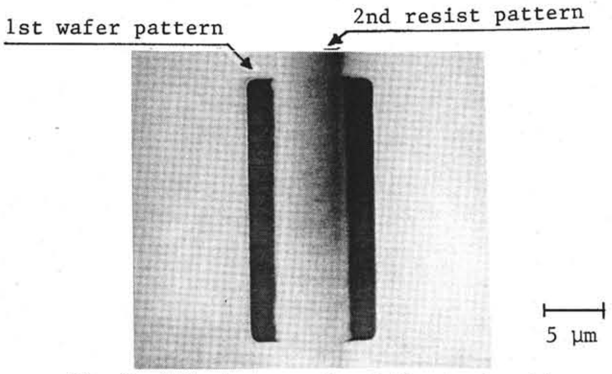

Fig.6 SEM photograph of the test pattern to examine the overlay accuracy

4. Summary

A new interferometric alignment method called holographic nanometer alignment has been applied to a wafer stepper. The sensitivity of the alignment signal was estimated to be 5 nm for various substrates including Aℓ-deposited wafers. Overlay accuracy better than 0.1 μm/3 sigma was achieved on etched SiO_2 and Aℓ deposited surfaces.

It has been confirmed that holographic nanometer alignment detector performed as an ideal interferometer.

As a result, the holographic nanometer alignment is thought to have a high potentiality enough to achieve registration accuracy better than 0.1 μm/3 sigma.

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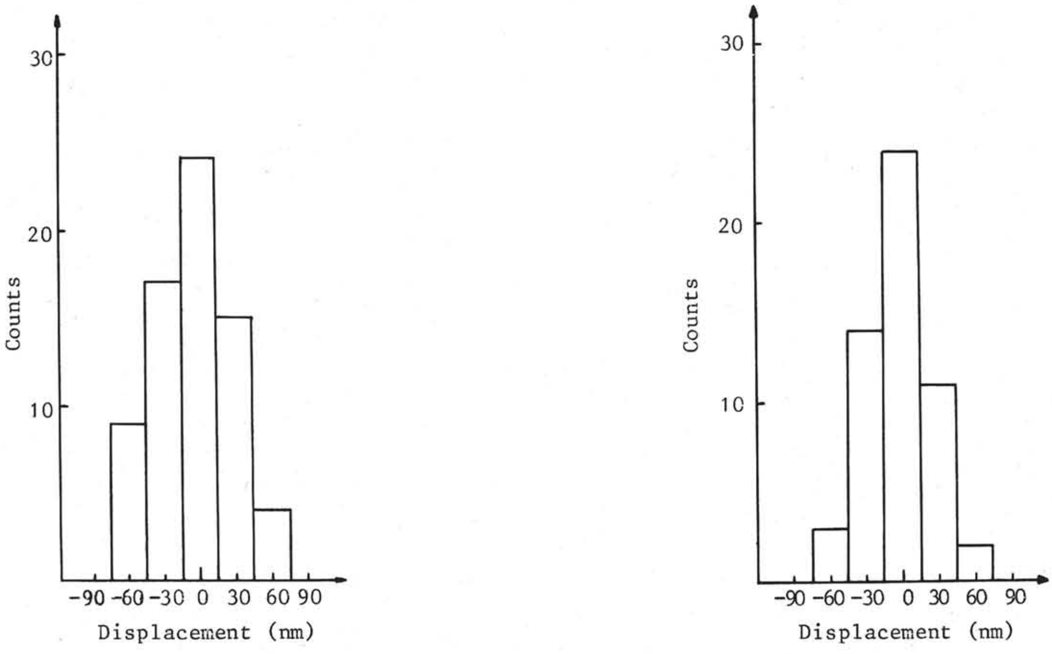

(a)

(b)

Fig.7 Histogram of the overlay accuracy on (a) a SiO_2 wafer and (b) a Aℓ deposited surface