The Improvement of Display Brightness in LCD-TV Panel through the Optimization of Organic Passivation Process

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Abstract

We report the improvement in brightness through the optimization of the organic passivation process for fabricating a TFT substrate for LCD-TV panel. In conclusion, the optimization of organic passivation was accomplished with improving over 10 cd/m^2 in brightness than that of a conventional organic passivation process.

1. Introduction

Recently, demand for a large size LCD-TV is surging in flat panel display (FPD) market and new advanced technologies are required to achieve high resolution, fast response, low power consumption and integrated driving circuits in the peripheral areas [1].

In TFT-LCD, a silicon nitride (SiNx) film was used for a passivation layer, but the dual-layered structure consisting of a SiNx film and an organic insulator was based on the process architecture to grow from a monitor to large-sized HD/Full HD television like 'Bordeaux' as possible to realize high aperture and high contrast [2,3,5-9].

However, the organic insulator plays an unfavorable role in both brightness and a stain by the absorption in visible wavelength from 380 to 500 nm. In display devices, brightness is one of the critical features as a measuring stick for the display performance.

In this paper, we will introduce to solve the problems through the optimization of the organic passivation layer through various simulation tools, design of experiment (DOE) and pilot test.

2. Experimental

2.1. TFT-LCD Fabrication TFTs were fabricated through 5 mask process. Other processes, such as a color filter substrate, an injection of liquid crystal and an assembling of back light unit (BLU) module, for fabricating TFT-LCD panel were followed by a standard process in each. In this paper, we will discuss only the process of organic passivation in detail. Also, TFTs were fabricated with bottom contact geometry with patterned Al/Mo gate and an insulating layer of silicon nitride. Data electrode was connected to pixel electrode and organic insulator was located between SiNx passivation and pixel electrode as the following figure.

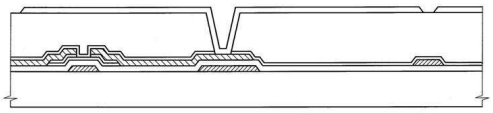


Fig.1 Cross-sectional array structure of conventional TFT substrate with an organic passivation

2.2. Organic passivation process After completing the source/drain process, TFT substrates were prepared from silicon nitride deposited by a chemical vapor deposition (CVD). The substrates were coated organic photoresist (an acrylic resin) in each thickness by slit linear coater and dried in vacuum dry chamber. The slit-coated organic photoresist was dried again by heating at 100 °C for ca. 2 min in proximity oven and then, exposed by suitable dose in aligner. The exposed organic photoresist was developed by 0.4% TMAH solution and then, exposed the entire surface by I-ray energy over 500 mJ/cm^2. Thermal treatment for curing the organic photoresist was performed at 230 °C under a nitrogen atmosphere in convection oven. The cured substrates were treated by sulfur hexafluoride (SF_6) gas plasma the silicon nitride passivation to etch and then, were performed pixel process.

3. Results and discussion

3.1. Optical Simulation Optical transmittance simulation was performed with WVSE32 software (J.A.Woollam Co.). We applied the Cauchy model in order to confirm the change of reflection and transmission for each layer on thin film transistor substrate. The experimental data were fitted using the Cauchy model,

$$n(\lambda) = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} \quad (1)$$

The Cauchy model is useful for many common dielectric materials and is given by the expression where *A*, *B*, and *C* are constants to be determined.

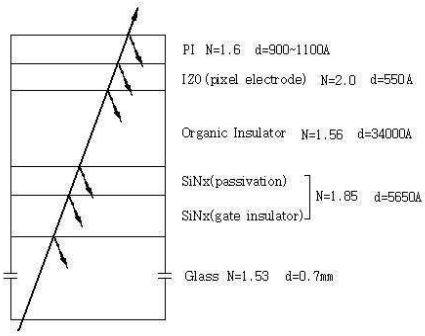


Fig. 2a. Initial array structure for optical simulation

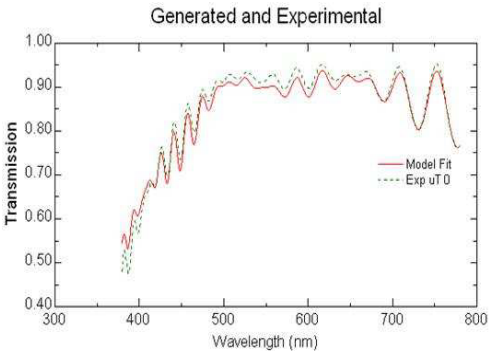
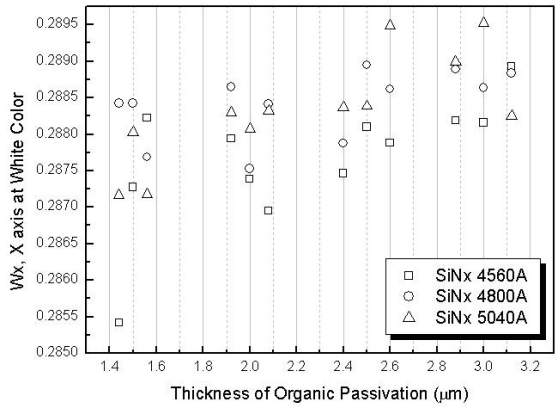


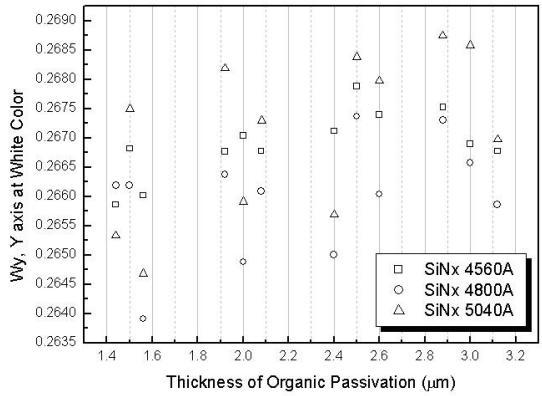
Fig. 2b. The initial example of approximately good agreement between calculated and experimental spectrum

Fig. 2a shows initial structure illustrating an array substrate with refractive index and thickness for each layer. This initial structure was improved into more efficient array structure by applying a proper thickness. Fig. 2b shows that the simulative spectrum was agreed to experimental spectrum as the results in each test.

We performed the simulation for the four cases from 3.0 ㎛ to 1.5 ㎛ by 0.5 ㎛ on the assumption that the thickness of a silicon nitride and an organic insulator was distributed in ±5.0% and ±4.0% on process, respectively. The simulation results are shown by plotting dots in Graph 1. We found the change of transmission by thickness to show a nonlinear feature on the simulation. The increase of Wx value results from the increase of the thickness in organic passivation, but their distribution is shown a decreasing tendency in Graph 1a. It will be explained the same that organic insulator composed of acrylic resin become reddish by increasing absorption in visible wavelength from 380 to 500 nm by increasing the final thickness in organic photoresist on glass substrate. The increase of Wy value in Graph 1b is also resulted from the increase of the thickness in organic passivation, but the increase of Wy value is insignificant for the reddish stain on panel.



(a)

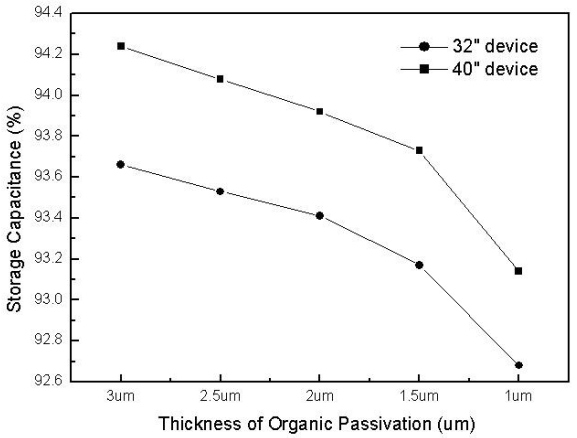


(b)

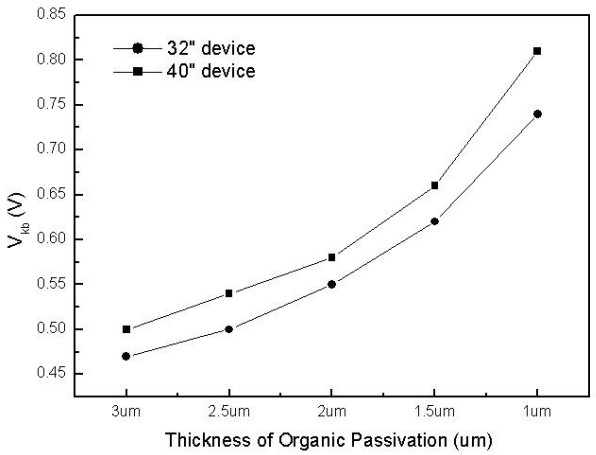
Graph 1. The shift of Wx and Wy on white color in different thickness of organic passivation

3.2. Electrical simulation Electrical simulation was performed by SPICE software (the EECS Department of UC Berkeley) on UNIX O/S. SPICE is a general-purpose circuit simulation program for nonlinear dc, nonlinear transient, and linear ac analyses. We performed the electrical simulation in terms of storage capacitance (C_s), kickback voltage (V_{kb}), gate and data line capacitance for 32 inch and 40 inch devices. We made use of the model modified to our device used

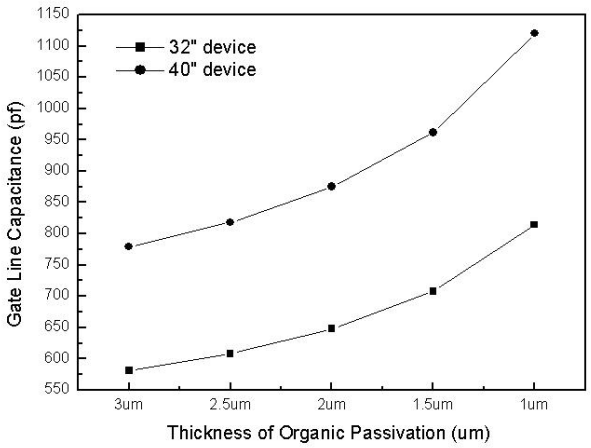
appropriately.



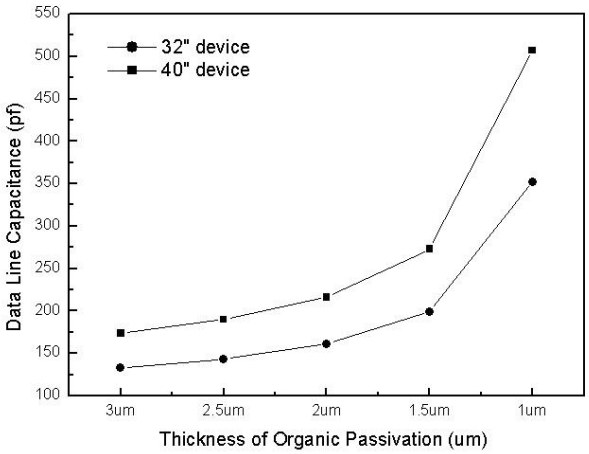
Graph 2a. The change of storage capacitance in different thickness of organic passivation



Graph 2b. The change of kick-back voltage in different thickness of organic passivation



Graph 2c. The change of gate line capacitance in different thickness of organic passivation



Graph 2d. The change of data line capacitance in different thickness of organic passivation

We performed the electrical simulation for the five cases from 3.0 ㎛ to 1.0 ㎛ by 0.5 ㎛, the final thickness of organic passivation. Although the storage capacitance (C_s) was decreased by reducing the thickness of organic passivation, it is insignificant in both devices. The kick-back voltage is increased by reducing the thickness of organic passivation. If the kick-back voltage is increased in large-size LCD panel, it is difficult to control flickering through the whole screen, because it is not able to make up for V_{offset} by one V_{com} on the entire LCD panel. Particularly, both of the gate and the data line capacitance are significantly increased by reducing the thickness of organic passivation. We could foresee the increase of RC delay from the results of the simulation. The increase of line capacitance and kick-back voltage raised a problem of weakening the operation margin on the LCD panel with the lower thickness of organic passivation. We need to introduce the 2 by 2 full factorial design of experiment for the thickness factors of Al gate electrode and organic passivation to solve the problem of the operation margin.

3.3. The optimization on organic passivation process The final thickness of organic passivation was controlled by the following two methods that apply the thickness on the process based on the optical and electrical simulation: (1) to control the dispensing amount of organic photoresist on a substrate, or (2) to control the etching amount of organic insulator on plasma etch process. In this research, we decided the final thickness through controlling the dispensing amount of organic photoresist on a substrate without the change of plasma etch condition. Table 1 is

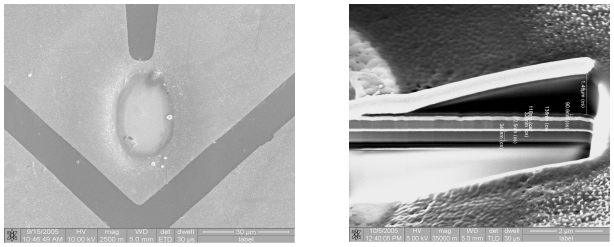
summarized the results after completing the plasma etch. We confirmed in equal processability to the conventional organic passivation process.

Table 1. Summary of the characteristics of organic passivation in each final thickness

Final thickness (㎛)[a]	Uniformity (%)[a,b]	Profile angle[c]	Transmission (%)at 400 nm[d]
2.98	7.3	23°	91.0
2.52	7.3	15°	93.5
2.31	5.1	22°	(94.4)[e]

[a] average of over 3 samples
[b] average of 18 points a sample
[c] average of two FIB images on contact hole
[d] UV-visible spectra on transmission mode
[e] an estimated value

It is important to control a proper angle of organic photoresist to contact between gate/data electrode and pixel electrode in each thickness of organic passivation. The profile angle of organic photoresist was decreased in proportion to decrease the final thickness. Fig. 3 shows a profile angle under 20° of organic passivation on contact hole in focused ion beam (FIB) image.



(a) top view (b) vertical view

Fig. 3. (a)SEM (top view) and (b)FIB (vertical) images on contact hole

Table 2. Summary of operating margin and optical properties in different thickness of organic passivation and gate electrode

Thickness (㎛) of g-Al, p-org	Operating frequency (Hz)[a]	Brightness (cd/m^2)[a]	
		Center	Average[b]
0.25, 3.00	81	490	465
0.25, 2.50	77	496	471
0.30, 2.50	84	506	479
0.25, 2.30	72	498	478
0.30, 2.30	75	508	478

Thickness (㎛) of g-Al, p-org	Chromaticity		Gate RC delay (μsec)[a]
	Wx	Wy	
0.25, 3.00	0.2827	0.2893	4.72
0.25, 2.50	0.2815	0.2880	5.12
0.30, 2.50	0.2815	0.2870	3.92
0.25, 2.30	0.2850	0.2890	5.52
0.30, 2.30	0.2860	0.2920	2.64

[a] average of over 2 samples
[b] average of 9 points a sample

4. Summary

The optimization of the organic passivation process has been verified through checking the various factors which are the material properties such as thickness, stain, etching, thermal reflow and the effects on the TFT operation such as gate/data line delay and display driving properties. The two main factors on the organic passivation process were to optimize the final thickness of organic passivation and gate electrode. The possible final thickness was found to be minimum 2.4 ㎛ through the optical and electrical simulation and the pilot test by the full factorial design. In conclusion, the optimization of organic passivation layer was accomplished with improving over 10 nits (cd/m^2) in brightness than that of a conventional organic passivation process.

5. References

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