New Generation Color Filter Technology in TFT-LCD

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Abstract

Color filter is a fundamental and necessary component to make a full-color TFT-LCD, its quality intensively influence the performance of TFT-LCD in the application of Notebook Computer, Monitor and Television. Color filter in chromaticity also make an effect for human visual system and video enjoyment. Recently, mother glass size is enlarged for demand of large-size panels and new generation color filter technology for large-size liquid crystal cell panels is also developed. Here, latest generation color filter technology in TFT-LCD will be discussed.

Introduction

Color filter(CF) with red(R), green(G), blue(B) is a key component part for full-color liquid crystal display and imaging system. Liquid crystal display(LCD) is composed by upper glass substrate with color filter and lower glass substrate with matrix-array thin film transistor(TFT), liquid crystal molecule with long-rod shape is injected between upper- and lower-glass substrates[1,3]. LCD is a non-emissive lighting device and an auxiliary backlight module with cold cathode fluorescent lamps is included in the LCD system. Liquid crystal molecules with long-rod shape will be rotated in different angles when the electric voltage is applied to TFT devices, the light transmission ratio is also adjusted and pass through color filter, finally exhibited multi-color static or dynamic images.

In general, basic structural arrangement for color filter is composed by a glass substrate, a black matrix layer, three separated red-green-blue color layer, an over-coating layer and an ITO layer for pixel electrode. The function of black matrix(BM) is the prevention of light leakage and enhance the color contrast. The versatile pixel sizes, ranging from 240μm~10μm, are designed for the requirement of resolution, contrast, brightness and view angle in the application of small- & medium-sized and large-sized video/audio IT and consumer products.

The requirement items for color filter in the applications of LCD monitor and LCD TV : high contrast, high color purity, high response rate, wide viewing angle. B/W contrast and view angle can be improved by novel structural design, new black matrix material and innovative wide-view-angle technique. The increment of response rate can be acquired by emerging driving mode and new liquid crystal materials. In the case of high color purity, present display system can achieve NTSC ratio of 70%, but the targeted value for NTSC ratio is ideally 100%, that is acquired by improving pigmented dispense technique and developing new pigmented photoresist.

Traditionally, fabrication of color filter is completed by lithography processes – a series of steps of exposure, develop, etch and form color pixel[6]. As the sizes of display panel are gradually and continuously expanded, the large-sized glass substrates are also required due to economical consideration, but the investment of production apparatus is rapidly heighten. Spin coating technology is successfully applied in the fabrication of color filter before 4.0G glass substrate, but pixel precious, homogenous coating thickness, production yield, alignment precious and decreasing pigmented photoresist loss are the huge challenge for >5.0G color filter production. Slit spin coating, spinless coating with slit and versatile novel coating such as inject printing, reverse printing and laser printing are developed for large-sized glass substrates. Here we will describe and make some comparison between the conventional and new generation color filter technology.

Conventional Color Filter Technology

On the basis of physical characteristics of materials, two kinds of color substances always used to fabricate three separated red-green-blue color layer in color filter array, one material is the pigmented photoresists and the other is the dyed photoresists[4]. For pigmented materials, pigment dispense method and evaporation method are used to form color filter; for dyed materials, the fabrication of color filter have dye dispense method and dyeing method, but pigment dispense method is the main stream for manufacturing color filter. In the case of thermal resistance, the pigmented photoresist materials are superior to the dye photoresist.

For pigment dispense method, four versatile standard manufacturing processes were developed and applied in the

present production lines. These standard processes are printing, lithography, etching and electroplating,. For the consideration of mass production with low cost and high reliability, lithographic process technology is still used in color filter manufacturing for 2.0G(mother glass size-mm : 370~400x470~500), 3.0G/3.5G(550 ~680x650~880) and 4.0G/4.5G(720x920) TFT-LCD.

Production lines for color filter in Japan almost targeted in the generation of 2.0G, 3.0G/3.5G in the present status, and 6.0G in the next step. For Taiwan color filter manufacturers initially entered in the generation of 3.0G/3.5G and then invested in 5.0G and 6.0G. For Korea color filter makers invested initially in 3.0G/3.5G, and then expanded in 5.0G, 6.0G and 7.0G. Business model for TFT-LCD makers initially is a single-model out-purchasing from Japan color filter makers and then transfer into the mixed-model of out-purchasing and in-house, however the mixed-model business relation will be continuing between TFT-LCD makers and color filter makers.

New Color Filter Technology for Large-sized TFT-LCD

Up to now, new generation color filter technology for large-sized TFT-LCD include reverse printing process, inkjet printing process and laser printing or thermal multi-layer process. These color filter technologies are described in the following.

Reverse Printing Process

Reverse printing process developed by Mistumura Printing Co. and Mitsubishi Heavy Co., the first prototype color filter apparatus successfully applied to 550x650mm^2 (3.0G)glass substrate and is considered as the potential candidate apparatus for 7.0G color filter technology. Its advantages include no expensive lithographic equipments, reducing the clean room and related equipments investment, fast fabricating process and enhance production yield, simpler manufacturing steps, but the drawbacks have less precious of reverse cylinder, total pitch and screen mask, no usable pigmented photoresist and photo spacer, no mature apparatus for mass production.

Four dedicated steps for reverse printing process are shown in Figure 1. The detailed procedures for operating reverse printing process are described in the following,
- The first step : the slit nozzle with super precious is used to coat photoresist on the surface of reverse cylinder.
- The second step : shift the reverse cylinder with photoresist to specified mask and scribe the residual photoresist.
- The third step : The patterned cylinder execute reverse printing and then finish coating on the substrate for one color layer.

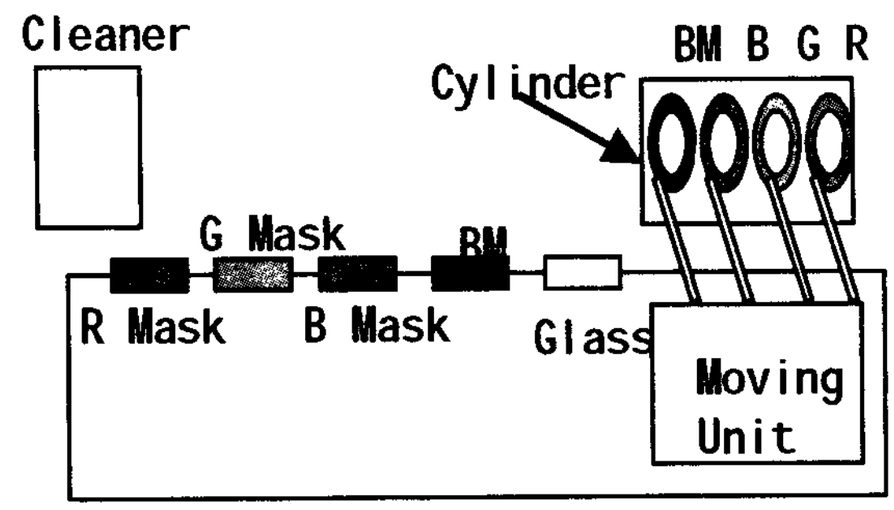

Figure 1 Schematic reverse printing equipment

- The fourth step : the above mentioned steps are operated repeatedly and then finish layer of black matrix, red, green and blue one-shop procedure.

Reverse printing process is the most potential process for large-sized color filter glass substrate such as 6.0G and 7.0G. Another competing and potential candidate process should be inkjet printing process, however the maturized mass production apparatus is still in the level of research and development.

Inkjet Printing Process

Inkjet printing process, shown in Figure 2, is similar to the generalized inkjet printing machines in office automation[5,7]. An inkjet printing head in the machine is directly used to inject three color inks into separated & independent pixels one time. Its advantages include reducing complex steps in traditional lithographic process, reducing the waste of expensive ink materials, one-shop process. Inkjet printing process had been regarded as the most potential manufacturing technology for over 7.0G large-sized color filter glass substrate. An inkjet printing head and pigmented ink are the core component and key material for inkjet printing process.

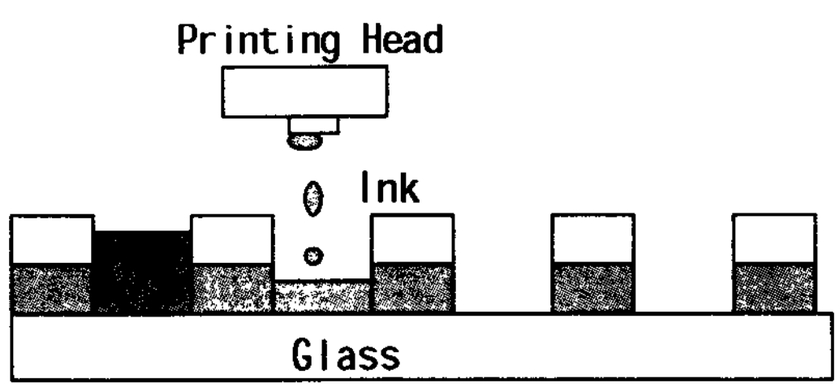

Figure 2 Schematic Inkjet Printing Equipment

The sequences of inkjet printing process : the barrier-like wall is formed on the resin- or Cr-black matrix(BM) pattern, and then the treatment of CF_4 plasma is executed to reduce surface energy of the barrier-like wall and avoid the occurrence of capillary because that result in its color bleeding and contrast deterioration. Inks with red, green, blue inject in the specified pixels through piezoelectric-type or thermal-bubble-type inject head, and then make an UV light exposure treatment, finally process an overcoat and ITO layers.

Laser Printing or Thermal Multi-layer Process

Laser printing process is developed by Du Pont Co.[8], this technique have two parts of donor film and thermal imaging system for curing donor film. Donor film consists of three-layer sandwiched structure, one layer is polyester film, interlayer is thermal sensitive film and the third layer is pigmented film. The dedicated laser printing equipment is shown in Figure 3.

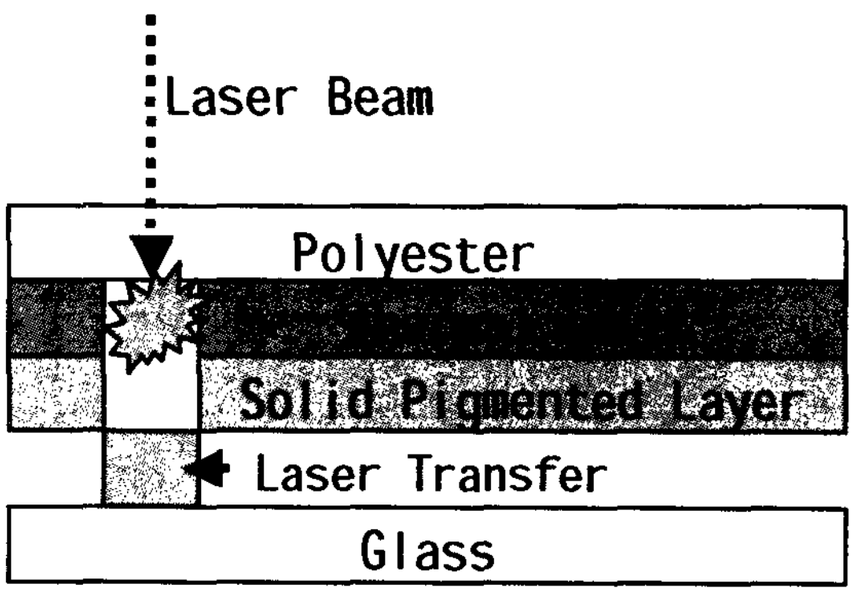

Figure 3 Schematic Laser Printing Process

Thermal imaging system is equivalent to exposure system in the conventional process, but its light source is laser beam and laser beam is controlled by software to focus the specified position of donor film. Thermal sensitive layer in the donor film is illuminated by laser beam and make a reaction, the solid pigmented layer is revered printing to glass substrate. Laser printing technique is a dry-type process and have no chemical pollution, but the conventional process including exposure, develop, etching and a wet-type process with the series pollution issue. Mask is required for the conventional lithographic process, but it is not necessary in thermal imaging technique. However, black matrix layer is still made by conventional process in laser printing technique, and color layer with red, green, blue had been fabricated by one-shop process in thermal imaging system.

Present Status and Future Development of Color Filter Manufacturer in the World

Initially, color filter is a out-purchasing component for TFT-LCD makers, but the demand of large-sized mother glass is predicable and shortage of color filter occur periodically, therefore new investment in 6.0G and 7.0G attempt to manufacture color filter in house. However, the professional color filter makers still invest to satisfy the TFT array manufacturers, especially new investment projects in China. New photoresist materials, emerging manufacturing techniques and novel production apparatus continuously develop to reducing the production cost and heightening throughput or yield efficiency.

New investment of large-sized TFT-LCD industry in Japan is slow down, but Taiwan and Korea continuously invest in 6.0G and 7.0G TFT-LCD industry and related technology, especially in the field of color filter fabrication. The complete industrial supply chain had been gradually constructed in Taiwan, and the clustering effect in TFT-LCD industry is also expanded from northern Taiwan to southern Taiwan.

Photoresist materials in color filter is very important and core technology, its characteristics influence the chromaticity of color filter and TFT-LCD. The self-developed photoresist with red, green, blue, resin black matrix and photo spacer had been completed successfully , and supply color filter manufacturers to be a second resource and an economical material. New photoresist with NTSC 100% is a challenges and the highest target for R&D scientists.

Production lines for manufacturing color filter are continuously expanded in the world, especially in Asia that include Taiwan, Korea, Japan and China[1,2]. Present status and future development of production lines for fabricating color filter in Taiwan, Korea, Japan is showed in the Table 1, Table 2 and Table 3.

Conclusions

The development of new generation color filter manufacturing technology is executed by large-sized TFT-LCD panel with high quality demand. Spinless slit printing had been developed for 5.0G(mother glass size-mm : 1,100 ~1,300x1,200~1,500) TFT-LCD process technology, reverse printing method, inkjet printing method and laser printing method are developing for 6.0G(1,500x 1,800~1,850 mm^2) and 7.0G(1,870x2,200 mm^2) TFT-LCD technology, especially reverse printing method and inkjet

printing method will be facilitated in 6.0G and 7.0G production firstly. The versatile novel and innovative color filter technology with economical consideration is still developed by color filter manufacturer.

Table 1 Production lines for manufacturing CF in Taiwan

Manufacturer	Glass Size	Production Capacity	Schedule
AMTC	650x750	90K	2001/Q3
	1100x1300	60 K	2005/Q4
CANDO	620x750	66 K	2001/Q1
	730x920	60K	2002/Q3
	1100x1300	75K	2005/Q4
HOSHIN	550x650	60K	2000/Q3
	620x750	60K	2001/Q4
	730x920	75K	2002/Q4
NANSHIN	1200x1300	75K	2005/Q4
TOPPAN	730x920	80K	2002/Q3
	1100x1300	80K	2004/Q4
	1100x1250	80K	2005/Q4
CMO	650x750	30K	1999/Q4
	680x880	60K	2001/Q4
	1100x1250	75K	2005/Q4
AUO	1100x1250	60K	2004/Q4

Table 2 Production lines for manufacturing CF in Korea

Manufacturer	Glass Size	Production Capacity	Schedule
Samsung	550x650	30 K	1
	600x720	40 K	1
	1100x1300	60 K	1
LG-Philips	590x670	40 K	1
	1100x1300	60 K	1

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Table 3 Production lines for manufacturing CF in Japan

Manufacturer	Glass Size	Production Capacity	Production Line
DNP	550x650	30 K	1
	600x720	40 K	1
Toppan	550x650	40 K	1
	650x750	30 K	1
	680x880	36 K	1
Sharp	550x650	30 K	1
	1100x1250	60 K	1
Toray	620x750	30 K	1
STI	600x720	40 K	1
Torison	550x670	30 K	1
Hitachi	650x650	25 K	1
Fujitsu	660x870	40 K	1