A Study of 1.0㎛ Patterning for 2000ppi Level High Resolution Panel

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ABSTRACT

A high resolution panel is needed in the Mobile, VR, AR as the panel size decreases and the required visual characteristics increases. As a trend of resolution increases, a precise pattern is need. A fine patterning to fabricate high resolution panel overcoming the limitations of equipment in the photo process plays an important role in VR and AR backplane. For improving over the equipment limit, over-exposure method and i-line photoresist were applied. In the case of line and space pattern, the 1.0㎛ metal layer with CV (coefficient of variation) 15% was formed compared to conventional 1.5㎛, CV 13%. And in the case of hole pattern, the 1.0㎛ inorganic layer with CV 14% was patterned compared to conventional 1.5㎛, CV 14%. As a metal line in the TFT backplane, we used Ti/Al/Ti (Titanium/Aluminium/Titanium) 500nm and as an interlayer we used SiNx /SiO2 600nm. As hole size decrease, to prevent un-filling from hole, we applied inclined 2-step slope and it showed zero point defect. In 4.3 inch panel, it has shown that an advanced resolution performance with applied 2200ppi, 1.0 ㎛ compared to 1500ppi, 1.5㎛ patterning.

1 INTRODUCTION

The OLED Display has been attractive because of its high contrast ratio, high resolution, high luminance, low power consumption and flexibility. A high resolution panel is needed in the mobile phone, watch, VR, AR as the size decreases and the required visual characteristics increases. [1][2][3]

It is shown in Fig.1 that a trend of PPI and resolution relationship affecting precise device fabrication. It is observed that as the PPI increases, resolution becomes decreases linearly.

A 1.0 ㎛ level uniform patterning of source/drain metal line and contact hole in OLED Panel is common interests for display concerned companies. The limit of photolithography that can be implemented in the equipment is 1.3 ㎛ with DOF(depth of focus) 1.0 ㎛ in the line pattern and 1.4 ㎛ with DOF 1.5 ㎛ in the hole pattern. The DOF margin is required as least 3.0 ㎛ to fabricate display panel without pattern variation. To make uniform pattern, it is applied that 1.5 ㎛ with DOF 7 ㎛ in the metal line and hole.

As a metal line in the TFT backplane, we used Ti/Al/Ti (Titanium/Aluminium/Titanium) 500nm and as an interlayer we used SiNx/SiO2 600nm. In this study, we report the reliability of patterning by developing over-exposure lithography, i-line PR (photoresist) and Phase Shift Mask (PSM) [4]. Fig.2.(a) shows line patterning in the equipment current limit status and Fig.2.(b) shows 1.4 ㎛ hole patterning in the equipment current limit status. The PR pattern shows a triangular pyramid shape, and the thickness decreases, showing an abnormal shape. In the hole pattern, as the hole size decreases, showing a degradation of step coverage of metal.

To confirm the uniformity, we measured coefficent of variation (CV %) and DOF margin. CV is smaller and better characteristics and under 20% is required. DOF is larger and better characteristics and 3.0 ㎛ or higher is required for VR,AR panel fabrication.

Since the hole size decreases, a degradation of step coverage of metal made a contact resistance increase and point defects in the panel. To prevent the defect from insufficient metal filling in the contact hole, we applied inclined step at the top of hole area.

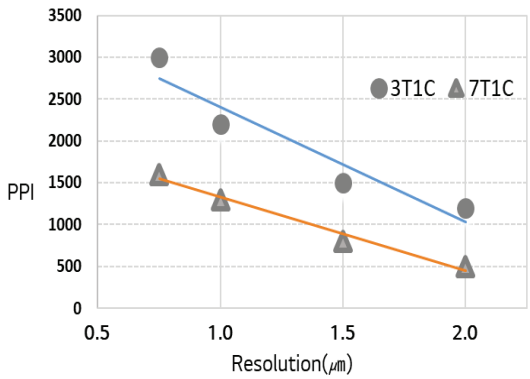
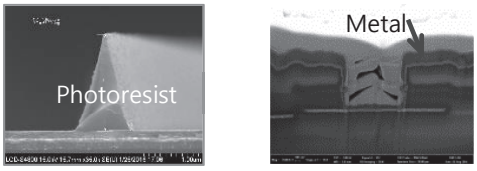


Fig.1 Resolution and PPI relation trend



(a) (b)

Fig.2 SEM cross section image of (a) line pattern in the current limit status (b) hole pattern in the current limit status

2 EXPERIMENT

For high resolution photo pattern, over-exposure method was used with photo-reactivity increased i-line PR. This PR is composed of i-line reactive component composed of p-Cresol component with hydrophilic properties. This PR increases light reactivity and reduces developer reactivity, thereby reducing PR thickness reduction and minimizing shape deformation, making fine patterns possible.

Over-exposure is refers to a method of increasing the amount of light by 100%,150%, 200% compared to usual amount. Although the exposure time increases, it is a method that can form small patterns depending on the amount of light compared to the photo mask.

As a Source/drain Metal, Ti/Al/Ti (Titanium / Aluminium /Titanium) 500nm was deposited by sputtering on SiO2 layer. SiNx/SiO2 multilayer 600nm was fabricated using plasma enhanced chemical vapor deposition (PECVD). SiNx was deposited with SiH4, NH3 and N2 gas was used as carrier gas. The gas flow rates were 3500sccm (N2), 600sccm (NH3), 100sccm (SiH4). The total gas pressure was maintained at 1500mTorr and power was fixed at 1100W. SiO2 was deposited with SiH4, N2O gas and the gas flow rates were 3900sccm (N2O), 65sccm (SiH4). The Power was fixed at 1000W. The distance between the dielectric plate and the substrate stage was 470mils.

As the hole size decreases, the step coverage of the metal decreases, which becomes a problem in contact resistance. To increase step coverage, we applied inclined 2-step slope and it showed zero point defect. This method is a technology that expands the metal deposition area by reducing the angle of the top where the hole is formed by repeating deposition and etching several times when etching a hole.

It is shown in Fig.3 that the 1.0㎛ pattern formation concept compared to photo mask by the over-exposure method. Fig.4 shows the hole image of the deposition and etch repetition results to improve step coverage. As shown in Fig. 4. the top Area of hole consist of stared structure.

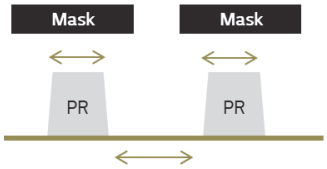
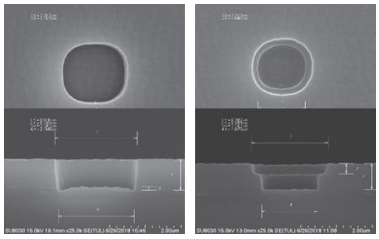


Fig.3 small pattern formation compared to photo mask by over-exposure method



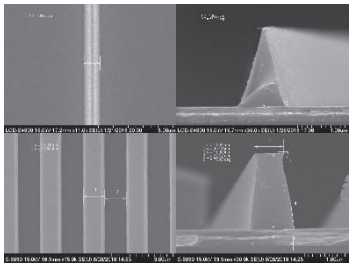
(a) (b)

Fig.4 a result of deposition and etch repetition hole formation plane and cross-section image (a) before (b) after application

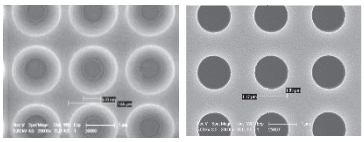
3 RESULTS and DISCUSSION

Fig.5.(a) shows 1.0㎛ line patterning with technology applied. The i-line PR is applied for increasing photoreactivity and decreasing developer reactivity.
and Fig.5.(b) shows 1.0 ㎛ hole patterning with technology applied. It is shown in the Fig.6 that 3㎛ DOF margin at the 15% CV in the Line/Space(L/S) and 20% CV in the hole. Resolution and design rules for developing high resolution panels have been established by securing fine patterns and uniformity. The PR pattern was formed stably and a uniform pattern was obtained when etching the lower part.

A contact hole SEM image is shown in Fig.7. Instead of one slope hole, a two step slop is shown. The metal step coverage could be increased from 30% to 60% and we solved the point defects. The sequence of two step slope was performed dry etch process without breaking the vacuum in the same chamber.



(a)



(b)

Fig.5 SEM image comparison (a) line and space pattern ; before (up) and after (down) skill applied. (b) hole pattern ; before (left) and after (right) skill applied

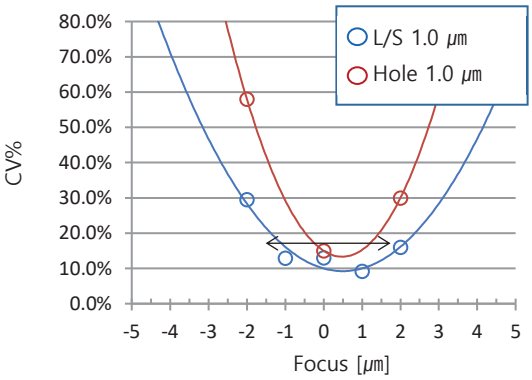
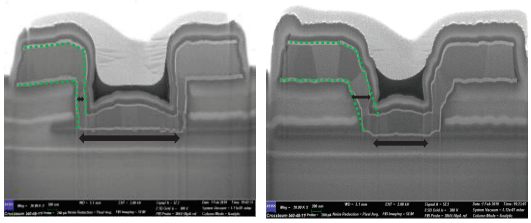


Fig.6 Depth of Focus(DOF) margin of 1.0 ㎛ Line/Space(L/S) and Hole Patterning



(a) (b)

Fig.7 SEM image comparison before (a) and after (b) technology applied in the hole patterning

The 6inch 7T1C Panel applied conventional 1.5㎛ resolution exhibited 800ppi, but the resolution increased when we applied 1.0㎛ skill to 1000ppi. The 4.3 inch 3T1C Panel applied conventional 1.5㎛ resolution exhibited 1500ppi, but the resolution increased when we applied 1.0㎛ technology to 2200ppi. It is shown that a microscope image applied 1.0㎛ pattern skill and 4.3inch panel image in the Fig.8.

To fabricate the high resolution panel in mass production, other technologies, such as a high resolution inspection, short channel TFT, high resolution organic layer should be developed and applied. As the demand of high resolution increases, under 1.0㎛ pattern skill will also increase.

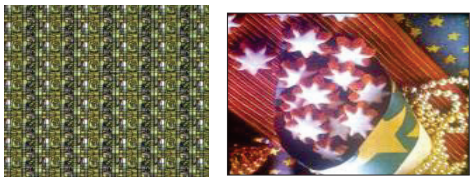


Fig.8 A microscope image applied 1.0 ㎛ pattern Process and 4.3inch Panel image

4 CONCLUSIONS

To have a qualified panel, we applied over-exposure method, i-line Photoresist in photolithography process. And To overcome step coverage issue, we applied deposition-etch repetition process. As a result, line and space pattern, the 1.0㎛ metal layer with CV 15% was formed compared to conventional 1.5㎛, CV 13%. And in the case of hole pattern, the 1.0㎛ inorganic layer with CV 14% was patterned compared to conventional 1.5㎛, CV 14%. 2200ppi panel samples showed good quality without a point defect. A uniform pattern was created by overcoming the limitations of equipment in the photo process. To achieve sub 1.0㎛ full display backplane process, an sub-micron inspection technology should also be accompanied.

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