Research on Design Electrode Channel in Microfluidic Chip

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Abstract. In recent years, microfluidic chips have been widely used in food safety, environment detection, clinical diagnosis and biochemical. However, Digital microfluidic chips(DMF) are attracting more and more eyes because picoliter-microliter-sized sample droplets can be accurately and automatically manipulated. In this paper, a method of design electrode channel height is studied to improve the efficiency of the voltage driving.

1. Introduction
As the development of MEMS technology and the interinfiltration between different subjects, the Lab-on-a-chip(LOC), which realizes the full auto-process and auto-analysis on a single chip, has attracted our attention in the future. Electrowetting-on-dielectric(EWOD)based digital microfluidics has been widely searched due to its unique advantages such as simple structure, simple operation and strong capability[1]. The theory of EWOD is shown in Fig.1, which obviously is accepted by us with the structure. The channel height between electrodes is an important part. Traditional chip still has low separation efficiency, high voltage, and poor accuracy, which limited the application and development. The digital microfluidic chips include electrode, dielectric material, hydrophobic layer and droplets. The factors affecting the performance of chips are above these. However, the channel height(d) and electrode size(L) are related to the voltage. According to driving theory, the contact angle hysteresis phenomenon required increased voltage value to drive the drops. So the advanced forum occurred. The separate voltage limit forum is about changing into like this in (1). The voltage must increase with the result of d/L with other conditions unchanged[2]. The material of dielectric layer was also related to the voltage. And the material of dielectric constant can be selected to reduce the voltage.
Figure 1. Structure of EWOD Chips

\[
v^2 - v_T^2 = \left( \frac{1}{R_2} - \frac{1}{R_1} \right) \frac{2 dt \gamma l \delta}{\cos \alpha \varepsilon R \varepsilon_0 d}
\]

In (1-1), \( \gamma l \delta \) means the surface tension, \( V \) means the electric potential, \( V_T \) comes from the threshold voltage, \( D \) is the channel height, \( R_1 \) and \( R_2 \) are the radius of curvature, \( \varepsilon_0 \) is the dielectric constant of vacuum, \( \varepsilon_r \) means relative dielectric constant of dielectric layer, \( \alpha \) is behalf of surface angle, \( t \) equals the thickness of dielectric layer. Suppose \( R_2 \approx L/2, R_1 \approx L (N^*+1)/2 \), so

\[
v^2 - v_T^2 \approx \left( 1 - \frac{1}{N^*+2} \right) \frac{4 dt \gamma l \delta}{L \cos \alpha \varepsilon R \varepsilon_0}
\]

The \( N^* \) means the numbers of electrode which are divided from one drop, \( \alpha \) and \( \gamma l \delta \) are related with the environment, the only reason influenced voltage is the value of \( d/L \).

According to the former different electrode shape design, the triangle interdigitated finger electrode was better than the rectangular interdigitated finger electrode design effect in Fig.2[3]. It showed higher voltage driving ability and driving speed. From another way, we can get the result that the sharper corner of triangles has, the smaller gap between electrodes. Even though there are various types electrode edge design, the practical application design mainly focuses on the normal electrode shape, such as rectangular electrode. How to improve the rectangle electrode voltage driving ability and speed? How to avoid the influence coming from the channel height?

Figure 2. Different Volumes of Droplets in Triangle and Rectangle Electrode

Many research and patent did studies on this filed[4]. The rectangle steps produced through making process in Figure.3(left) The gap is so big that the droplet moving efficient got influence. With the development of manufacturing process in EWOD, the dielectrode film mulching in Figure.3(right) is used to reduce the steps of channel height to make it smooth. So that the driving speed and ability are better than the left method.
In this paper, the author wants to try a novel way to change the producing process, which maybe simple the technology, reduce the cost and get high benefit.

2. Experiment

Most EWOD chips set the dielectrode layer on the electrode layer in Fig.4[5]. So the channel height will produce following the electrode inks thickness[6].

According to the original thinking, normal and complex pattern are designed with the software Adobe Illustrator. There are same channel sizes among the normal rectangle electrodes. The distance is about 0.3mm, the electrodes sizes are about 2-4mm, so the microscope image pattern is very visible in Fig.5. In order to consider different kinds of designs as totally as possible, the novel pattern electrodes are designed in Fig.5 (right). The pictures are used to test the dieletrode layer uniform. The electrodes edge has narrow or wide gap. They look so complex that it is difficult to set the guide line from the electrode.

The purpose of next process is to output these patterns on the basement layer. To keep the dielectrode layer uniform, printing the designed patterns on the prepared dielectrode layer is a creative method to solve these questions such as gap size effect, driving speed and driving ability. For complex pattern, another way to set guide line to power from electrode edge is to design a new layer under electrode layer which avoid circuit shortcut in Fig.6. The top layer means hydrophobic layer, the second layer means dielectrode layer, the bottom layer three rectangles mean electrodes.
Figure 6. Relationship with Hydrophobic, Dielectrode and Electrode Layer

3. Analysis and Conclusion

In this paper, the experiment was printed with Inkjet printer (Dimatix 2831) for test. With different purposes design, the electrodes printed into PI film such as three layers in Figure 7.

![Figure 7. Printing Sample](image)

In order to verify the effect on different between droplet sizes, various droplets sizes should be used as Diameter A=0.6mm, B=0.8mm, C=1.00mm, D=1.20mm and E=1.40mm with gap size as 0.3mm and 0.6mm to test the driving speed in Figure 8.

From the Fig.7 analysis, we found that new way to print electrode on the back side of dielectrode
completely missed the step influence. Then the channel gap couldn’t take any effect on driving ability. The data showed that driving speed is suitable to the voltage variable. The droplets driving speed isn’t linear to the gap size change.

This paper only compare limited filed to prove the channel size influence, offer one way to set electrode on the back of dielectrode layer because of search time. In fact, we have more ways to compare to solve the possible question. One is to fill the gap between electrodes with normal ink to ensure the surface smooth. The other way is to think about the normal ink layer with hole to link the electrode and guide line to power. We will discuss in the future. The purpose in this paper to try the novel way is to use better produce process to improve the electrode accuracy and channel gap, so the droplets size will be researched and developed to meet the volume of the business requirement.

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4. Reference
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