Selective Wetting Technique for Fabrication of Color Filters

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Abstract

We report on a new method of fabricating color filters based on selective wetting of color inks. The reversible formation of a hydrophobic layer provides sequential generation and protection of successive color filter patterns through a simple coating process. The transmittance and geometrical properties of the fabricated color filter were described.

1. Introduction

A color filter is an essential component for producing chromatic characteristics of liquid crystal displays and photonic systems such as image sensors and line sensors [1]. It is generally comprised of red (R), green (G), and blue (B) sub-pixels to convert white light into three primary colors.

In manufacturing color filters, a pigment dispersion method [2] has been extensively used due to good color purity and reliability. However, this method has several drawbacks including the need of sophisticated manufacturing processes and high consumption of color resists and chemical solvents. Recently, an inkjet printing method [3,4] has been employed for production of color filters but it suffers from the compatibility problem between an ink solution and a nozzle.

In this work, we developed a new method of manufacturing color filters, which is based on a selective wetting inscription (SWI) technique [5]. The color patterns are spontaneously formed on a hydrophobic layer with tailored surface wettability using a simple coating process. Since the hydrophobic layer protects former color patterns during the subsequent coating process, each unit process can be simply repeated to form RGB color patterns. Our approach is suitable for production of color filters with high resolution over large-area using a typical coating technique.

2. Experimental

Figure 1 shows a schematic diagram of the unit process of fabricating single color patterns. A hydrophobic layer (Durasurf, Harves Co., Ltd.) was first spin-coated onto a glass substrate and subsequently cured at 85°C for 30 min. Then, the hydrophobic layer was irradiated with a KrF excimer laser through a photomask having an array of sub-pixel patterns, as shown in Fig. 1(b). The surface wettability of the exposed area in the hydrophobic layer is selectively changed to be hydrophilic by laser-assisted inscription. This technique, called SWI [5], provides precise self-registration of color patterns using a simple coating processes such as spin-coating, dip-coating, or slit-coating. In our case, the substrate was dip-coated in a pigment-based color ink so that

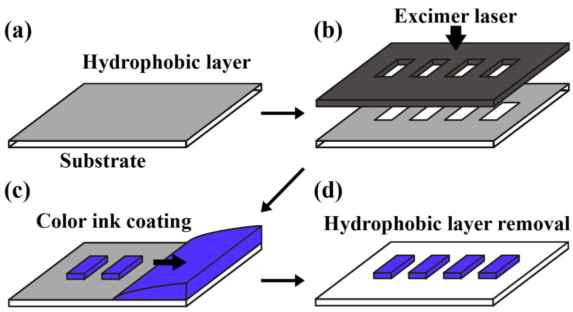

Fig. 1. A schematic diagram of fabricating sub-pixel color patterns by the SWI technique: (a) preparation of a hydrophobic layer on a substrate, (b) excimer laser irradiation through a photomask on the substrate, (c) selective wetting of the color ink during a simple coating process, and (d) fabricated color patterns after removing the hydrophobic layer.

color patterns were spontaneously produced only in the wetting regions. The thickness of the pattern can be controlled by varying the concentration of the color ink and the dip-coating speed [6]. Specifically, we used color inks with three different concentrations of 20%, 30% and 35%. The dip-coating speed was varied from 50 mm/min to 300 mm/min. After the dip-coating process, the color patterns were prebaked at 100 °C for 30 min, followed by UV curing at the intensity of 150 mJ/cm^2. The hydrophobic layer can be easily removed by immersing the substrate in a weak fluorinated solvent without damaging the color patterns as shown in Fig. 1(d). This unit process was sequentially performed for three primary color inks to produce RGB color patterns.

3. Results and discussion

On the basis of the selective wetting process described in Fig. 1, we first examine how the wetting properties of a color ink vary with the dip-coating speed. We fabricated blue color patterns at four different dip-coating speeds of 50 mm/min, 100 mm/min, 200 mm/min, and 300 mm/min, respectively. The concentration of the color ink was fixed to be 35%. As shown in Fig. 2, the transmittance through a blue color pattern varies from 65% to 75% at the wavelength of 450 nm. This is because the thickness of the color pattern increases with increasing the dip-coating speed. Thus, our method provides a simple way of tailoring the spectral characteristics of the color filters.

We now examine the surface morphologies of the color patterns fabricated by the SWI technique. Figure

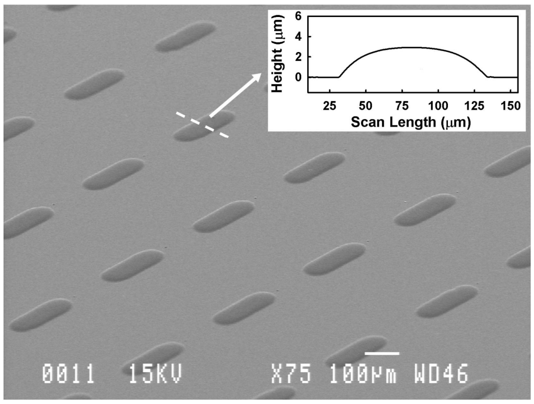

Fig. 3. A SEM image of the color patterns fabricated using the SWI technique. The inset represents the surface profile of a sub-pixel pattern.

3 shows the scanning electron microscope (SEM) images of the blue color patterns. The concentration of the color ink was 35% and the dip-coating speed was 200 mm/min. Clearly, a regular array of color patterns was produced. The width and the length of each pattern were 100 μm and 300 μm, respectively. The thickness of a color pattern was measured to be about 2 μm using a surface profilometer (Alpha-step 500, KLA Tencor Co.) as shown in the inset of Fig. 3. Note that by optimizing the viscosity and the evaporation speed of the color ink, the uniformity of the pattern thickness can be improved.

The most important feature of our technique is that the color patterns can be stacked in pattern-on-pattern fashion by successive coating processes. As shown in

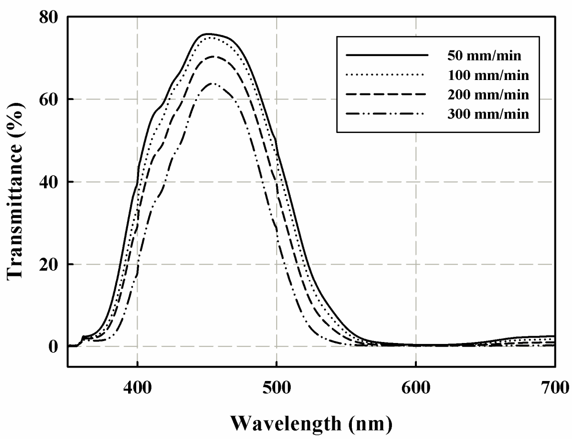

Fig. 2. Transmittance spectra of the blue color patterns fabricated under different dip-coating speeds.

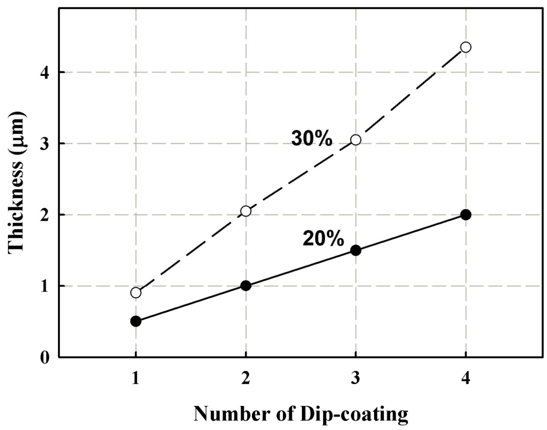

Fig. 4. Thickness of a blue color pattern as a function of the number of dip-coating process using color inks with two different concentrations of 20% and 30%.

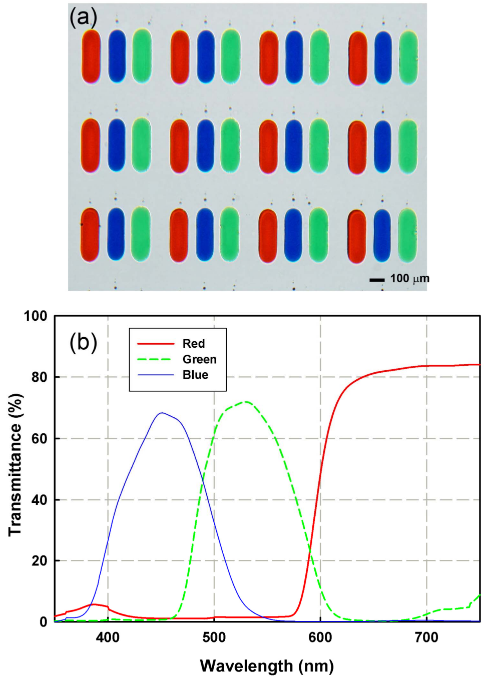

Fig. 5. (a) An optical microscopic image of the RGB color patterns fabricated on a glass substrate, and (b) transmittance spectra of the color filter.

Fig. 4, the thickness of a color pattern linearly increases with the number of the dip-coating and curing processes. This indicates that our fabrication method is applicable for high-resolution color filters that need high aspect-ratio patterns to obtain desired chromatic properties.

Figure 5(a) shows the optical microscopic image of the RGB color patterns produced on a glass substrate by sequentially applying the unit process. Well-defined and highly uniform RGB patterns were produced. Figure 5(b) shows the transmittance spectra of RGB color patterns. The transmittance of a blue color pattern was measured to be about 70% at the wavelength of 450 nm while those of green and red were higher than 70% at the wavelength of 530 nm and 610 nm, respectively.

4. Summary

We developed a selective wetting method of fabricating color filters through a simple coating process. The SWI on the hydrophobic layer provides precise self-generation and protection of color patterns without extensively using a wet chemical etching process. This method would be useful for low-cost and time-saving manufacturing of color filters for optoelectronic and photonic systems including information displays.

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5. References

1. R. W. Sabnis, *Displays*, **20**, 119 (1999).
2. K. Takanori, N. Yuki, N. Yuko, Y. Hidemasa, W. B. Kang, and P. G. Pawlowski, *Jpn. J. Appl. Phys.*, **37**, 1010 (1998).
3. P. Calvert, *Chem. Mater.*, **13**, 3299 (2001).
4. H.-S. Koo, P.-C. Pan, and T. Kawai, *Appl. Phys. Lett.*, **88**, 111908 (2006).
5. Y.-J. Na, S.-W. Lee, W. Choi, S.-J. Kim, and S.-D. Lee, *Adv. Mater.*, **21**, 537 (2008).
6. A. A. Darhuber, S. M. Troian, J. M. Davis and S. M. Miller, *J. Appl. Phys.*, **88**, 5119 (2000).