

Manufacturing Mobile Displays & Systems on Glass (“SOG”s)

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Abstract

Future Mobile displays and the emerging systems on Glass for the upcoming TFT_LCDs or Active-OLEDs based on LTPS, and the exciting c-Si critically require very-high resolution lithography. We report the methodology and latest results on the alignment, magnification control and stitching systems on a HMA500 holographic mask aligner for printing 0.5µm-resolution display patterns onto glass substrates of dimensions up to 500mm x 400mm.

1. Objective and background

The Display Mega Trend is towards 0.5µm resolution patterning. These include such display technologies under development as low-temperature polysilicon LCDs and OLEDs, or c-Si, which require 0.5µm resolution exposure equipment for their manufacture. Lithographic equipment based on total internal reflection (TIR) holography has demonstrated that it can satisfy these new applications: it has, for example, been employed to fabricate 0.5µm-gate polysilicon TFTs and for printing arrays of 0.6µm-diameter holes for seeding growth of silicon crystals for fabricating single-grain silicon TFTs using the µ-Czochralski process.

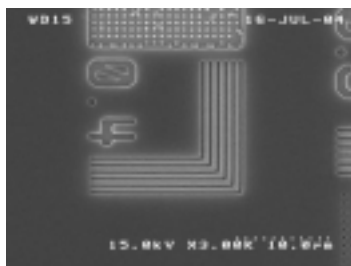


Fig 1. SEM picture of 0.4µm lines and spaces
Photo courtesy of Seiko Epson

2. Results

2.1 Alignment system and magnification correction

The alignment system on the HMA500 (see fig. 2) employs four microscopes for viewing sets of alignment marks located at the edges of the patterns recorded in the hologram mask and on the display substrate. The marks are viewed by each microscope by illuminating them with an LED and imaging the reflected light onto a CCD. The relative positions of the marks in the hologram mask and on the substrate are determined by a Cognex image processing system, following which the alignment errors are corrected by translational and rotational displacements of the substrate produced by horizontal-axis piezo-electric transducers (PZTs) in the substrate positioning system. The PZTs operate in closed-loop with a 3-axis interferometer system that accurately measures and controls the displacements of the substrate.

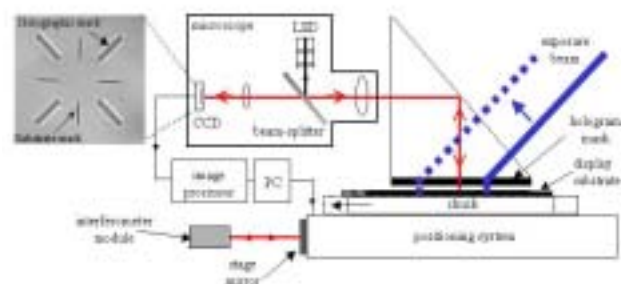


Fig2: Schematic of alignment system and magnification correction

The measurement beams of the interferometer system are configured parallel to and close to the plane of the substrate and are reflected from two mutually

orthogonal mirrors having high surface flatness which are mounted to the substrate positioning system alongside the substrate chuck. Two of the beams are retro-reflected from a mirror parallel to the machine x-axis and the third beam is retro-reflected from a mirror parallel to the y-axis.

The relative positions of the alignment marks determined by the different microscopes allow not only measurement of the alignment errors between the pattern in the hologram mask and that on the substrate but also any magnification errors between the 2 patterns caused by, for example, thermal expansion. Compensation of such errors, whose magnitude may be different in orthogonal directions and which may include a trapezoidal component, is important if accurate overlay is to be achieved over the entire pattern.

The magnification components measured by the four microscopes are corrected during the exposure operation. Again with reference to fig. 1, exposure on the HMA500 system is performed by a laser beam scanning in a raster pattern over the hologram mask mounted beneath a glass prism. Before the scanning sequence begins the substrate is displaced by the horizontal-axis PZTs in the substrate positioning stage such that patterns on the substrate and in the hologram mask are aligned at the corner where the exposure beam starts its scan. Then, while the beam scans back and forth across the hologram mask, the substrate is continuously displaced laterally in the x and y directions by the PZTs, controlled by the interferometer system, so that at all times the part of the pattern being illuminated by the beam remains accurately aligned with the corresponding part of the pattern on the substrate.

2.2 Overlay evaluation

The performance of the alignment system and the pattern magnification capability have been evaluated by aligning and printing an “upper-level” pattern of dimensions 100m x 80mm from a hologram mask onto four “lower-level” patterns etched into metal layers on each of three 300mm x 300mm glass substrates. The resulting overlay accuracy achieved between the various patterns was determined from overlaid sets of Vernier scales. Fig. 3 below shows a histogram of the x and y components of the overlay errors, from which the 3σ values are calculated to be 0.25 and 0.23 μ m respectively.

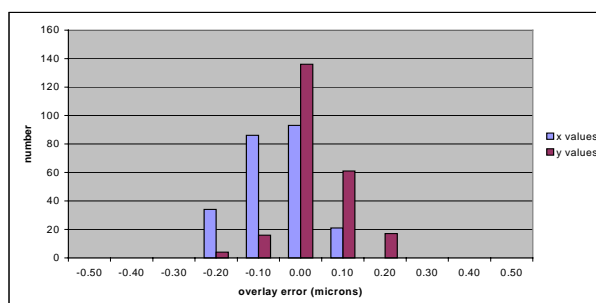


Fig. 3 Histogram of overlay errors

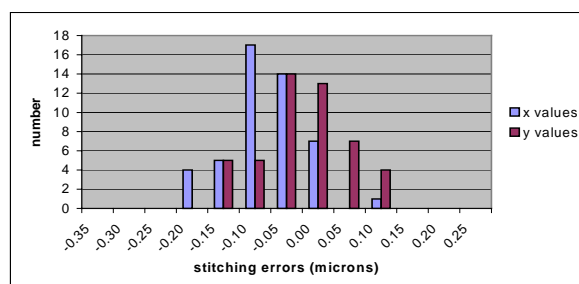
2.3 Field-to-field stitching

High-accuracy stitching between patterns printed using a step-and repeat exposure sequence is obtained by controlled displacements of the substrate using the 3-axis interferometer system.

The magnitudes of the displacements required in the x and y directions depend not just on the dimensions of the pattern to be printed but also on the following parameters: i) the angular offset, ϕ , between the co-ordinate system of the pattern in the hologram mask and the interferometer co-ordinate system, ii) the magnification errors, M_x and M_y , between the two co-ordinate systems, and iii) the orthogonality error, ω , between the x and y mirrors of the interferometer system. The HMA500 automatically determines these values by using the alignment microscopes to successively align a reference alignment mark on the substrate chuck with alignment marks in the hologram mask, the values then being calculated from the displacements of the reference alignment mark, as measured by the interferometer system, between each of the alignments. The displacements of the substrate, S_x and S_y , required with respect to the x and y axes of the interferometer system for accurately stitching a pattern of dimensions $D_x \times D_y$ (according to the co-ordinate system of the hologram mask) are given by:

$$S_x = M_x D_x \cos\phi + M_y D_y \sin(\phi + \omega)$$

$$S_y = M_y D_y \cos\phi - M_x D_x \sin\phi$$



The 2 interferometer beams parallel to the y axis measure the rotation of the substrate so that angular errors can be corrected during the displacement.

2.4 Stitching evaluation

The stitching accuracy of the HMA500 has been evaluated by stitching together 2 x 2 matrices of elemental patterns of dimensions 100mm x 100mm, thus producing a composite pattern of dimensions 200mm x 200mm, and reading the stitching errors from overlapping Vernier scales at the boundaries between the elemental patterns. A histogram of the resulting stitching errors for patterns printed on a series of 4 plates is shown in fig. 5 below.

| Plates | 1703OT 6 | 1703OT8 | 1703OT9 |
|----------------|--------------------|--------------------|--------------------|
| 3 x sigma in X | 0,16 μm | 0,12 μm | 0,14 μm |
| 3 x sigma in Y | 0,15 μm | 0,17 μm | 0,15 μm |

Statistical analysis of these values yields 3σ values for the x and y components of 0.18 and 0.21 μm respectively.

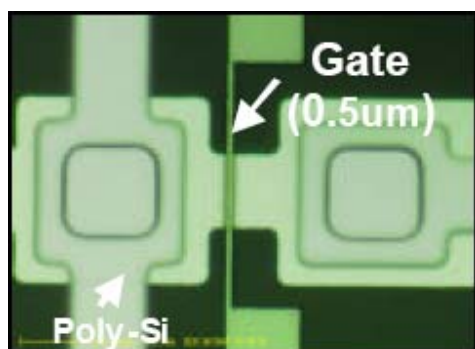


Fig.4. 0.5 μm gate length [10]

3. Impact

The overlay and stitching data presented in this paper demonstrate the capability of this new exposure equipment for satisfying the sub-micron lithographic requirements for new and future generations of displays and the emerging systems on-glass. The industrial success of the technology will enable the commercialisation of the next generation of commercially hot items such as, say, OLED based TVs. In view of the relative simplicity of the equipment and the modularity of its sub-systems, the technology is well adapted for scaling up to larger substrate sizes, such as the Gen 3, Gen 4 and Gen 5 for the said applications. The system will then be able to fill the Fabs being vacated now in the move towards Gen 7 & 8, substrate sizes. As the *only* commercially available 0.5 μm high resolution exposure equipment, with relative simplicity for upgrades, both with respect to substrate size and performance, the HMA exposure systems will have

considerable impact on the display industry. Indeed a clear existing path is being taken today, which will be rendering the next systems such as Gen 4 towards mass production. In the meanwhile a major corporation¹⁰ has laid the grounds of the development of its future technology on the present system.

4. Acknowledgements

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