Flow Behavior of Micro Inkjet Drop on the Layer Surface of Micro Color Device

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Abstract

Flow behavior for micro liquid drop has been studied in the paper. First of all, some micro patterns were formed on flat surface of substrates specific. Note that the patterns could be either strip or rectangular block types where each micro block has hundreds of micro meters (µm). Then the liquid drop having volume of less than 100 pico-liters could be shot by an inkjet print head of printing robot. Thus, by varying the geometrical structures of those blocks, the inkjet flow behavior can make difference on the layer of substrate. With the fundamental of micro flow behavior, it could help applying the inkjet technology onto the color (Red, Green, Blue) coating process of micro substrate, such as color filters and PLED devices. Hence, it's expected that those industrial application of opto-electronic devices by inkjet method will be pretty promising in the near future.

Introduction

Flow behavior in micro scale ranging from micro-meter (µm) to sub mini-meter (mm) is much of interest in the paper. Particularly, while applying individual micro liquid drops to form one micro flat coating layer of substrate (in general, the coating thickness is approximately 1µm left), how the liquid flows on or in the surface actually determines the final quality of coating process. Hence, understanding the essence of micro flow behavior truly helps how to design one fine coating thin layer in many jetting applications, such as color filters of LCD (Liquid Crystal Display) panels, Polymer LED (Light Emitting Display), and so on.1

It is first noted that there have already been several papers in last decades studying the impact situations when one jetting drops falling on the surface.[2,3] Those studies indicated that either deposition or splash could happen on those impacts. However, since the splash may cause serious color defects in jetting applications, only the deposition is of interest in our study. Secondly, during the very short period of deposition, the dominant physical parameters for the liquid should be identified which could include surface tension and viscosity of drops. Finally, the conditions of layer surface also could decide the eventual result of flow behavior. Its effect may be so significant that proper treatment for the surface should be carefully considered. These factors concerning the flow behavior will be described for details in the following sections.

Flow Behavior on the Surface of Substrate

Substrate of Micro Color Device

In a typical flat panel display (FPD), one color filter (CF) substrate is generally required to transform the white light into three colors of red(R), green (G), and blue (B). Its basic configuration can be shown in Figure 1.

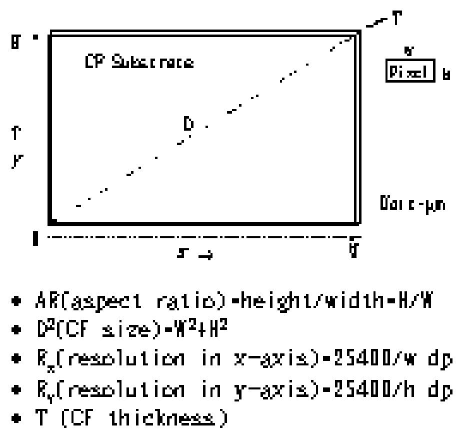

Figure 1. Configuration of Color Substrate

Meanwhile, it is noticed that one tiny pixel is comprised of R, G, and B color block by definition. Additionally, each color in one pixel is spaced with one black matrix (BM). Therefore, the width of one pixel will be the sum of width of the three colors and three BMs. It is clear that lesser width of pixel will give higher resolution in the x-axis of Figure 1. Similar results can be found in the y-axis of Figure 1. In general, the width of pixel is approximately hundreds of micro-meter (µm) as a so-called micro color device.

For example, the typical specifications can be given as shown in Table 1.

Table 1. Specifications of color substrate

Our Specifications:

- AR=H/W=3/4
- D=10.4 inch
- W=300 μm
- R_x=25400/300=85 dpi
- R_y=25400/300=85 dpi
- T =700 μm
- W_R=W_G =W_B=80 μm
- W_K=20 μm
- t=1 μm

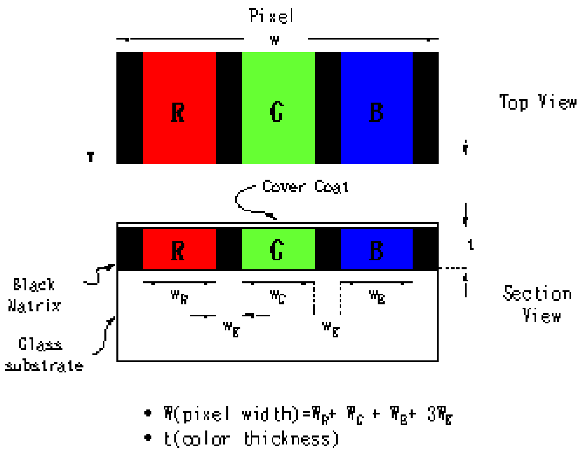

Figure 2.Tiny Structure of Pixel

In addition, for our interest of paper, the corresponding structure of pixel can be shown in Figure 2.

There are several methods already invented to fabricate the micro color device in the last 20 years.[4,5,6] Instead of those methods, the jetting method will be explored as follows in the study.

Inkjet Printing Method

Inkjet technology has been already invented more than 20 years and is currently getting more and more significant influence on the printing industry.7 One tiny ink drop with volume ranging from hundreds of pico-liters to several pico-liters can be easily generated by drop-on-demand (DOD) type of print head, in either thermal bubble or PZT ways. It is important to notice that the scale of micro ink droplet seems to match very well with the scale of forementioned color pixel of the device. Therefore, it is quite interesting to motivate us to try applying the inkjet printing method onto the fabrication. With careful consideration of scale matching for the diameter of droplet and width of each color pixel (R, G, or B), the jetting flow by one print head can be reasonably described as shown in the Figure 3.

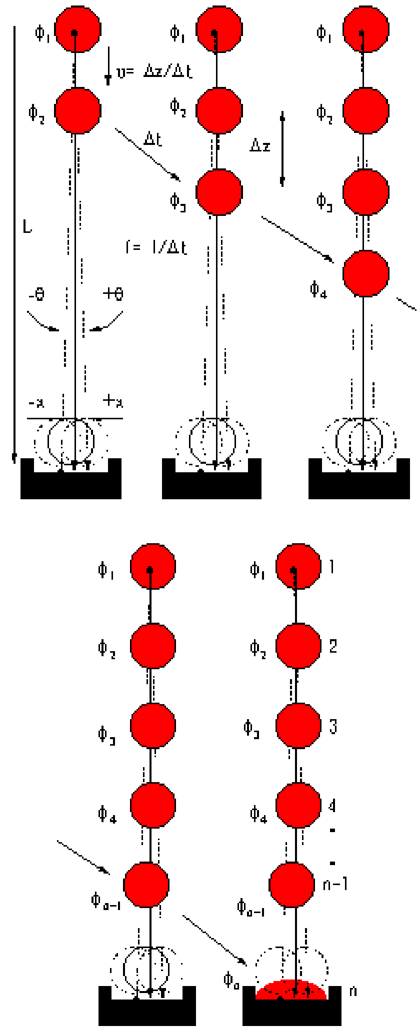

Figure 3. Jetting Flow by Inkjet Print Head

There are five picture frames presented in the physical model of Figure 3. Meanwhile, each frame is showing the drop behavior during the short flying period (e.g. several mini-seconds). It should be pointed out that the deviation of positions among those droplets could always occur due to the uncertainty of shooting angles generated in nature. Consequently, it's important to predict and control the tolerance of variation of position.

More importantly, what we are interested in is to explore that flow behavior after these droplets impact the surface of color device. It's depicted in the last picture frame of Figure 3. We should notice herein that the properties of droplets (such as surface tension and viscosity) and the conditions of layer surface would decide the eventual result of flow behavior after the impact. These results could mainly divided into two catagories in terms of conditions of the surface, i.e. surface with receiving layer and surface without receiving layer, individually.

Surface with Receiving Layer

When the surface is coated with one receiving layer, the color droplet could impact on the receiving layer and penetrate into the layer in very short time and very short distance. In the case, the dominant property would be color concentration of the layer and droplet. In other word, the diffusion is the key to coloring, and is well expressed by Fick's law of Equation 1 as shown.[8]

$$J=-D\times(\partial C/\partial x) \quad (1)$$

where J=particle flux, in particles/(m^2s)
D=diffusion coefficient, in m^2/s
C=concentration, in particles/m^3

It's importantly noted that since the diffusion acts in quick time and short distance, uneven coloring may possibly happen. For example, one design pattern of micro color device is depicted in Figure 4. As a result, its experimental simulation on general inkjet transparency by a CMY (Cyan, Magenta, Yellow) color head was made in Figure 5. Although the quality is not good, it's explicitly shown the diffusion effect therein.

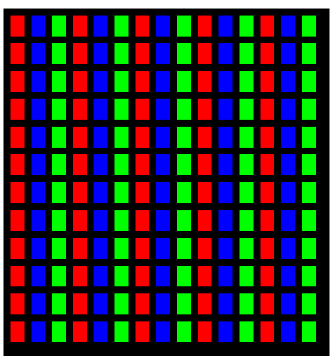

Figure 4. Design Specified for Micro Color Device

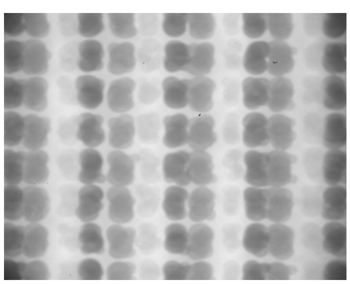

Figure 5. Printing Result for Micro Color Device

Surface without Receiving Layer

When the surface is clear without any receiving layer, the color droplet could freely flow and move on the surface in longer time and larger distance than previous case. In the case, the dominant property would be surface tension of the layer and droplet. In other word, the capillary force driven by the surface tension is the key to coloring, and is well expressed by Equation 2 as shown.[8]

$$F=2\pi r\times\gamma\times\cos(\theta) \quad (2)$$

where F=capillary force, N
r=radius of contact, m
γ=surface tension, N/m
θ=contact angle

It's noted that since the surface tension acts in longer time and larger distance, the coloring layer might be much more even than that of previous case. Moreover, it seems more promising that the strip block of coloring path could be used to eliminate the possible defects caused deviation of positions of droplet. Those results could be predicted with better quality than those with receiving layer if no color mixing happens.

Conclusion

The paper first quickly reviewed the configuration of the display panel related to micro color devices; and some typical specifications were pointed out subsequently. Then, based on the fundamental principle for the inkjet print head, the jetting process has been explored and built up. Hence, by applying the physical model, the two main types of flow behaviors have been explored in the paper, including flow behavior on the surface with receiving layer and flow behavior on the surface without receiving layer. In short, the main result of study can be summarized as follows: (1) flow behavior on the surface with receiving layer: the dominant property would be color concentration of droplet on the layer. In other word, the diffusion is the key to coloring (2) flow behavior on the surface without receiving layer: the dominant property would be surface tension of droplet on the surface. In other word, the capillary force driven by the surface tension is the key to coloring.

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Biography

Chin-Tai Chen received his B.S. degree in Engineering Science from the National Chung-Kung University at Tainan of Taiwan in 1992 and an Engineer Degree in Aeronautics & Astronautics from Stanford University at Palo Alto of USA in December,1997. Since 1998 he has worked at Optics-Electronics & System Labs of Industrial Technology Research Institute in Hsinchu, Taiwan R.O.C.. His work has primarily focused on the system integration of thermal inkjet printer, including mechanical design, ink cartridge, ink supply system and pressure control issues.

Tz-Ya Yang received her B. S. degree in 1995 and M. S. degree in 1997 both in Mechanical Engineering from National Chiao Tung University in Hsinchu, Taiwan. She is now a mechanical engineer in the Printing Technology Division, Optics-Electronics and Systems Laboratories of Industrial Technology Research Institute in Hsinchu, Taiwan. Her researches include media-handling mechanism design of ink-jet printer and manufacturing process of color filter by ink-jet method.