Z-correction, a method for achieving ultra-high absolute pattern placement accuracy of large area photomasks

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Abstract

Photomasks are used in the production of LCD, OLED and other kinds of displays. For TV displays these photomasks, made of quartz glass with a Cr pattern, may have sizes up to 1.62 x 1.78 m^2 and a thickness up to 16 mm. The absolute placement accuracy, i.e. X,Y position of a pixel or line in the mask pattern needs to be better than 150 nm (3σ). The demand for higher resolution displays has led to tighter flatness requirements of the photomask, to secure that the chrome pattern is always in best focus. In contrast to small area semiconductor masks with dimensions up to 300 x 300 mm^2 and three point supports, the large area photomasks have to rest on a large stage in the mask writer. It is then unavoidable that distortions will be induced due to the fact that the glass backside or stage surface is not perfectly flat. If not corrected for, these distortions in Z direction can easily generate geometrical errors in the X,Y plane corresponding to pattern displacements of several hundred nanometers. To avoid these X,Y errors we have developed a technique called Z-correction. It is a function developed for correcting the mask pattern placement prior to the writing process in the pattern generator or in a verification measurement in the MMS15000 metrology tool [1]. This is the first time this method is used for improving the accuracy of photo masks. It is based on height measurements of the quartz glass when it is resting on the stage during the temperature stabilizing time. Without using Z-correction it is very challenging to achieve an absolute uncertainty better than ~200 nm (3σ) over an area of 0.8 x 0.8 m^2. With Z-correction it is possible to enhance this number to < 100 nm (3σ). In the MMS15000 metrology tool the performance is even better, ~50 nm (3σ) over a 0.8 x 0.8 m^2 stage area when using Z-correction in the self-calibration process. [2] [3].

1 Introduction

The purpose of Z-correction is to compensate for deformations of the quartz glass due to gravity when it is resting on the stage. To describe the principle we assume that a matrix of measurements marks (crosses) is written on a perfectly flat top-surface of a quartz plate and represents a perfect grid with constant pitch in X and Y. We also assume that the bottom-surface of the glass and the stage is perfectly flat. Then the plate is placed on the MMS15000 stage on top of a small particle residing on the stage surface. The effect will be as illustrated in Fig. 1 and the coordinates of the marks will not describe a perfect grid in the YX-plane any more. The reason is that the quartz glass does not act as a stiff body but will be deformed by the particle. By measuring the height of the top-surface relative to a reference plane, e.g. the topsurface plane of the plate, the height deviation of the plate can be transformed to the deviations of the measurement marks in the XY-plane.

2 Model

A very simple mechanical model is used for the estimation of these deviations in the XY-plane as a function of the measured heights. The principle is shown in one dimension in figure 1 and assumes the centreline of the plate to be unaffected.

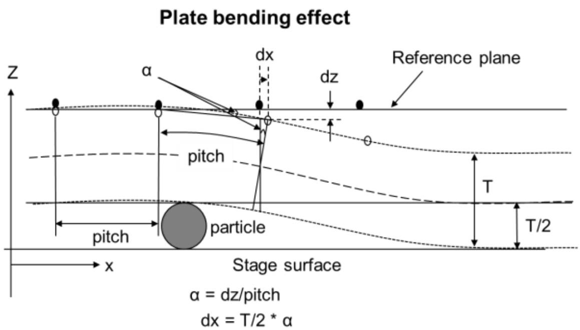

Figure 1: The top-surface will stretch so the marks on the plate (open circles) will be displaced from the original locations in the reference plane (black dots) due to the bending caused by the particle. The deviation is strongly exaggerated in the figure. In practice *T* is approximately 10-16 mm and *dz* is in the range 10-20 µm.

In a reference plane close to the topsurface the deviations of the measurement marks *dx* can be calculated when the height of the particle-shifted measurement mark is known. In practice the model is used in two dimensions so deviations throughout the full XY-plane then can be estimated. The deviation of the measurement mark location depends on the Young's modulus of the glass [4], but since we measure the effect of the induced distortion as a height variation of the glass it is not required as a parameter for the calculation of the deviations in the XY-plane.

3 Discussion

It makes no difference if a particle, a nonflat bottom surface of the plate, or a combination of them causes the height distortion. The same model can be applied and after having the height data measured it is a trivial task to generate a two dimensional correction map for real time corrections during writing or in a verification measurement. But, what happens when also the topsurface of the glass is non-flat? To answer this question we need to consider how the photomask is fixed in the mask aligner later on in the lithography process [5]. In the aligner the mask is supported along the edges as shown in figure 2.

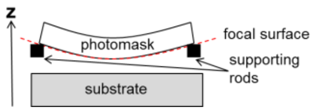

Figure 2: The principle of the support of the photomask in the aligner.

In the exposure stage the mask pattern resides on the bottom surface of the photomask. Due to gravity the plate will bend significantly and deform the pattern, this can be compensated for. However, it is not easy to compensate for the defocus due to local variations in the Z-direction of the mask image along the focal surface. For this reason this patterned surface of the mask has a much tighter tolerance regarding flatness than the other surface of the plate. So even if we cannot separate flatness variations of the two surfaces in our height measurements, Z-correction will still make a good job. Thanks to measurements by the quartz glass supplier data about the surfaces can be applied today. By using this information it is possible to use the real front surface as a reference instead of the compromise of using a flat reference plane.

4 Results

To show the effect of Z-correction in practice we have chosen an example (figure 3) of an overlay measurement of four rotations of a quartz plate in the MMS15000.

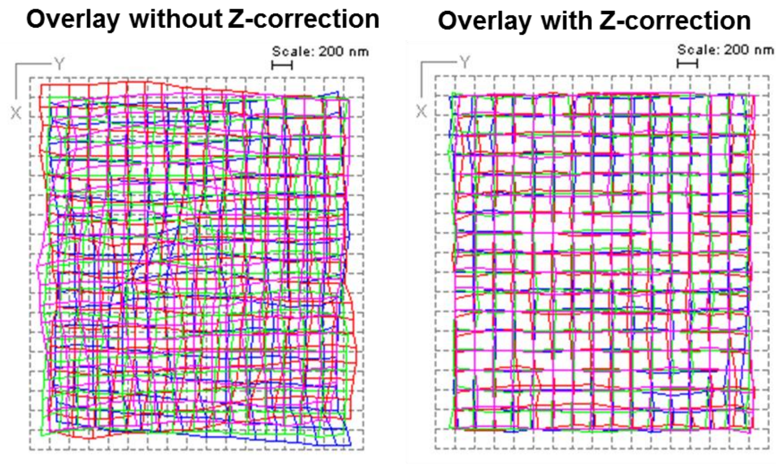

Figure 3: Measured deviation without/with z-correction at 0^o,90^o,180^o,270^o and 0^o of a 0.8 x 0.8 m^2 quartz plate filled with a symmetric matrix of measurement marks.

Without using Z-correction the overlay (3σ) of the four measurements is in the range of 175-270 nm. When using Z-correction the overlay is in the range 57-83 nm.

References

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