Color Filter Pattern Generation by Screen Printing

Yong-Jung Choi, Taik-Min Lee**, Soo-Yong Nam***, Yong-Sung Kim**, Dae-Yup Na***, Choon-Woo You*, Dong-Youn Shin**, Kwangyoung Kim , Kwang-Il Jung**
***Zeus Co. LTD., Osan, KOREA**
****IT Machinery Research Center, KIMM, Taejon, KOREA**
*****Pukyung National University, KOREA**
Phone:82-31-377-9500, E-mail: honestchoi@zeuscoltd.com
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Abstract

In this research, we present color filter which is patterned by screen printing method. Analysis of screen printing process, screen printing system, experiment for uniform printing in large area, characteristics of screen printed CF are investigated .In spite of limitation of precision, screen printed color filter is very cost- effective in respect of manufacturing facility and ink usage.

1. Introduction

As the competition of FPD market such as LCD, PDP, FED, and OLED is accelerated, FPD manufacturers make great effort on reducing manufacturing cost and increasing productivity.

The conventional LCD and color filter (CF) manufacturing procedures consist dominantly of versatile kinds of super vacuum systems for fabricating functional thin film and lithographic process for patterning pre-designed devices such as red, green, and blue pixels[1]. The function and performance of CF include high contrast, high color repetition, high color saturation, high color purity, fast response time, wide viewing angle, low reflectivity, low production cost and so on[2-4]. There are lots of color filter manufacturing methods such as the dyeing, electro-deposition, pigment dispersion, printing and so on [5].

Among the manufacturing methods, printing methods, including reverse printing, inkjet printing, gravure printing, screen printing, and so on, have been spotlighted as the most promising technology considering high efficient production with low cost.

The inkjet printing method has the advantage of non-contact digital print and controllable quantity ejection. However, surface energy relationship between the glass substrate, CF ink, and black-matrix (BM) should be well established and preserved constantly. Ink drying condition should be controlled subtly for obtaining a flat CF surface geometry. More than a dozen inkjet heads, consisting of 128 nozzles respectively, should be involved and controlled precisely for large area CF printing. In spite of these painstaking efforts, if there is model change of LCD CF geometry, almost all of the processes and ink should be reformulated again.

The Gravure offset and reverse offset method also have difficulties in the uniformity of gravure plate pattern for large area CF printing and the uniformity maintenance of surface energy of the blanket for offsetting during repeated printing process.

Although screen printing method has basically similar problems of printing, it has a great advantage in viewpoint of cost and productivity. Screen printing method has the advantage of low cost investment in equipment and reduced number of process, high manufacturability, and cost reduction of ink. However, it is necessary to develop the ink for CF screen printing, optimized printing process, and highly precise screen printing system for making fine patterns.

In this research, analysis of screen printing process, screen printing system, experiment for uniform printing in large area, characteristics of screen printed CF are investigated.

2. Screen Printing Method

The CF patterning by using screen printing method depends on whether the geometrical, optical, and chemical specification of CF pixel can be satisfied. These pixels should be printed

uniformly on whole LCD glass area and RGB should be overlayed in turns.

In order to satisfy the geometrical specification of CF, the surface energy relationship between the ink, screen mesh, and substrate is very important. Viscosity of the ink, contact angle of the ink and substrate, thickness of the patterned bottom coated layer of the screen mesh are critical parameter.

The required thickness of CF is generally thin around 1-2um and surface roughness is around 100-200nm. In order to meet these condition with screen printing method, the contact angle between the ink and substrate and and the viscosity of ink should be lower than general screen inks. Otherwise, the pixel is not filled and the speed of filling is slow.

In order to print large area uniformly, the surfaces of substrate, screen mesh, squeegee should be flat uniformly. Identical screen printing condition should be applied on the whole area.

2.1 Analysis of screen printing process

In order to print fine pattern in large area through screen printing method, the most critical thing is to understand the relationships between precisely grinded squeegee, adequate ink formulation, printing process technology, screen of fine mesh, and precise screen printer. The figure 1 shows the schematic picture of screen printing process in which patterns are generated after off-contact between the screen and the panel. In the figure 1, the section C and D are the most critical processes, in which the ink is transferred from the screen to the panel. Therefore, it is the most important that the off-contact speed should be kept invariant, if we want same patterns through all over the panel

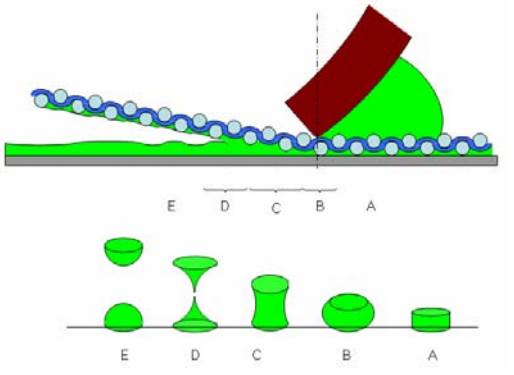

Fig. 1. Screen printing process.

The equation (1) is the analyzed relationship between the off-contact speed and squeezing velocity.

$$\frac{dx}{dt} = \left(-\frac{x}{y} - \frac{h^2}{x \cdot y} \right) \frac{dy}{dt} \cong -\frac{1}{y} \cdot \frac{dy}{dt} \cdot x \qquad (1)$$

From the equation, when squeezing velocity value is fixed, as the squeezing is advanced, the off-contact speed becomes reduced. It means that it is almost impossible to get even printing result at all over the large area. In order to make the off-contact speed be same, the squeezing velocity is calculated reversely through the equation (1)(see the figure 2).

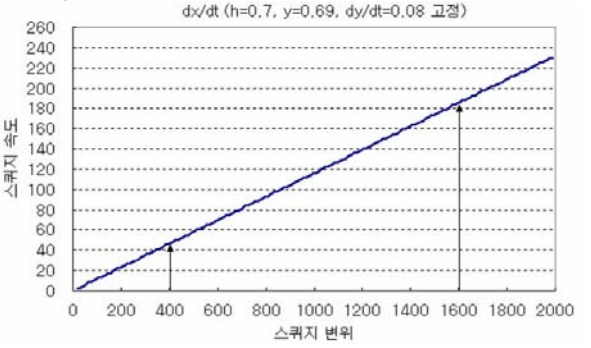

Fig. 2. Squeezing velocity for maintaining same level of off-contact speed.

2.2 Development of screen printing system

The figure 3 shows the developed screen printer for color filter printing. For even and precise screen printing result in large area, we tried to improve flatness, straightness, accuracy, and velocity vibration. All parts of screen printer are controlled not to make particles during screen printing. The specification of screen printer is as the table 1.

Table 1 Specification of screen printing system.

Item	Specification (mm)
Machine size	2800 x 2800 x 1900
Screen Size	1800 x 2000 x 40
Stage Size	1300 x 1350
Stage precision	5um
Optics precision	1um
Substrate holding	vacuum
Curing	Thermal + UV

Fig. 3. Developed precise screen printer for color filter printing.

3. Screen Printed Color Filter

3.1 Experiments of screen printing process for color filter

For obtaining uniform pattern on all over the area, various printing conditions were experimented such as off-contact distance, printing pressure induced by squeezing, scraping height, printing direction, and so on. The patterns were measured by using 2D microscope for printing width and confocal microscope for printing height. We found the experimental result as follows.

(1) As the off-contact distance increases, the printed pattern width decreases and the variation of pattern width also decreases. As it increases, the effectiveness of the off-contact distance is saturated and an excessive off-contact distance makes the screen of mesh broken. Therefore, optimal off-contact distance is appropriate.

(2) As the printing pressure increases, the printed pattern width get wider over all. The variation of pattern width looks not affected

(3) The scraping height does not make significant influence on the printed pattern.

(4) the patterns parallel with the squeezing direction are printed without the variation of the pattern width and height in comparison with vertical patterns.

3.2 Color filter results

As regarding Ink formulation, the relationship between RGB ink, black matrix, and LCD glass is very critical in order to satisfy the existing CF specification for LCD. We tested several kinds of oligomor and mill base from the viewpoint of viscosity, contact angle, chromatography, color stability, storage stability, and other rheological characteristics of ink.

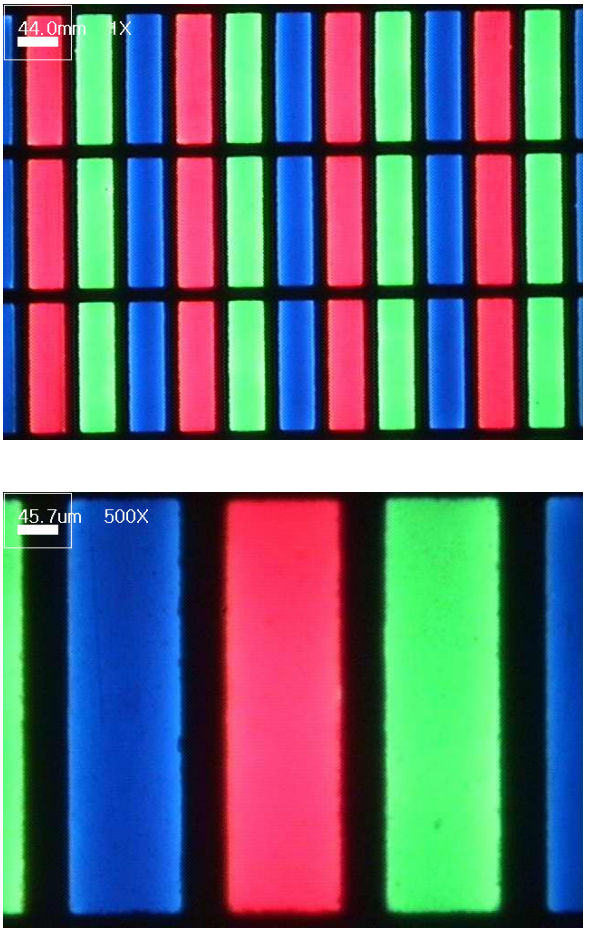

Fig. 4. Screen printed color filter.

The figure 4 shows the color filter patterns by using screen printing method. The figure 5 shows the CIE coordinate of screen printed inks and the table 2 indicates the color gamut and CIE coordinate correspondent to NTSC. It shows that the screen printed ink has more than a color reproducibility of 70% in NTSC and it is appropriate for liquid crystal display devices for desktop monitors and liquid crystal televisions.

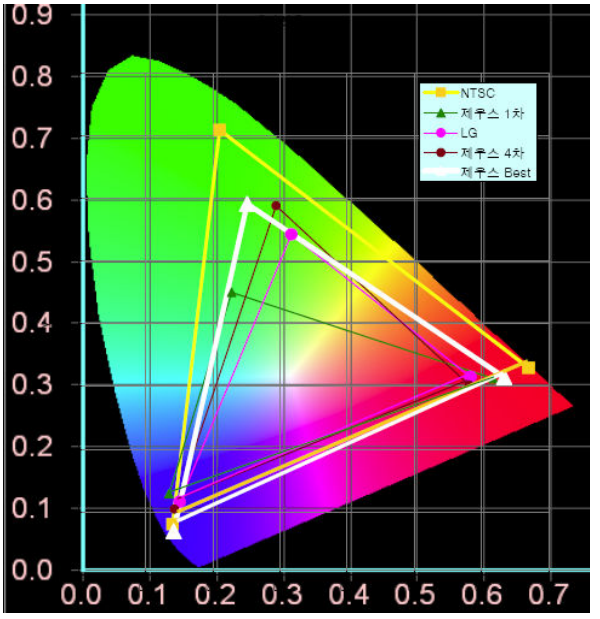

Fig. 5. CIE coordinate of screen printed inks.

Table 2 Color gamut and CIE coordinate correspondent to NTSC.

		R	G	B	Gamut
NTSC	x	0.67	0.21	0.14	100%
	y	0.33	0.71	0.08	
Product	x	0.63	0.25	0.14	72.8%
	y	0.32	0.59	0.069	

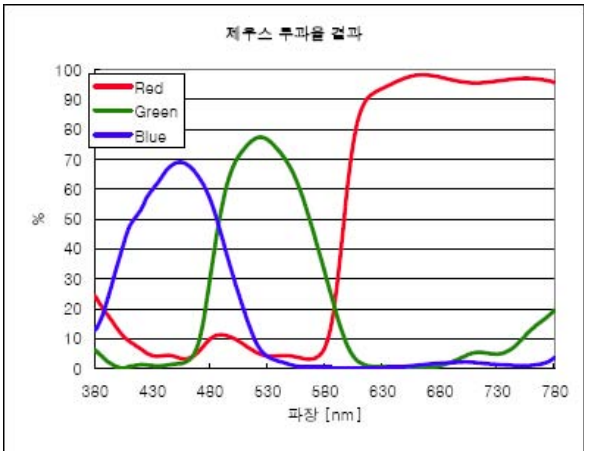

Fig. 6. Transmittance spectral characteristics of the screen printed CF.

4. Conclusion

In this research, analysis of screen printing process, screen printing system, experiment for uniform printing in large area, characteristics of screen printed CF are investigated.

Optimal squeegee moving speed was formulated in viewpoint of identical off-contact speed. The screen printing system, improved flatness, straightness, accuracy, and velocity vibration, was developed. Various printing conditions were experimented such as off-contact distance, printing pressure induced by squeezing, scraping height, printing direction, and so on. Finally, we obtained screen printed color filter and it has more than a color reproducibility of 70% in NTSC.

This paper is very unique in that color filters are patterned by using screen printing method. Screen printing method has the advantage of low cost investment in equipment and reduced number of process, high manufacturability, and cost reduction of ink. We expect that it is appropriate for liquid crystal display devices for desktop monitors and liquid crystal televisions.

5. References

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