Novel Development of Electrowetting Display

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Abstract

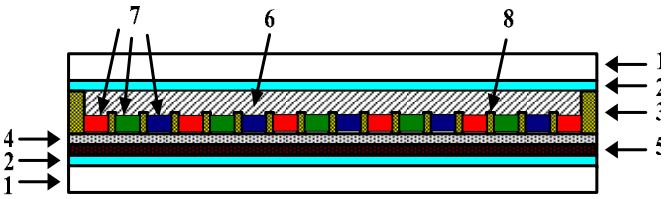
The 6- inch electrowetting display (EWD) can be successfully developed by ink jet printing (IJP) technique. Due to the drop-on-demand characteristic of IJP technology, colored oil can be precisely dosed into the unit pixel. Here, we present the active matrix EWD in this article. By adopting this technique to dose different colored oils, single layer Multi-color EWD without adopting color filter can be achieved in the future.

1. Introduction

In recent years, many different technologies have been proposed for use in reflective displays [1-5]. One of the emerging technologies is the electrowetting due to its high contrast ratio, video speed and low power consumption.

Electrowetting display (EWD) is first proposed by Hayes and Feenstra by manipulating the movement of the colored oil film with applying voltage [3]. For full color EWD, they proposed 1-layer and 3-layer architectures [4]. However, 1-layer architecture needs to adopt the RGB color filter which will reduce the optical performance of the display due to the light adsorption of the color filter, and for 3-layer architecture, complicated fabrication process is the drawback. To solve these issues, we proposed single layer multi-color EWD by dosing different colored oils with ink-jet printing (IJP) technique in the unit pixel individually. As shown in Fig.1, no need to use color filter of this display makes it have a better optical performance and easy to assemble. Based on the drop-on-demand characteristic of ink jet printing, the colored oil can be injected into the pixel separately and can reduce the waste of the colored oil.

In this study, we had tried to adopt the IJP technique to dose the blue, red, and black oils into the unit pixel of the panels, respectively, and the result evidenced that the IJP technique we purposed is very promising for EWD manufacturing. Also, a 6-inches active matrix EWD by using this technique had been showed to illustrate the potential of this technology for oil dosing. By adopting this technique to dose different colored oils, single layer multi-color EWD without adopting color filter can be achieved in the near future.



1. Substrate; 2. Electrode; 3. Sealant; 4. Hydrophobic layer; 5. Dielectric layer
6. Polar liquid; 7. Non-polar liquid ; 8. Hydrophilic rib

Fig. 1. Schematic diagram of 1-layer architecture reflective EWD without color filter.

2. Experimental

The EWD panels were fabricated in Gen. 2 LCD facility. First, SiNx layer was deposited on the 370 mm × 470 mm glass substrate (with TFT-array or ITO) by using PECVD, and its thickness is 1000Å. After that, the fluoropolymer with a thickness of 1500 Å was coated on the SiNx. After pre-bake of the fluoropolymer, a plasma treatment technique was adopted to improve the wettability and the adhension of the photo-resist solution to uniformly cover and spread on the surface of the fluoropolymer. After photolithography process, the hydrophilic rib was fabricated, and the rib height was 10μm. Afterward, the colored oil was dosed into the unit pixel cell accurately by ink-jet printing. Then, the water was dosed to cover the oil, and a second glass substrate with ITO layer was used to assemble the EWD panel [5].

3. Results

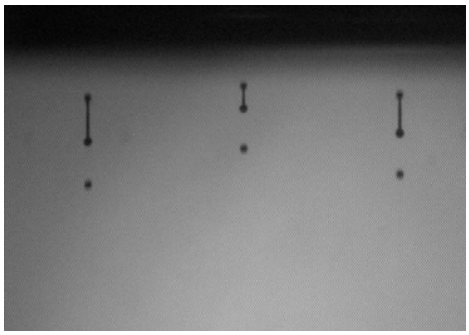
3.1 Oil dosing by ink jet printing

As we knew, fluid behavior of the colored oil usually affects the jetting performance of ink jet printing (IJP). The viscosity, surface tension, and the stability of the fluid are the key parameters for dosing the colored oil. Table 1 tabulates the criteria of the fluid behavior for IJP.

TABLE 1. Criteria of the fluid behavior for ink-jet printer

Fluid property	Preferred value/parameter
Viscosity	> 2 cps and < 20 cps of the ink Minimal viscoelastic and Newtonian behavior
Surface tension	> 20 dynes/cm and < 50 dynes/cm
Stability	Chemical stable
Boiling point	> 100^0C

(a)



(b)

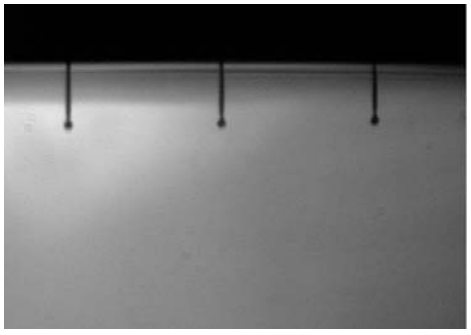


Fig. 2. Fluidic evaluation from the printing head. (a) before fine tuning and (b) After fine tuning the operation parameters of IJP facility.

After finishing the solvent selection to meet the above criteria, the dye was mixed with this solvent and stirred until the dye was completely dissolved. Here, we used tetradecane as the solvent.

Fig. 2 shows the fluidic evaluation before and after fine tuning the operation parameters of IJP facility. As shown in Fig. 2(b), regular and consistent jetting behavior can be made by fine tuning the operation parameters. Figure 3 shows the result of oil jetting into the unit pixel. As shown in Fig. 3, the distributions of the oil droplets are very regular and uniform. The drops of the colored oil did not contact or mix together. Also, the drop of the oil did not foul the hydrophilic rib. By noticing the criteria of fluid properties and fine tuning the operation parameters of ink-jet printer, single layer multi-color EWD without adopting color filter could be achieved in the future.

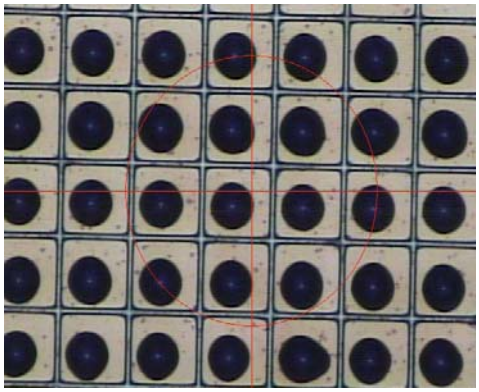
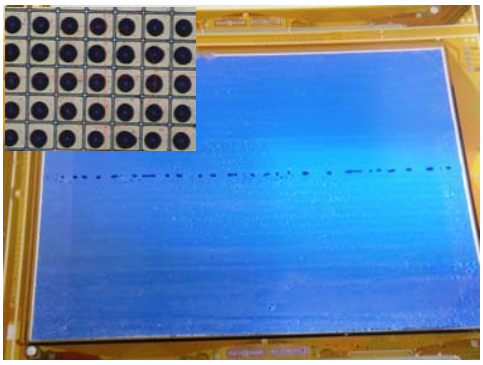


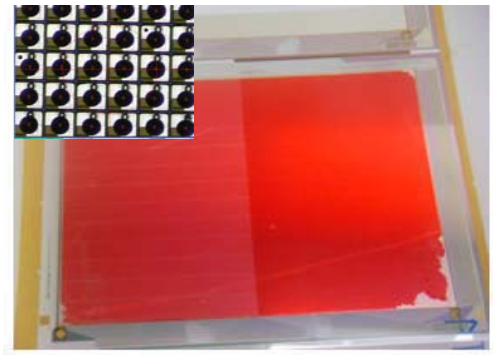
Fig. 3. The distributions of oil droplets in the unit pixel (pixel size: 151μm × 153μm) by using ink jet printing.

Fig. 4 shows the blue, red, and black color panels, respectively. By using the ink jet printing technique to dose the colored oils, various colored panels can be achieved. This result also evidences that the ink jet printing facility we used can fit the criteria of various colored oils. However, one thing should be noticed is that oils with different color dye or dye concentrations make the voltage applied on the piezoelectric film of the ink jet head need to be changed for jetting a better oil droplet. As the dye concentration of colored oil increased, the surface tension and the viscosity of colored oil will change. Thus, to obtain a well distribution and reduce the volume deviation of the oil droplet, the jetting performance for different color oil needs to be fine tuned with respect to the physical characteristic of the colored oil.

(a)



(b)



(c)

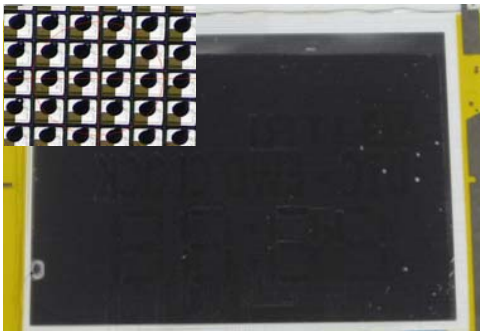


Fig. 4. Panels with (a)blue, (b)Red, and (c)Black colored oils dosed by ink jet printing technique.

3.2 Active matrix typed EWD

To evaluate the panel performance which used IJP technique for dosing the colored oil, an active matrix typed EWD was made. Fig. 5 shows the 6-inch active matrix typed EWD. The related specifications are shown in table 2. By applying the voltage, the oil can be pushed aside by the water and the aperture ratio of the unit pixels can be adjusted with regard to the different applied voltage. Thus, a picture image with SVGA resolution can be shown. This result implies that the IJP technology can dose the oil very accurately.

TABLE 2. Panel specifications of EWD

Color	Blue
Resolution	6-inch SVGA (800x600)
Pixel size	151 μm x 153 μm
Rib height	9~10 μm
Rib width	15 μm
Cell gap	100um
Aperture ratio	＞60%
Mode	Active matrix

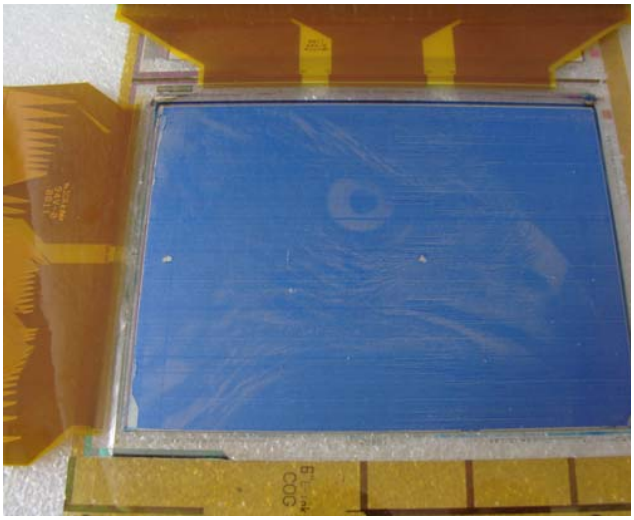


Fig. 5. The 6-inches monochrome AM EW panel

4. Summary

In this paper, we had successfully evidenced the potential of the ink jet printing technique. By this technique, various colored oils can be dose into the unit pixel of the panel precisely. Also, the 6-inches active matrix EWD was shown to evidence the ink-jet printing technique is very suitable for EWD fabrication. By fine tuning the operation parameters of the IJP facility and the ink jet head, various colored oils can be dosed into the unit pixel accurately. This result shows that, by adopting our proposed techniques, single layer multi-color EWD without color filter becomes possible and easy to commercialize.

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6. References

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