

Article ID: 1007-2780(2011)01-0019-04

Low Dielectric Acrylate Resin as Passivation Layer on TFT-LCD

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Abstract: A low dielectric material, acrylate resin has been investigated as a passivation dielectric layer for thin-film transistor (TFT) arrays in this paper. Compared with the conventional nitride film (SiN_x , $\epsilon \approx 7$), the acrylate resin passivation layer exhibits a flat surface and a low dielectric constant ($\epsilon \approx 4.5$) which lowers the RC delay in a device. The high transmittance and good planarization characteristics of the low dielectric acrylate resin film enhance the brightness and aperture ratio of thin film transistors liquid crystal displays (TFT-LCDs), and lower the manufacture cost.

Key words: TFT LCD; low dielectric constant; acrylate resin; passivation layer

应用低介电材料丙烯酸酯树脂作为 TFT-LCD 的钝化层材料

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摘 要: 将具有低介电常数的丙烯酸酯树脂作为薄膜晶体管液晶显示器的钝化层整合到阵列基板中。与传统的 SiN_x 薄膜($\epsilon \approx 7$)相比, 丙烯酸酯树脂钝化层具有平坦的表面, 其低介电常数($\epsilon \approx 4.5$)可以降低器件的 RC 延迟, 这都将有利于提高薄膜晶体管液晶显示器的开口率, 从而提高显示器的亮度, 降低能耗和制作成本。

关 键 词: 薄膜晶体管液晶显示器; 低介电常数; 丙烯酸酯树脂; 钝化层

中国分类号: O436.1; TN141.9 **文献标识码:** A **DOI:** 10.3788/YJYXS20112601.0019

收稿日期: 2010-04-21; 修订日期: 2010-05-27

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1 Introduction

SiN_x film has been used as a dielectric layer in most of amorphous silicon (a-Si:H) thin-film transistors liquid crystal displays (TFT-LCD) for a long time^[1]. For the requirment of lower energy consumption, the TFT device characteristic, RC delay^[2] and aperture ratio are calling for further increases. There is a lot of space that hasn't been used between pixel electrode and bus area in traditional a-Si TFT-LCD array substrate's pixel design. It's because the dielectric constant of SiN_x thin film is high ($\epsilon \approx 7$). If expanding the pixel electrode to the bus area, serious capacitance coupling between pixel electrode and data line will occur, and it will cause the RC delay of signal increasing^[3]. In order to minimize the capacitance coupling and to improve the aperture ratio of TN, VA series products, the organic material whose dielectric constant is low should be used as dielectric layer. So far, there are siloxane-based hydrogen silsesquioxane (HSQ)^[4], methyl-Silsesquiazane (MSZ)^[5], etc. that have been reported.

In this paper, photosensitive acrylate resin^[6-7] is used as the passivation layer in array substance of TFT-LCD. The electric characteristic and the via hole profile are also characterized. By the study on the electric characteristic, comparing with SiN_x passivation layer, the acrylate resin passivation layer shows stabler dielectric constant, better electric characteristic, and more planar surface. The acrylate resin is a kind of insulator material which has the potential to improve aperture ratio.

2 Experiments

2.1 Equipment and Main Material

Electric measurement system is used to measure TFT device characteristic and dielectric constant. SEM is used to inspect via hole profile. Optical measurement system is used to measure transmittance^[8]. Coating & developing

system, and scanning steppers have been used in experiments to make passivation layer and via hole pattern.

2.2 Manufacture of Acrylate Resin Passivation Layer

Firstly, clean the glass substrate and spray the HMDS (Hexamethyldisilazane) on the surface of the glass. Then coat 61 mL photosensitive acrylate resin (viscosity is about $0.01 \text{ Pa} \cdot \text{s}$) on the glass through "Slit & Spin" mode. After low pressure drying, pre-bake around 110°C , exposure with high exposure dose over $128 \text{ mJ}/\text{cm}^2$, developing in 2.43% TMAH (tetramethylammonium hydroxide), broad band exposure with exposure dose over $500 \text{ mJ}/\text{cm}^2$, heating in the electrical resistance furnace at 230°C , after $5 \sim 10 \text{ s}$ traditional ashing and gate insulate dry etch, $2 \mu\text{m}$ acrylate resin passivation layer and via hole have been manufactured^[9-10]. Finally, prepare TFT substrate with traditional process.

3 Sample Profile Characterization and Discussion

The samples are characterized by scan electron microscope and optical measurement system. The cross section of via hole is showed in Fig. 1. The relation diagram between taper angle of via hole and exposure dose is showed in Fig. 2. Fig. 3 is the thin film transmittance curve of acrylate resin. Fig. 1 indicates that the surface of photosensitive acrylate resin film is planar, and the via hole profile is in good condition after TFT substrate is prepared completely. Fig. 2 shows that the taper angle of via hole has positive correlation with exposure dose, and the fitting formula is as following:

$$T = 20.787\,04 - 10\,151.113\,06 \times 0.915\,76^E \quad (1)$$

In this formula, T is the taper angle of resin via hole, and E is the exposure dose of UV.

Fig. 3 indicates that the film shows high transmittance in the visible range, and the transmittance average is up to 93.5%.

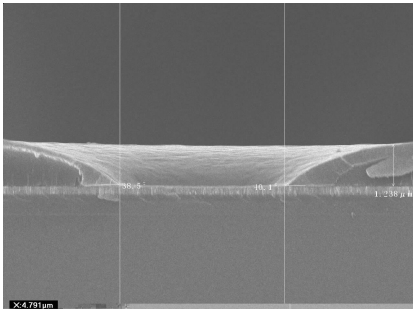


Fig. 1 SEM image of via hole cross section

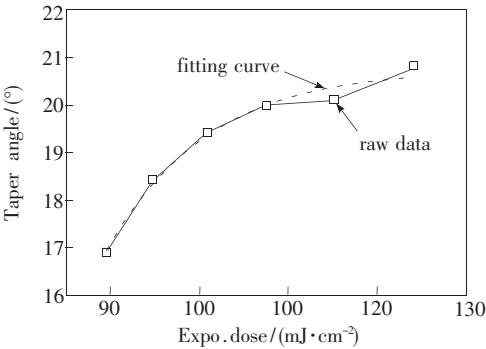


Fig. 2 Relation between taper angle of via hole and exposure dose

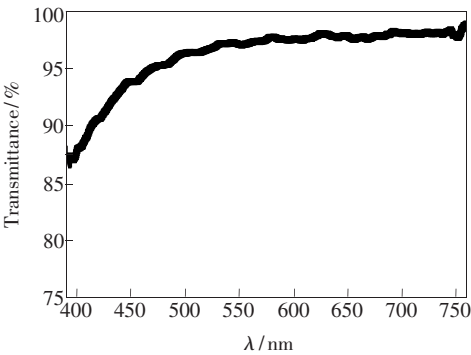


Fig. 3 Thin film transmittance curve of acrylate resin

4 Dielectric Constant Performance

The dielectric constant and its uniformity of both acrylate resin passivation layer and SiN_x passivation layer on the whole glass are measured through capacitance method. The measurement results show that the dielectric constant of acrylate resin passivation layer is 4.54 ± 0.08 , and the dielectric constant of SiN_x passivation layer is 7.15 ± 1.86 . Thus the dielectric constant of acrylate resin is much lower than that of SiN_x, and the uniformity of acrylate resin

is much better than that of SiN_x. It indicates that applying acrylate resin on TFT-LCD array substrate as passivation layer can decrease the capacitance coupling between pixel electrode and data line, and the capacitance coupling is uniform. It has the potential to improve aperture ratio.

5 TFT Characteristic Test

The TFT device characteristic of both acrylate resin and SiN_x passivation layer is measured at the same condition. The result shows that the TFT device characteristic of acrylate resin is much better than that of SiN_x as passivation layer. It's specifically expressed in whether there is light or not, comparing with SiN_x passivation layer device, acrylate resin passivation layer device has larger open current (I_{on}), lower threshold voltage (V_{th}), and the shutdown current of both these devices has no difference. Those are showed in Table 1 and Fig. 4. SiN_x passivation layer is loose, while acrylate resin is compact. It can be conjectured that the thick and compact acrylate resin protects channel by preventing harmful substance, such as water, alkalinity substance, and so on, from damaging channel. In this way, the thick organic acrylate resin can make channel keep better status (low V_{th}) than what SiN_x passivation layer dose. The open current (I_{on}) can be expressed as [3]:

$$I_{on} = \mu C_{ox} \frac{W}{L} (V_{gs} - V_{th}) V_{ds}$$

(2)

in which μ is the carrier mobility, C_{ox} is the capacity of gate insulate, W/L is the breadth length ratio of channel, V_{gs} is the potential

Table 1 TFT device characteristic of acrylate resin and SiN_x as passivation layer

Passivation Material	Dark			Photo		
	I_{on}	I_{off}	V_{th}	I_{on}	I_{off}	V_{th}
	(μA)	(pA)	(V)	(μA)	(pA)	(V)
Acrylate	5.70	1.49	0.24	5.92	29.33	-0.18
SiN _x	4.73	1.60	1.13	5.43	28.93	0.55

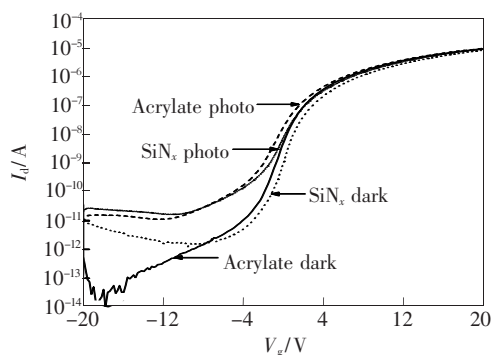


Fig. 4 TFT device characteristic of acrylate resin and SiN_x as passivation layer

difference between gate and source, and V_{ds} is the potential difference between source and drain. It shows that low V_{th} will cause high I_{on} .

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6 Conclusion

The experiment results indicate that the acrylate resin passivation layer has planar surface, good via hole profile, high transmittance in visible range. Acrylate resin has more uniform dielectric constant than SiN_x . The TFT device characteristic with acrylate resin as passivation layer is much greater than that with SiN_x as passivation layer. These all show that acrylate resin as passivation layer can decrease the capacitance coupling between pixel electrode and data line greatly, and can improve TFT device characteristic. Acrylate resin is an insulator material which has potential to improve pixel aperture ratio.