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A MICROCOMPUTER CONTROLLED ALIGNMENT SYSTEM USING MOIRÉ SENSORS

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ABSTRACT

This paper deals with an automatic and precision alignment technique for proximity printing in x-ray lithography, using two pairs of moiré gratings, with moiré signals from each pair being 180° out of phase with each other. We constructed an automatic and precision alignment experimental system which could measure both transmitted moiré signals and reflected moiré signals at the same time. The automatic alignment was achieved using transmitted moiré signals and also reflected moiré signals as a control signal for a stage driver. The alignment position of the system was monitored not only by a control signal but also by a non-control signal. The effect of transmitted and reflected moiré signals upon alignment accuracy was discussed. We concluded that the technique using diffracted moiré signals is a viable automatic and precision alignment technique.

1. INTRODUCTION

The demand for high resolution in the lithographic process is increasing so as to reduce the minimum feature size of microcircuits for VLSIs. X-ray lithography is a promising method for the fabrication of VLSI circuits with a lower submicron minimum feature size. It requires highly accurate alignment between the mask and wafer, as well as precise proximity control between the two. The required alignment accuracy is about 1/10 of the minimum pattern line width. Several methods have been proposed to attain this alignment accuracy, such as the diffracted moiré method, optical heterodyne method, Fresnel lens method, and so on.

We have proposed an automatic and precision alignment technique using diffracted moiré signals[1]. We used two pairs of moiré gratings with moiré signals from each pair being 180° out of phase with each other. This technique is relatively simple, but is still capable of an alignment accuracy in the order of a nanometer. It was shown with numerical calculation that the characteristics of moiré signals from reflection gratings were as useful to alignment as those from transmission gratings[2]. In a transmission type moiré system, we obtained precision better than 120 nm by using a grating pitch of 200 μm[1]. In a reflection type moiré system, control reproducibilities better than 32 nm and 40 nm were obtained by using a grating pitch of 200 μm and 16 μm respectively under different experimental conditions[3,4]. We have constructed an experimental system which detects both transmitted and reflected moiré signals under the same experimental conditions[5].

In this paper, we will discuss the effect of transmitted and reflected moiré signals upon alignment accuracy.

2.ALIGNMENT METHOD

Two parallel gratings set to the proper gap are illuminated by a laser beam. The zeroth order diffracted moiré light varies periodically with relative displacement of the gratings. The periodicity corresponds to the pitch of the gratings. Alignment is achieved by using two pairs of gratings, with their spatial phase relationship as shown in Figure 1(a). If gratings C and D are moved laterally relative to gratings A and B, then we get two moiré signals which are 180° out of phase with each other, as shown in Figure 1(b). The magnitudes of these two signals are equal at position P_O, at which point the difference between these two signals will be zero. This position is defined as the position of alignment. In the vicinity of position P_O, both signals are approximately linear and steeply angled. Automatic alignment is achieved using the difference between these two signals as a control signal. Therefore, very high alignment sensitivity is obtained.

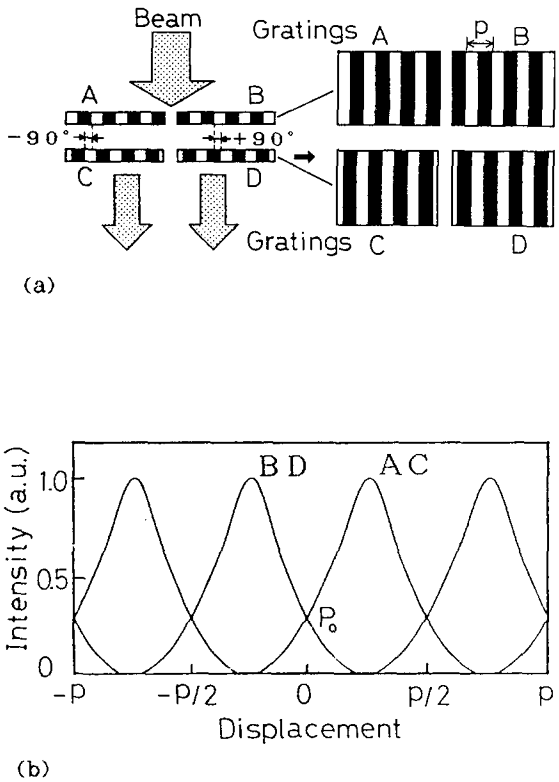

Figure 1 Principle of the moiré alignment method.
(a) Spatially phase shifted gratings.
(b) 180° out of phase moiré signals in zeroth order beam.

3.EXPERIMENTAL

The schematic diagram of the experimental apparatus is shown in Figure 2. A laser beam is divided into two parallel beams by a half mirror

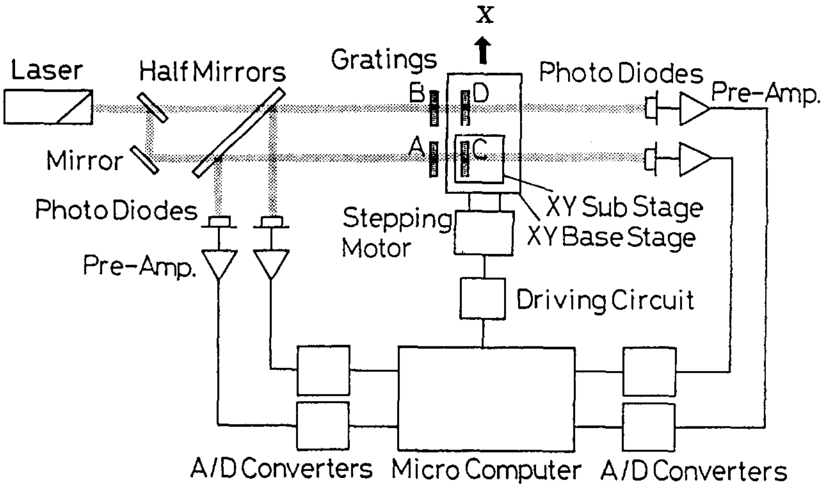

Figure 2 Schematic diagram of the experimental system.

and a mirror. The two beams are diffracted by the two grating pairs AC and BD. A XY substage is used for making the spatial phase shift between C and D. A XY basestage is moved in the direction of X with the help of a stepping motor. The zeroth order diffracted transmitted and reflected moiré lights are respectively received by two photodiodes. The signals are amplified by each preamplifier. The signals are converted into digital signals by each A/D converter, and the digital signals are fed into a microcomputer. The difference between the two signals is then calculated. The calculated difference value is compared with predetermined upper and lower reference values. The stage is moved step by step until the difference value falls within the reference values.

The experiments were carried out under the following conditions. A 0.633 μ m He-Ne laser was used for the alignment light. Grating pitches were 25 μ m. The minimum displacement corresponding to one step of the stepping motor was 7.8 nm. The resolution of the A/D converters was 12 bits. The response time of the system was 0.3 s.

The experiments for the automatic alignment were carried out under the following process. After the automatic alignment from arbitrary position was carried out, the position of the stage was shifted according to the pulse number chosen by the microcomputer. The initial position of the stage was intentionally varied every 50 steps, for example at +50, -50, +100, -100, +150 and -150. The stage was aligned from its initial positions by turns.

4.RESULTS AND DISCUSSION

The transmitted moiré signals obtained by moving the basestage in the direction of X are shown in Figure 3(a). Two good contrasts were obtained from the moiré signals. The difference between the two signals are shown in Figure 3(b). A smooth s-control curve was obtained.

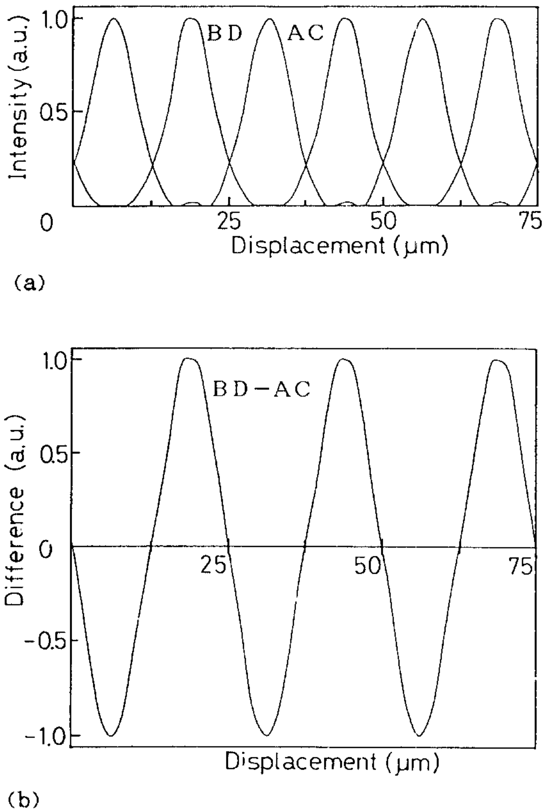

Figure 3 Typical transmitted moiré signals for free running of the stepping motor.
(a) 180° out of phase moiré signals.
(b) The corresponding different signal.

Figure 4 shows an example of data compiled from experiments for automatic alignment using transmitted moiré signals. Curve (a) shows the controlled signal. Curve (b) shows the monitored signal obtained from reflected moiré signals monitored at the same time. Figure 5 shows an example of data compiled from experiments for automatic alignment using reflected moiré signals. Curve (c) shows the controlled signal. Curve (d) shows the monitored signal obtained from transmitted moiré signals monitored at the same time. The position of the stage corresponding to the difference between the moiré signals is plotted along a vertical axis. The two broken lines show the upper and lower reference values. The automatic alignment was achieved using transmitted moiré signals and also reflected moiré signals as a control

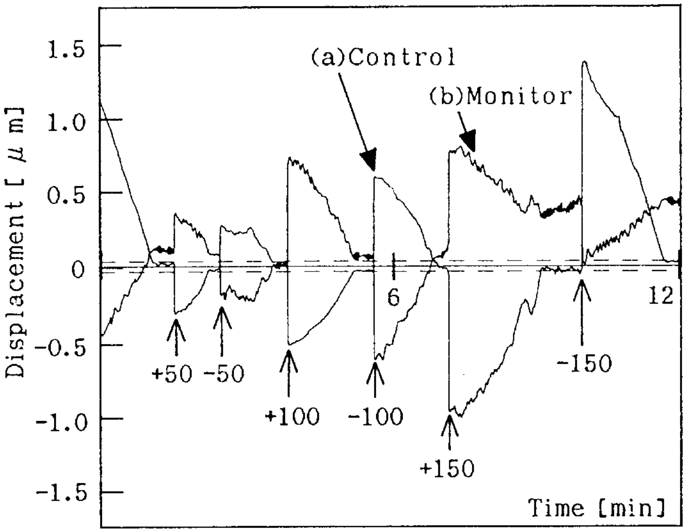

Figure 4 Example of automatic alignment using transmitted moiré signals. (a) alignment controlled signal and (b) corresponding alignment monitored signal.

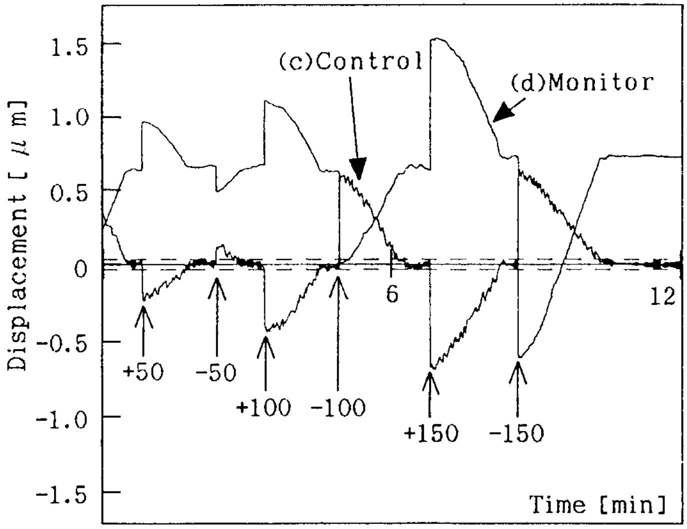

Figure 5 Example of automatic alignment using reflected moiré signals. (c) alignment controlled signal and (d) corresponding alignment monitored signal.

signal for the stage driver. In both experiments, the alignment was achieved within ± 34 nm of the dead zone corresponding to the reference values. The stage was automatically aligned in various positions. The alignment precision of the present system depends on the reference values.

The intensity of reflected moiré signals was poor compared to that of the transmitted moiré signals. The signal-to-noise (S/N) ratio in the reflected moiré signals was inferior to that of the transmitted moiré signals. Therefore, the precision of the alignment system using the transmitted moiré signals was better than that of the alignment system using the reflected moiré signals.

The alignment precision of the present system indicated by the dead zone corresponding to the reference values resulted from the noise in the moiré signals, the pitch of the gratings, the displacement per step of the stepping motor, the resolution of the A/D converters and the response time of the feedback loop.

5.CONCLUSIONS

(1) Automatic alignment was achieved using transmitted moiré signals and also reflected moiré signals as a control signal for the stage driver.

(2) Control reproducibility better than ± 32 nm was obtained under the same experimental conditions for both, in transmission and in reflection.

(3) The S/N ratio in transmitted moiré signals was superior to that of reflected moiré signals.

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