Z-correction, a new method to improve TFT mask set overlay for TFT production yield enhancement

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Abstract

Z-correction is new method to be used when measuring pattern registration of photomasks. The method is based on measurement of the plate profile in the Z-axis and takes into account the impact on the registration deviations caused by plate support, contamination as well as the photomask flatness itself. Z-correction further facilitates a more neutral way of judging the overlay properties between individual photomasks within a mask set.

1. Introduction

With increasing photomask sizes and tighter design rules in TFT-LCD manufacturing today, the requirements on absolute registration as well as overlay increase. One of the yield and quality-limiting factors is the overlay performance between the individual photomasks within a mask set.

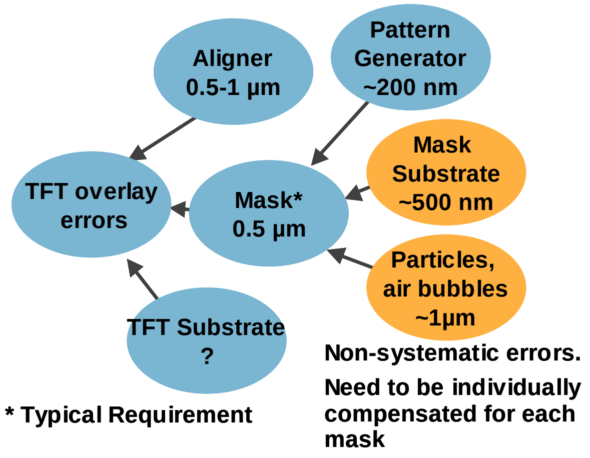


Figure 1 TFT overlay error sources.

A major contribution to overlay deviations comes from the errors in the flatness of the substrate itself as well as plate support effects and contamination effects when the photomasks are written and measured. These errors can be in the range of 0.5 to 1 µm compared with typical photomask registration specifications of 500 nm (see Figure 1).

For a high-quality photomask the flatness is in the range of 10-30 µm (see Figure 2). Flatness variations of this magnitude corresponds to an overlay deviation of about 500 nm for quartz masks of 10 mm thickness Contamination trapped between the stage and the photomask during exposure and measurement introduce additional overlay deviations.

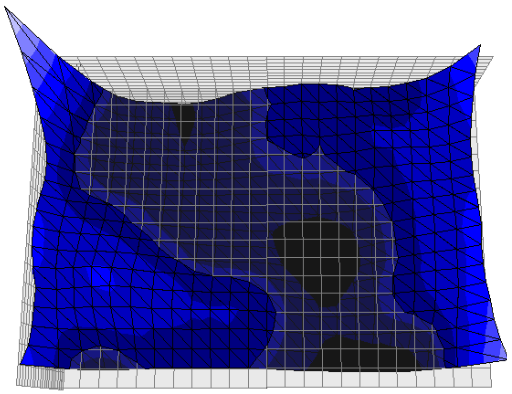


Figure 2 Thickness variations on a 900 x 1200 mm photomask, range 30 µm

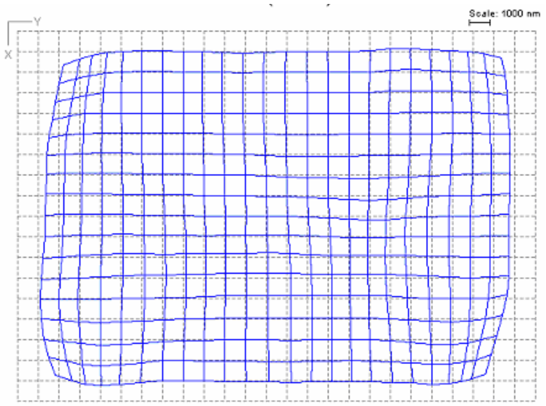
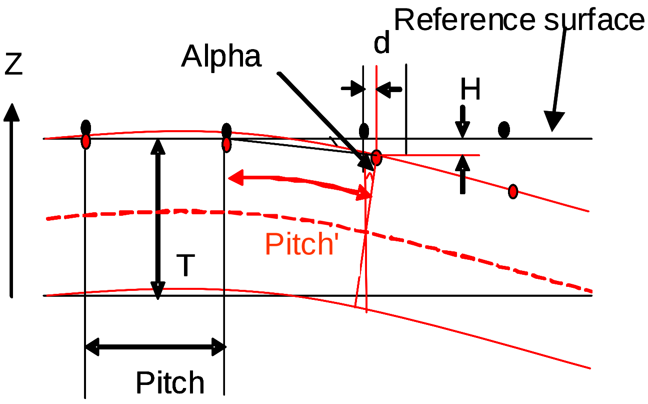


Figure 3 The distortions in the XY plane caused by the thickness variations of the substrate in Figure 2: 367 nm (3σ) in X and 522 nm (3σ) in Y.

Even though the registration capability for both pattern generators and measurement systems currently are in the range of 100-200 nm (3σ) the problem with overlay still exists when using the different photomasks in a mask set in mask aligners during TFT production. The fact that the plate is not clamped in the same manner in the aligner as it is during writing and measurement is the main factor here.

2. Registration Errors Caused by Mask Deformation on a Flat Stage

Consider the case of a photomask with a non-flat backside placed on the flat stage surface of a pattern generator or measurement tool. The photomask will be deformed and this will affect the top surface of the mask, causing registration deviations. Since both the pattern generator and the measurement systems typically have flat stages this will not be detected. When the photomask is later used in an aligner these deviations will not be present since the mask is clamped face down in the aligner, i.e. resting on the top surface, at the edges of the photomask. This basically means that two photomasks with perfect overlay values in a conventional measurement system can actually result in major overlay errors when used in the aligner.



Alpha = H/pitch

d = T/2 * Alpha

Figure 4 A simplified model of the registration deviation caused by substrate distortion. The deviation, d, can be calculated using the deviation, H, in the Z-axis.

In order to have better control over the previously discussed registration problems, the Z-correction method has been developed. By measuring the variations in the top surface of the substrate in relation to a known reference surface, the X- and Y-axis registration deviations can be calculated (see Figure 4).

The Z-correction method has no fundamental limitation in the choice of reference surface as long as there is a stable reference plane in the tool where the Z-correction is used. This means that the result can be compared in e.g. a flat (ideal) reference plane, the front surface of the photomask or even in the photomask surface created by the clamping in the aligner, if this is known.

3. Experiment

An 800 x 920 x 8 mm quartz photomask with an array of marks for registration measurements was measured in a Micronic MMS15000 registration measurement system. The photomask was measured in 4 rotations: 0, 90, 180 and 270 degrees. Since the same photomask is used one of the largest error sources, errors from varying flatness of the mask itself, will not be present. Only errors from the flatness variations in the system stage and any contamination will be present. The results were analyzed both with and without Z-correction.

4. Results

The registration values are calculated as the deviation from the nominal mark positions. The measurement data from the four orientations were rotated back to 0 degrees and compared.

The measured values for the registration deviation without Z-correction varied between 195 nm and 234 nm (3σ), (see Figure 5). There is one value for the X deviation and one value for the Y deviation for each rotation, a total of 8 values.

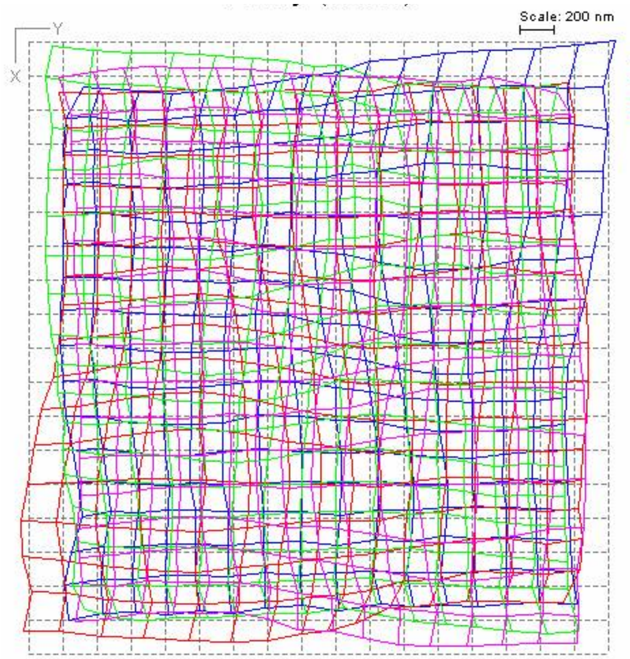


Figure 5 Measurements from the MMS15000 of the same 800 x 920 mm photomask in 0, 90, 180 and 270 degrees without Z-correction. The resulting in a registration is around 200 nm (3σ).

When applying Z-correction the values were reduced to between 70 nm and 116 nm (3σ), clearly showing the improvement achieved using Z-correction (See Figure 6). The improvement of approximately 100 nm is basically from removing the influence of variations in stage flatness, which is typically 2 µm. Since the flatness variations of photomask substrates are 10-20µm, errors such would be 5 to 10 times larger, i.e. 500 to 1000 nm.

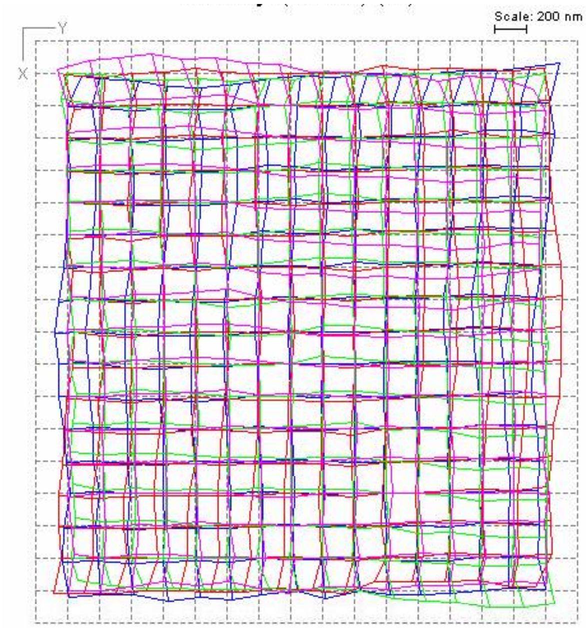


Figure 6 The measurement results of the same photomask as in Figure 5using Z-correction was around 100 nm (3σ).

Another example of the results of Z-correction is the case where a particle is located between a 10 mm thick quartz photomask and the system stage. The photomask was measured once with a particle on the stage. The particle was located and the size was measured to 16µm. A second measurement was made after the particle was removed and the two measurements were compared. Without Z-correction the deviations of over 500 nm are easy to see in Figure 7. The Z-data clearly show the difference in plate surface height. After applying Z-correction the error caused by the particle is removed.

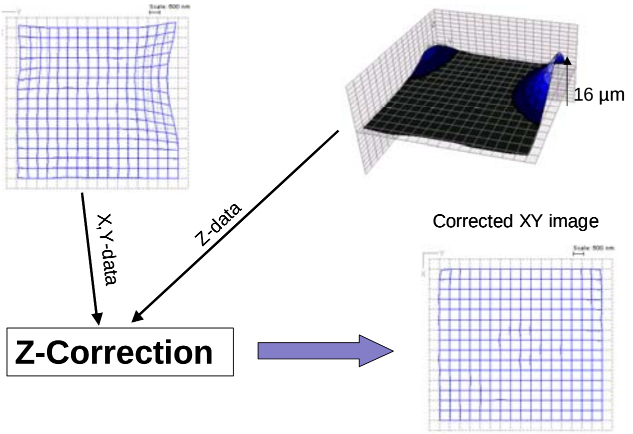


Figure 7 The distorting effect of a 16 µm particle on a 10 mm thick photomask. Using Z-correction the effect can be removed.

5. Discussion

The errors caused by substrate flatness deviations are normally not possible to detect. Assuming that both the pattern generator used to write the photomask and the measurement system have perfectly flat stages, the substrate will be distorted in the same way both during patterning and measurement. However, when the photomask is used it is not placed with the rear surface on a flat stage, so here the errors will be visible. Z-correction removes these errors leading to better overlay between different masks in a mask set.

The current Z-correction method measures the top surface of the photomask, and compensates for deviations and reconstructs an image in a flat reference plane. If the flatness data of both sides of the photomask is known, the front surface can be used as the image surface instead. This may be a better representation of the pattern since in this case only deviations caused by deviations in the rear of the plate is compensated. Both the reference plane and the top surface represent more neutral ways to compare the pattern registration, however the real test of the pattern overlay is when the mask is used in TFT manufacturing. To reach the optimal evaluation of overlay performance, the reference surface should be the shape that the photomask has when it is used in the aligner. This is a function of how the photomask is clamped in the intended aligner type. If this surface is known it is possible to use this as the reference in Z-correction.

6. Further development

The real benefit of Z-correction comes when the method is used also in the pattern generator. Then it will be possible to improve the pattern locations on the photomask, instead of just being able to identify the problem during measurement, when the errors cannot be corrected. Z-correction for pattern generators is currently being developed. Using substrate flatness data in Z-correction in both pattern generator and measurement system will further improve the mask overlay performance. Finally if the surface created by clamping in the aligner is known, and used to correct the pattern when writing, another error source can be greatly reduced.