New Applications of Optical Proximity Correction (OPC) Technology in the Display Industry †

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Abstract

This article introduces two new application cases of Optical Proximity Correction (OPC) technology in display backboards. The first method is to use OPC technology on the mask template layout to solve the Mura defect problem caused by diffraction induced exposure increase during the splicing process of the Over Coat (OC) layer mask template. After simulating the exposure energy curve of the spliced Aerial image and correcting the graph using Aerial image simulation and OPC technology, the Mura defect problem was successfully solved.Another approach is to replace halftone technology with OPC technology, which enables the synthesis of Pixel Define Layer (PDL) and Photo Spacer (PS) into a single mask. The same layer of Resin adhesive is used to achieve a two-layer film structure, saving production costs.

Author Keywords

Photolithography, Proximity Effect Correction (OPC), Splicing Mura defect, Half tone technologyOrganic photodetector

1. Objective and Background

With the development of the display industry, the increasingly complex graphics in each layer of the backplane are driving the development of lithography technology towards refinement.Among them, the resolution enhanced lithography techniques for semiconductors mainly include axis shift illumination (OAI), double exposure (DE), phase shift mask (PSM), optical proximity correction (OPC), etc.OAI technology requires various equipment modifications and is not suitable for FPD applications. DE technology has more stringent requirements for overlay accuracy and reduces production efficiency by half, making it unsuitable for FPD mass production. PSM and OPC technologies have more possibilities for application in FPD. This article mainly introduces OPC technology [1-3].

In the areas where the shapes are adjacent to each other, due to the significant interference and diffraction effects of light waves, the deviation of the shapes will be relatively large. For example, the deviation is more obvious at the top of the line segment and the corner of the shape.And these graphic parts often play a critical role in the electrical performance and circuit function of the circuit, thereby affecting the circuit characteristics of the entire circuit and even leading to circuit failure.The phenomenon of deviation between the lithography pattern and the mask pattern due to light wave diffraction and interference is called optical proximity effect (OPE).In the photolithography process, optical proximity effect is inevitable, so corresponding measures must be taken to correct the deformation and deviation of the mask pattern to the substrate pattern as much as possible to ensure the yield of the display backplane.

This article introduces OPC technology to solve the Over Coat (OC) splicing Mura defect problem and replace halftone technology with other technologies. Firstly, OPC technology is used to solve the Mura defect problem of OC layer Mask splicing. Based on the Aerial image simulation of the spliced exposure energy curve, Dummy graphics are designed at the edge of the Mask, and OPC graphics are used to adjust the energy balance of the overlapping exposure area, thereby solving the Mura defect problem.Another approach is to use OPC technology instead of half tone technology. In the mask layout, the half diffraction area is designed as PDL pattern, and the unexposed area is designed as PS pattern, thus achieving the sharing of PDL and PS on the same mask and saving production costs.

2. Experiments and Results

The process is as follows. The back panel of the splicing problem is made by splicing two Masks to directly prepare a negative adhesive OC film on the glass. OPC replaces the half tone structure with a layer of Resin adhesive, and a conventional BP Mask lithography is used to fabricate a two-layer structure of PDL and PS.

2.1 Principle of Aerial image

In optical modeling, the lithography system is divided into several optical components: light source, converging lens, mask plate, and projection lens. These parts make up the illumination system.

Simple modeling approximates the light source as a spatially coherent point light source. The actual light source is a spatially partially coherent light source with limited dimensions. The correction model for the size of the light source will be supplemented in the later part of the report.

Convergent and projection lenses are considered basic lens elements in modeling. The distance between the point light source and the converging lens is far enough, so the light reaching the mask can be considered as plane light. Diffraction occurs at the mask, and the diffracted light is collected by the projection lens, forming an aerial image on the substrate surface. Aerial imaging refers to the energy distribution of light field illumination intensity. [4]

2.2 Application of Mura defect problem in splicing

OC photoresist belongs to negative photoresist, and the characteristics of negative photoresist are shown in Figure 1.

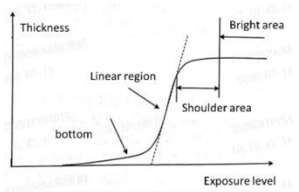
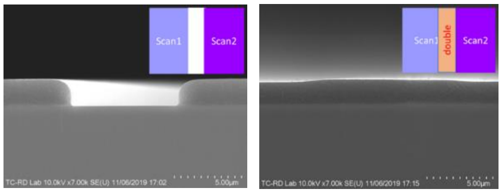


Figure 1. Characteristic curve diagram of OC negative adhesive

OC has energy differences in the Mask splicing part, resulting in differences in adhesive thickness and causing Mura defect. Structure of which is shown in Figure 2. However, the contract curve of the negative gel shows the principle that the film thickness of the negative gel will not change again when the dose is large enough, so theoretically, the larger the energy, the smaller the Mura defect.

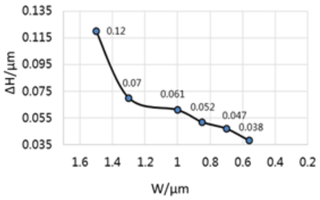


(a) (b)

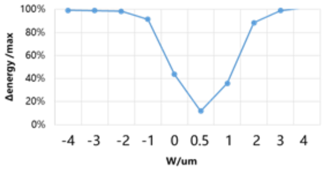
Figure 2. Sectional structural diagram (a) Two separate scans with clear exposure boundaries; (b) The overlapping exposure of two scans is obvious, with a protrusion and a break of 0.3um in the overlapping area

Due to the different characteristics of each negative gel, the corresponding contrast curve is different, and simply increasing the dose will increase the process time. Using OPC graphics to adjust the energy balance of overlapping exposure areas can reduce the height difference of overlapping areas and improve the splicing Mura defect.

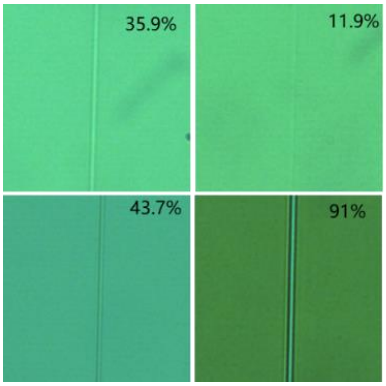
Based on the simulation design of the template splicing layout, the influence of splicing width, small square duty cycle, number of strips, and area on the splicing space phase is simulated. The splicing pattern is designed to reduce or remove the Mura defect at the splicing point.



(a)- Experimental results



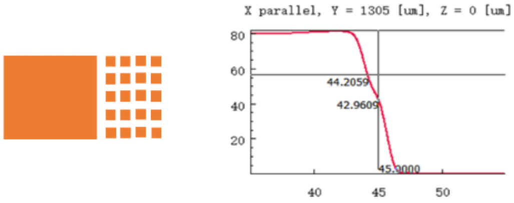
(b) - Simulation and emulation



(c)

Figure 3. (a) The difference in photoresist thickness after the measured width change, (b) the difference in energy fluctuations between simulated and simulated width changes, and (c) microscopic photography of Mura defect images under different energy fluctuations.

According to diffraction theory, the size of the overlap distance at the joint will affect the distribution of energy produced by the joint, thereby affecting the thickness of the negative adhesive at the overlap. Therefore, adjusting the joint distance can adjust the Mura defect distribution. The spatial phase energy at the joint increases with the increase of joint width, and the maximum energy fluctuation at the joint first decreases and then increases with the increase of joint width. There exists an optimal joint width that minimizes the energy fluctuation at the joint. When the splicing width is about 0.5 microns, the maximum light intensity is 82.41, the minimum light intensity is 80.02, and the minimum fluctuation is 2.39%. The strip-shaped Mura defect is invisible to the naked eye. The size of the splicing distance is determined by the accuracy of the equipment itself, so splicing must also consider whether the equipment accuracy can meet the requirements. The experimental and simulation results of the splicing width are shown in Figure 3.

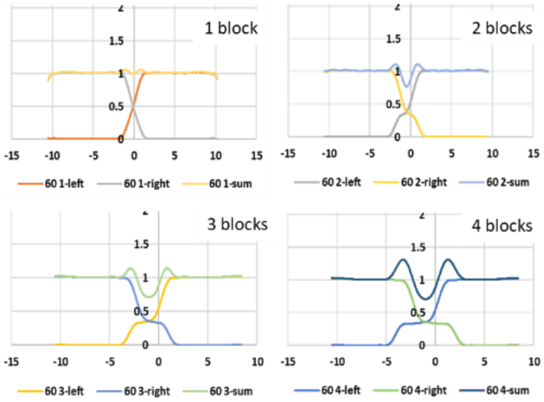


(a)- Layout diagram（blocks） (b)-Aerial image

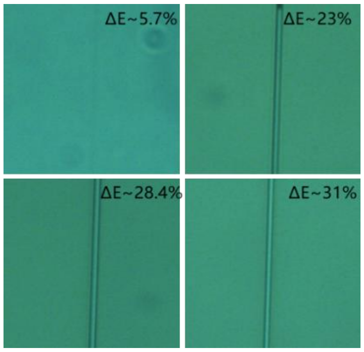
Figure 4. (a) Layout diagram, (b)-The aerial image,

Based on the spatial image of the contact pattern, add a contact pattern at the junction of the mask template, adjust the energy distribution at the junction, and thus adjust the distribution of Mura defects. The size of the contact graphic design affects the aerial image of the contact, and the manufacturing accuracy of the mask determines whether the Mura can meet expectations while also considering device accuracy. The size of the contact graphic design affects the Aerial image of the contact, and the manufacturing accuracy of the mask determines whether the Mura defect can meet expectations while also considering equipment accuracy. Add small square graphic design at the edge of the mask template, as shown in Figure 4.

The influence law of the number of small squares: Adjusting to the optimal splicing width, the fewer the number of small squares, the smaller the spatial phase energy fluctuation at the splicing point, and the margin of the splicing width decreases accordingly. The experimental results and spatial image simulation results of different numbers are shown in Figure 5.



(a) Aerial image



(b)

Figure 5. (a) Simulation results of spatial images with different numbers; (b) Experimental results with different numbers of samples.

In short, according to the negative contrast curve of the adhesive, once the exposure energy reaches a certain threshold, the adhesive thickness no longer changes. Therefore, finding a high energy threshold can eliminate the discontinuity caused by different energies. In the simulation space, when the splicing width is ⩾ 0.5um, the fluctuation of light intensity increases with the increase of negative adhesive splicing width; Splicing width=0.5um, with minimal energy fluctuation, and simulation results consistent with experimental results. Based on the simulation results of the influence of splicing width, small square duty cycle, number of strips, and area on the splicing Aerial image, design a splicing mask to reduce or remove the Mura defect at the splicing point. Figure 6 shows the improvement results of Mura defects.

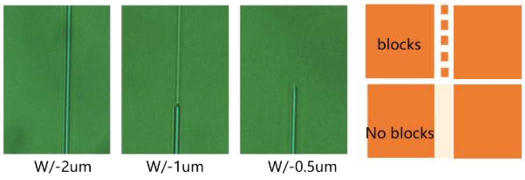
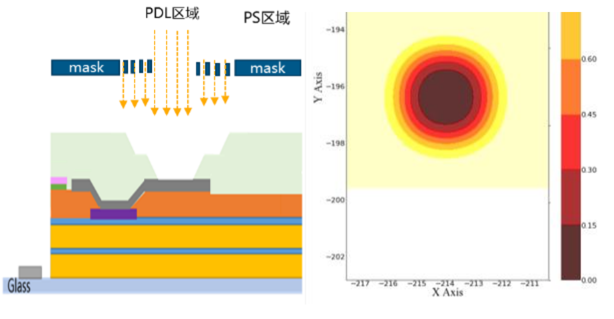


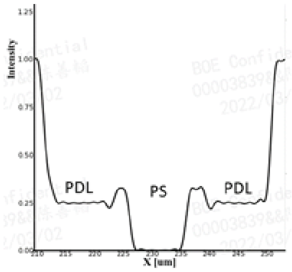
Figure 6. Current-voltage characteristics. (a) Comparison histogram of light state current of normal and thinned ETL devices; (b) EQE of devices.

2.3 OPC technology replaces halftone technology

Application case of OPC technology replacing half tone technology, OPC applied to PDL and PS layers. Firstly, a layer of Resin adhesive is applied, and after the same Mask exposure and development, a stepped PDL and PS two-layer structure is achieved.



(a)- Principle diagram (b) - Diffraction simulation diagram

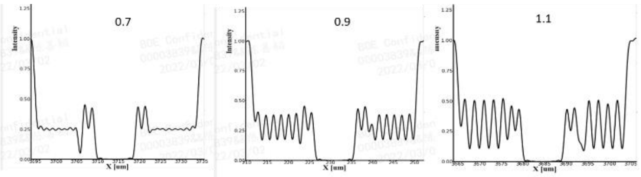


(c)- Aerial image

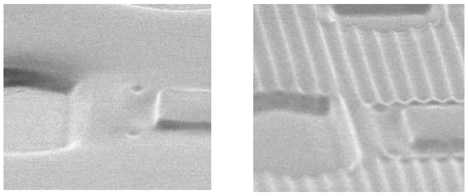
Figure 7. (a) Principle diagram, (b) Diffraction simulation diagram, (c) Aerial image.

Add uniform lines/spaces to the PDL graphic area in the mask layout to achieve a uniform dimming effect, thereby achieving a halftone equivalent function with a stepped distribution of energy.

Divide the entire area into full exposure area area, PDL semi diffraction area, and PS non exposed area. The full exposure area is the display pixel area; the design of Line and Space in the semi diffraction region has a certain transmittance, forming a PDL semi mask area; the completely opaque graphic is the PS area. According to the simulation results of the spatial phase, the changes in energy distribution can be clearly seen. Add several circles of LINE and Space design around PDL pixels and PS graphics, and correct the slope of PDL and PS structures. The structural diagram is shown in Figure 7.



(a)- Aerial images



(a)- 0.9*0.9 (b) - 1.1*1.1

Figure 8. Different sizes of Line/Space design. (a) Aerial images designed with different sizes of Line/Space; (b) Microscope images designed with different sizes of Line/Space.

According to spatial phase simulation, there is a diffraction zone in the pattern boundary region. The diffraction zone cannot be a large line size, as the pattern will be distinguished after exposure. In order to achieve energy balance, it is necessary to be indistinguishable. Figure 8 shows the aerial image simulation results and microscope images of Line/Space designs with different sizes. Different device platforms have a certain impact on the spatial phase results, mainly caused by differences in device parameters (resolution, NA, projection magnification), so the diffraction zone Line and Space size are determined by the device resolution.

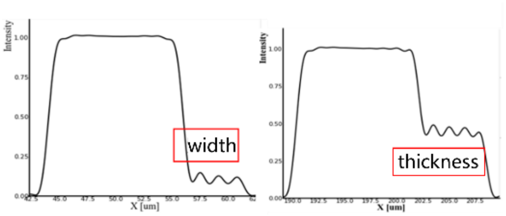
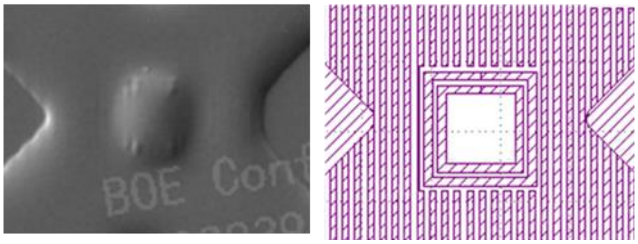
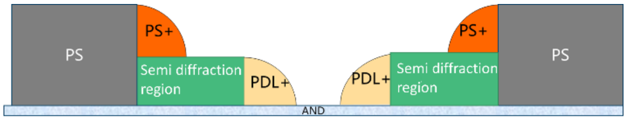


Figure 9. Aerial images

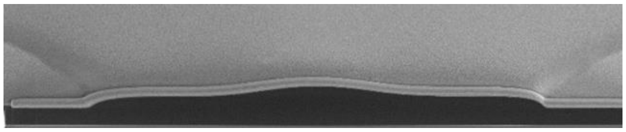
The overall width of Line and Space in the layout will affect the half diffraction area width of the spatial image. The width of the line is the determining factor affecting the thickness of the photoresist and the intensity of the half diffraction zone. The spatial image diagram is shown in Figure 9.



(a) Microscopic image (b) - Layout diagram



(c) Schematic diagram of cross-sectional structure



(d) Sectional structure diagram

Figure 10. (a) Microscope image of experimental sample, (b) Layout diagram, (c) Schematic diagram of cross-sectional structure, (d) Microscopic image of the cross-section of the sample.

By adjusting the distribution of energy space field strength, OPD technology can replace halftone technology. Thus, sharing a single mask between PDL and PS layers can reduce production costs and expand the application of adjusting photoresist angles. The microscopic image of the experimental sample is shown in Figure 10.

3. Conclusion

OPC technology has many mature applications in the semiconductor industry, with relatively few applications in display backplanes, mainly for correcting complex graphics. This article uses photolithography simulation as the method and OPC technology as the technical means to deeply explore the application of OPC in display backplane structure. It focuses on introducing two new application cases of OPC technology in display backplane. One of them is to use OPC technology to solve the Mura defect problem caused by diffraction induced exposure increase in OC layer mask splicing. Based on the Aerial image simulation of the spliced exposure energy curve and the correction of the pattern using Aerial image simulation and OPC technology, the Mura defect problem was successfully solved. Another approach is to replace halftone technology with OPC technology, which enables the synthesis of PDL and PS into a single mask. The same layer of Resin adhesive is used to achieve a two-layer film structure, saving production costs. Integrating OPC technology and display technology closely, fully utilizing photolithography technology to optimize production and improve production efficiency.

4. References

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