Process and Material for Color Filter Preparation in Liquid Crystal Display

Hisashi Aruga

T.M. R&D Section, SEIKO EPSON CORPORATION

Suwa South Plant, Fujimi machi, Suwa gun, Nagano ken, JAPAN

The color filter for liquid crystal display(LCD) has been developed about 7 years ago in order to fabricate poli-silicon-TFT active matrix LCD. The CF for CCD was popular at that time, but the different characteristics had to be given to the LCD-CF owing to producing good color reproducibility on Pocket Color LCTV. Nowadays, the large size CF is required for the Lap-Top computer display, this size will be more than 10 inch diagonal. Many kinds of CF have been generated for the LCD applications, however, the ideal CF that is applied for all kinds of LCDs is not still be developed, so the situation of the CF market is very complicated now.

We LCD makers have several problems to fabricate those large size CF on the high yield, because the severe color uniformity and low fabrication cost are required as indispensable condition. In addition to that, very strict surface flatness on CF is necessary for performing good image quality. In this paper, I will explain about recent state of development about the CF for the active and the non-active LCDs.

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1. Introduction

In the year 1984, SEIKO EPSON produced the full color liquid crystal TV that was called "Pocket LC-TV". It was the first time when the poli-Si TFT(Thin Film Transistor) was delivered in the commercial market, and on the other hand it was the debut for the color filter(CF) as the application of liquid crystal display. This CF had almost same structure to the CCD's composed of dichromated gelatin or fish glue with a photosensitizer. The size of the substrate was 3 inch round similar to the silicon wafer, it created only below 4 inch diagonal CF. After that, the LC-TV has become very popular due to the small size, low power consumption and light weight. Many kinds of devices and CFs applied to LC-TV have appeared, and the fabrication process has been greatly changed. The size of LCD has become 14 inch diagonal and the glass substrate has become more than 300mm square. The structures of CFs are complicated and the compositions of LCDs are diversified. The LCDs are almost classified to two categories, one is the active matrix LCDs that include the TFT(Thin Film Transistor), MIM(Metal Insulator Metal) and the other is the passive LCDs that include STN(Super Twisted Nematic), Double-STN and color STN. However, CF can not be classified as like these. The LCD-CFs are complicated, so it causes several problems. I will explain about our problems of CF and discuss the way of resolution.

2. CF Classification on the Structure of LCDs

Fig. 1 shows the organization of LCDs. The active matrix LCD is expected to occupy the flat display market in the future, however, there will be a little more time to realise it due to what with its much investment and what with a high fabrication cost. Accordingly, giving color to STN is also greatly expected. The controversy that which will be mainstream between the active LCD and the passive LCD is changing to the debate that what kind of the picture quality will be achieved by the passive LCD. It can be said that the key of the color STN depends on the CF structure. Since there is not a good quality and low priced CF in the market, so the color STN has the difficulties in fabricating at high yield. As compared with STN-CF, the CF for TFT (TFT-CF) can be made at a low price and high yield because there is no need of ITO patterning. Fig. 2 shows the cross sectional view of TFT-CF. Fig. 3 shows the cross sectional view of CF for MIM (MIM-CF). These two CFs are for the active LCD. The MIM-CF needs ITO pattern, because in the case of MIM the device has two terminals. The CF for the two terminal device is similar to the STN-CF. Fig. 4 shows the cross sectional view of the color STN-CF. The CFs which will be expected in the LCD market are limited to those three types. Each type of LCD has the problem that reduces the yield, and some part of it derived from CF structure.

Fig. 1 The organization of LCDs

Fig. 2 The cross sectional view of the TFT-CF

Fig. 3 The cross sectional view of the MIM-CF

Fig. 4 The cross sectional view of the color STN-CF

3. Fabricating process of CF

There are various CFs for LCDs in the market as follows.

- (1)Dye type
- (2)Pigment-dispersed resist type
- (3)Color resist etching type
- (4)Electro deposition type
- (5)Print type

Fig. 8 shows the fabricating conditions that are included the additional process as follows.

- (a)Black Matrix(BM) or Black Strip(BS)
- (b)ITO
- (c)Passivation layer

Not only fabricating the CF pattern on the glass substrate, but also those (a)~(c) process are required for LCD's application. Even if the CF pattern is formed through comparatively short process and its cost is low, but above (a)~(c) may give more process and cause high fabrication cost. Several CF makers participate in this market and try to develop the new CF, but the mainstream of it is still the Dye type CF as it used to be, because those additional process may be something like a burden. In addition to that, the aligning layer that is coated on the top of the CF has to be taken into consideration.

Fig. 9 shows the feature of respective CF. This figure shows the difficulties of fabricating of the color STN-CF due to complicated additional specifications, especially for below two reason.

- ① Low yield from the structure of "ITO on CF"
- ② Degradation by "Surface undulation and roughness"

4. Specification of The Color STN-CF

[ITO on CF structure]

The yielding ratio of the color STN-CF is affected by the ITO patterning process. The thermal expansion ratios are different between upper two layers, because the ITO is the inorganic substance as against the CF and protect layer are the organic material. The ITO is sputtered on the CF layer or protect layer at the low temperature (180 °C ~ 250 °C), the enough adhesion strength is obtained at this time. However, on the assembling process, the heat about 160 °C ~ 180 °C is applied to the CF on the process of the baking aligning layer and the baking sealing material. Therefore, the adhesion strength is reduced. There is not big affection when the ITO has no pattern, but there is need to be patterned for the color STN, in addition to heating, the strong acid wet etching and the strong alkali resist stripper are added. The conditions of wet etching are as follows.

ITO etching :	component material	HCl :HNO ₃ :H ₂ O
	condition	40 °C ~ 60 °C, 5 ~ 10min.

The conditions of resist stripping are as follows.

Resist stripping :	stripper	strong alkali liquid (KOH etc.)
	condition	40 °C ~ 60 °C, 5 ~ 10min.

As several kinds of strippers are used in this process, so only one stripper has not been limited. When the unnecessary ITO is eliminated by the wet etching, the CF or protect layer become laying bare to the

Fig. 5 The cross sectional view of CF Pad area

Fig. 6 The method of making flatness on STN-CF

Fig. 7 The principle of twisted-nematic LC

① Cr sputter	1000~1500Å
② Resist coating	
③ Exposure	
④ Development and Baking	
⑤ Cr Etching	
⑥ Resist stripping	
⑦ CF material coating	
⑧ Exposure	Repeat 3 times (Red, Green, Blue)
⑨ Development and Baking	
⑩ Dyeing	
⑪ Protect layer coating	
⑫ Baking	
⑬ ITO sputter	

Fig. 8-a Ordinary process of Dye-type CF for the TFT

① Cr sputter	1000~1500Å
② Resist coating	
③ Exposure	
④ Development and Baking	
⑤ Cr Etching	
⑥ Resist stripping	
⑦ CF material Printing	Repeat 3 times (Red, Green, Blue)
⑧ Baking	
⑨ Protect layer coating	
⑩ Baking	
⑪ ITO sputter	

Fig. 8-b The Printing CF for the TFT

① Black resist coating
② Exposure
③ Development and Baking
④ CF color resist coating
⑤ Exposure
⑥ Development and Baking
⑦ Protect layer coating
⑧ Baking
⑨ ITO sputter

Repeat 3 times
(Red, Green, Blue)

Fig. 8-c The process of pigment-dispersed CF for the TFT

① Black resist coating
② Baking
③ Posi-resist coating
④ Exposure
⑤ Development and Baking
⑥ Etching
⑦ resist stripping
⑧ CF color resist coating
⑨ Posi-resist coating
⑩ Exposure
⑪ Development and Baking
⑫ Etching
⑬ Resist stripping
⑭ Protect layer Coating
⑮ Baking
⑯ ITO sputter

Repeat 3 times
(Red, Green, Blue)

Fig. 8-d The process of resist-etching CF for the TFT

① Black resist coating
② Exposure
③ Development and Baking
④ CF color resist coating
⑤ Exposure
⑥ Development and Baking
⑦ Intermediate layer coating
⑧ Exposure
⑨ Development and Baking
⑩ Flatness treatment
⑪ ITO sputter
⑫ Resist coating
⑬ Exposure
⑭ Development and Baking
⑮ ITO Etching
⑯ Resist Stripping

Repeat 3 times
(Red, Green, Blue)

Fig. 8-e The process of pigment-dispersed CF for the color STN

	T F T	2 terminal	color S T N
I T O pattern	×	○	○
C F flatness	×	×	⊙
Black Matrix	○	○	?
Terminals	×	○	○

×:no need ○: need ? :not clear

Fig. 9 The additional specifications of CF

etchant, therefore, there have to be the intermediate layer between the ITO and the CF layer. The material of this layer is one of the organic materials, and PI, acrylic resin or epoxy resin is used in general. This layer is required to have tolerance for the strong acid and alkali and sometimes for the organic solutions. In order to decrease the ITO-open-failure, it is needed to select good intermediate layer. It is the very important point that the enough adhesion between the organic and inorganic materials have to be obtained.

[Strict surface flatness]

The strict surface flatness is required for the color STN-CF because it depends on the peculiarity of STN structure. The structure of TN LCD is shown in Fig. 7. It is STN LCD that the more $70 \sim 80^\circ$ is added to the twisted angle on this figure. Two LC panels are used in original STN LCD, but the polarized film is recently substitutionally used in the main. The retardation coloring is very sensitive due to the large twisted angle. The retardation coloring is derived from the below equation.

$$R = d \cdot \Delta n \cdot \sin \phi(V) \quad \cdots *$$

d : cell gap, Δn : the difference of refraction index between long and short axis,
 $\phi(V)$: tilt angle of LC molecular

Generally speaking, $\pm 0.03 \mu\text{m}$ is needed to attain good picture quality. If there is a undulation over this regulation, it decrease the picture grade as the non-uniformed contrast ratio. The undulation of CF layer is unavoidable due to making RGB pattern, therefore, making flatness is examined by the intermediate layer. The means of making flatness are shown as follows.

- ① leveling of material by itself
- ② polishing
- ③ pressing

Though the ① is the most low priced way, the undulation of below CF layer have to be needed to eliminated, but the making flatness of CF layer is unexpectedly difficult. In general, it is ordinary way by means of polishing or pressing the intermediate layer or piling up the intermediate layers. However, as the intermediate layer becomes multilayers, it causes the contamination problem and leads to high fabrication cost. It is recently considered that making flatness of CF layer is needed as much as possible. It is the key what kind material will be selected for intermediate layer.

5. Black Matrix(BM)

In addition to the intermediate layer, the black matrix or black stripe is important too. This is the layer that is set to prevent the transmitting light as light shield among RGB pixels. The kinds of BM are as follows.

- ① Cr pattern
- ② Ni pattern
- ③ black resist
- ④ multilayers pattern

The BM is inevitable for getting high contrast ratio, especially for on the normally white mode. Though the BM is apt to be omitted on the normally black mode, it is better to be set in order to obtain good color

reproducibility by means of avoiding the retardation color of the non-ITO area. The BM of the color STN is the same to the normally black mode. The Cr pattern is originally used for TFT-CF. We adopted the Ni pattern for TFT-CF in the past due to its low fabrication cost, but it was difficult to control the fabrication condition because the Ni caused the erosion by the acid. The ③, ④ are practical for the normally black mode, but it is not enough for the light shield as for the normally white mode. As the ④ is employed for the MIM LCD, it is enough, however, we think it can not be the mainstream because the double layered BM thickness gives the damage to the flatness. The narrow line width ($10 \sim 30 \mu\text{m}$) and the precise pattern pitch are inevitable to obtain the high aperture ratio of LCD, so the ③ is expected in near future. As taking these two points into account, the printing method seems to be difficult to create the good BM. We expect the pigment-dispersed photopolymer due to its high tolerance for heat and light.

6. Eliminating the organic layer in the Pad area

On both of TFT-CF and STN-CF, the CF and the intermediate layer have to be eliminated in the ITO-pad area. When the organic layer remains on the pad, the conductivity between the ITO and peripheral circuit becomes worse, and when the organic layer exists below the ITO-pad, the ITO is stripped from the surface by the detaching the peripheral drivers, so the CF and the intermediate layer have to be patterned by the photolithography or the printing method. After eliminating the CF and intermediate layer in the pad area, a step is formed on the border between the display area and the pad area. It is needed that the taper on the intermediate layer is formed to prevent the ITO line from being cut (See Fig. 5). It is unexpectedly difficult to set this taper, so higher technology is required.

7. Summary

Many technical subjects about the fabricating CF are concentrated on the color STN-CF, because the dependence ratio of STN-CF on the LCD is higher than the TFT's. The selecting CF, intermediate layer, ITO materials is very important technology. If the 10 inch diagonal STN-CF will be fabricated at low price and high quality, the multi-color STN-LCD will be used in several fields.

8. References

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