# Improvement of Lithography Process Capability under Limit Pitch Design in TFT-LCD Devices

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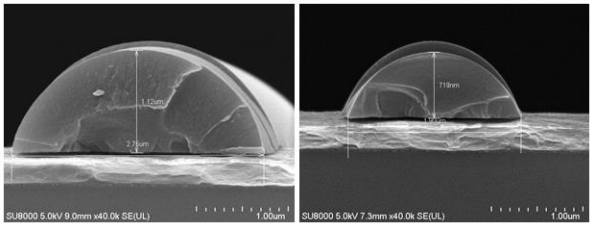
**ABSTRACT**

*Full-screen-display with line pitch 4um was developed and fabricated successfully under Nikon 68s lithography system with normal mask. Key parameters including PR THK and taper through lithography process were studied. Finally, we have realized the mass production of pitch 4um lithography process and the capacity is increased by 30%.*

## 1 Introduction

Nowadays, LTPS-LCD is widely used in many aspects. One of the most important parts is the mobile phone. Benefiting from its portability and heritage, the mobile phone has become an indispensable part of our lives. For a mobile phone product, the user experience is more and more important. Among all the user experiences, the screen-to-body ratio is a key factor for user's visual effect. The larger the screen-to-body ratio is, the more information the mobile phone will show with a fixed-size. One way to increase the area of the screen is to compress down border by narrow the line space and width of the signal line in down border.



(a)PHT PR CD 2.8 um (b) PHT PR CD 1.9 um

**Fig. 1 Appearance of PR with different CD**

However the narrower the line width is, the thinner the photoresist (PR) residue is. As shown in Fig.1, with the decrease of the line width, the PR residual thickness becomes less, and the taper also becomes smaller, which enlarge the CD loss after dry etching.

As shown in Fig.2, we define the PR THK more than 400nm as the effective CD. When the PR thickness is less than 400nm, the pattern under it will be etched after dry etching. Thus the *CD loss* shows as follows:

*CD loss=PHT PR CD-Effective CD*

When the *PHT PR CD* is fixed, the *Effective CD* decreases with the increase of *CD loss*. But the *Effective CD* should reach a certain value to meet the requirement of the wiring resistance. Thus we need to increase the *PHT PR CD*, which the line width can't be reduced effectively.

How to overcome the *CD loss* enlargement under limit line width design? The critical factor is to increase of PR taper and PR THK without the change of *PHT PR CD*. Here we have done a research of the appearance of PR after development and postbake with different initial PR THK and we have tried to find the optimum lithography process for pitch 4um at the same time.

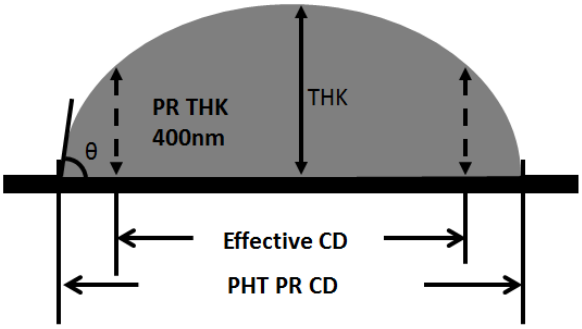



**Fig. 2 Key parameters of PR appearance**

## 2 Experiment

### 2.1 Methods of PR taper improvement

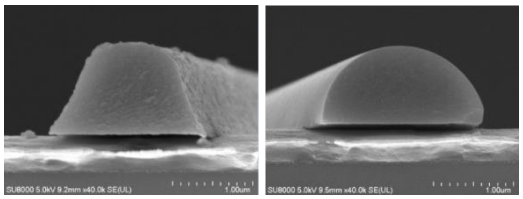
As shown in Fig. 3, the cross section of PR appearance after development shows like a trapezoid, which is affected by the light intensity and diffraction.

During exposure,the light intensity decreases from the top to the bottom when the light passes through the photoresist. The more the light illuminance is, the more the photochemical reaction is. Thus the top of the PR is easier to be developed,which makes the PR with appearance of the trapezoidal shape. On the other hand, the diffraction effect reduces from the top to the bottom with the decrease of light intensity, which also helps to form the trapezoidal shape. After post-bake,the top of the PR is softened and returns to the bottom to form the circular arc shape. The schematic of the PR appearance in lithography process is showed in Fig. 4.

In order to enlarge the PR taper after the post-bake treatment, we need to enlarge the PR taper after development. It is reported that the cone angle *θ1* of PR after development increases with the increase of the

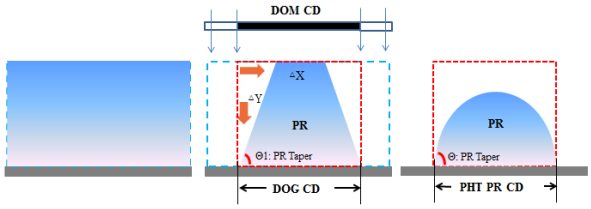
light density [1]. That is because the bottom part of PR also receives more light with the increase of the light density and more photochemical reaction helps to the development of the bottom PR. Therefore, the cone angle $\theta 1$ increases on the bottom part of PR. But the increase of the light intensity also enhances the diffraction of light, which causes the CD on the top part of PR getting smaller. As a result, the cone angle $\theta 1$ of PR declines. Thus we need to study the optimum lithography process.

Another way to increase the taper is to thicken the PR thickness. As shown in Fig. 4(b), $\tan\theta 1 = \Delta Y/\Delta X$, $\Delta Y$ is the PR THK after development, $\Delta X$ is the CD loss caused the the light diffraction effect. When the $\Delta X$ is fixed, the cone angle $\theta 1$ increases with the increase of $\Delta Y$.



**(a)After development (b)Atfer post-bake**

**Fig. 3 PR appearance after development**




**(a) Bofore exposure (b)After development (c)Atfer post-bake**

**Fig. 4 Schematic of taper for PR in lithography process**

### 2.2 Experimental Data

The following experiments were carried out on Nikon 68s lithography system. Here we have carried out a series of lithography processes of different coating PR THK of 1.4 um to 2.2 um by the step of 0.2 um with the same mask design and the CD after postbake is about 2um. The PR appearances with different PR THK after development or postbake were observed by using scanning electron microscopy (SEM). All the pictures of the PR appearance are shown in Fig. 5.

## 3 Results

As shown in Fig. 5, the dose of light in lithography process increases with the increase of the PR coating THK. The taper and THK of PR after development or postbake with different coating THK under lithography process are shown in Fig. 6. The PR THK after development increases with the increase of PR coating THK. The taper of PR after development increases with the increase of the PR coating THK at first and then goes to a peak value with coating THK of 2 um. Besides, the THK of PR after postbake shows a peak value between 1.8 and 2 um coating THK.

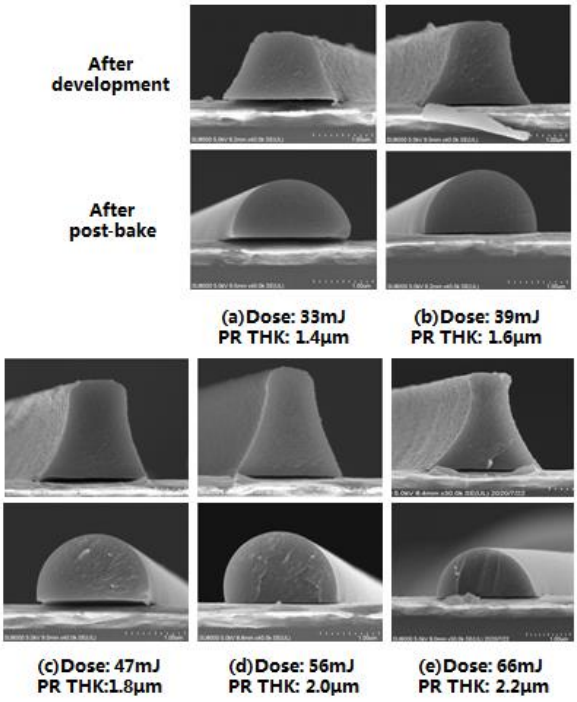



**Fig. 5 Taper appearance of different photoresist thickness and dose**

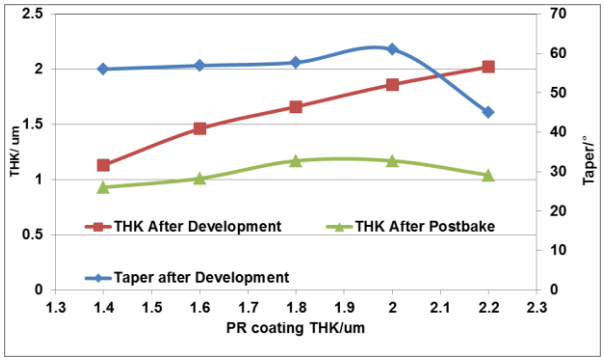



**Fig. 6 Taper/THK of PR of different PR coating THK under lithography process**

## 4 Discussion

These abnormal phenomena of PR taper and THK are related to the diffraction of light. Due to the increase of the dose of light, the light diffraction is enhanced with the increase of PR THK.As a result, the CD on the top part of PR becomes thinner and the cross-sectional area of PR also becomes smaller. All the above contribute to the reduction of PR THK after postbake when the coating PR THK is thicker than 2um.

Through the above analysis and verification, we have optimized the PR coating thickness to 1.8um instead of 2.2 um, which increases the lithography capacity by 30%.With the optimum lithography process, we have promoted the mass production of the design of pitch 4um.

For the pitch reduces from 5um to 4um, the height of fanout area of data line can be reduced by 20%. As shown in Table 1, basing on the specification of our 6.67" FHD prototype (V: 2400, H: 1080 x RGB), the height of the fanout area reduces 140 um with the pitch changing from 5um to 4um.

Table 1 Parameter of the height of fanout area

| **Item** | **Specifications** | |
|---|---|---|
| Display Size | 6.67 | |
| Resolution | 1080*RGB*2400 | |
| Fanout Pitch | 5 um | 4 um |
| Width of fanout area | 780 um | 640 um |

## 5 Conclusions

We have optimized the pitch 4um lithography process through the analysis of the PR appearance of different initial PR thickness after lithography process on Nikon 68s lithography system. Finally, we have realized mass production of the lithography process for the design of pitch 4um and the lithography capacity is increased about 30%.

## References

[1] D. Liu, Q. Chen, S. Huang, G. Qin, P. Gao, H. Chen, X. Cai, B. Wang, J. Feng, L, Fang, "Influence of lithography process parameter on DICD and taper of photoresist", Chinese Journal of Liqiud Crystals and Display, Vo1.34 N0.2.