정전기력 잉크젯의 Ground 위치에 따른 DOD 분석
Drop Demand Analysis of Electrostatic Inkjet Considering Ground Position Effects

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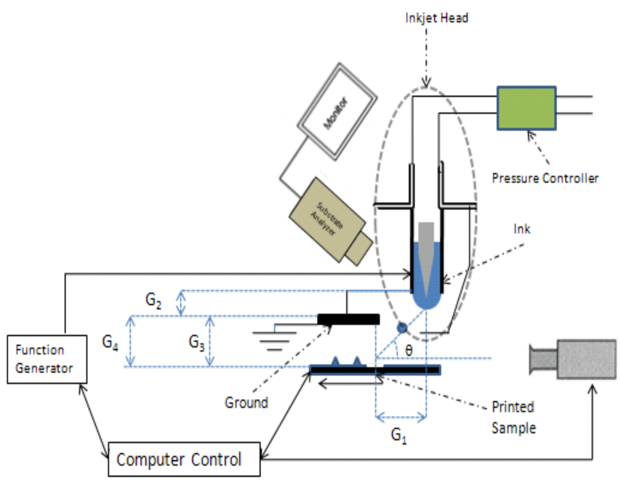
1. Introduction

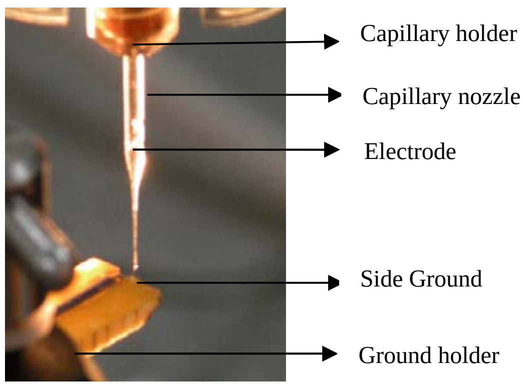
There have been growing interests in direct patterning of metallic contents on the surface of the substrate without including complex steps of the micro fabrication lithography process [1, 2]. The direct fabrication process using ink-jet printing can be expected to be a powerful tool for both nanotechnology research and applications such as micro electronics. The electrostatic inkjet system has a huge number of applications in terms of cost reduction and time effected manufacturing of printed electronics like RFID, electronic devices and flexible display, solar cell, sensors etc. Inkjet printers operate by propelling small size droplets of conductive ink onto the substrate. To be used for additive manufacturing, the liquid droplets must contain nano-particles. The ink is forced through a small orifice with the help of electrostatic forces by countering internal forces.

For experimental purpose, an integrated electrostatic inkjet nozzle head was fabricated. For the charging of ink meniscus, an electrode is inserted inside the nozzle head containing conductive ink. The difference between the charged meniscus and ground electrode depends on the ink properties like surface tension, viscosity and number of metallic pigments. Therefore, for the extraction of droplets, a side pin type ground terminal with adjustable electrode is employed. The paper is focused on the drop on demand behavior of metallic ink between the terminals of integrated electrostatic inkjet nozzle head and different parameters like meniscus shape and reduction in the satellite drops are being evaluated through experiments. Material handling through electrostatic droplet manipulation technique, with high precision, is of paramount importance and is powerful technique that has received interests in the recent years in fields; like protein crystallization, drug discovery, printed electronics, solar cell etc [3].

2. Experiment setup



(a)



(b)

Figure 1: (a) Schematic diagram of the electrostatic contactless printing system (b) shows the physical setup of the nozzle head

The experiment setup and print head driven by on demand electrostatic forces is shown in the figure 1. Glass capillary is used for this setup having orifice of 80 µm and with hole type structure [4] having electrode size of 50 µm. The apparatus consists of X-Y stage, electrodes, a high voltage source, an observation system, ink supply system, and nozzle holder with z-axis control. The two types of electrodes were used for the ejection of droplets are: the actuating electrode and ground electrode.

The ground electrode is connected to the negative potential of the high voltage source and the other potential in the nozzle head for activating the ink and providing the necessary potential to the ink in the nozzle head for the drop extraction and charging of the ink. To control droplet ejection, the square wave form is applied between the nozzle head and the ground electrode to develop extraction potential. The duty cycle maintained 50% at all frequencies.

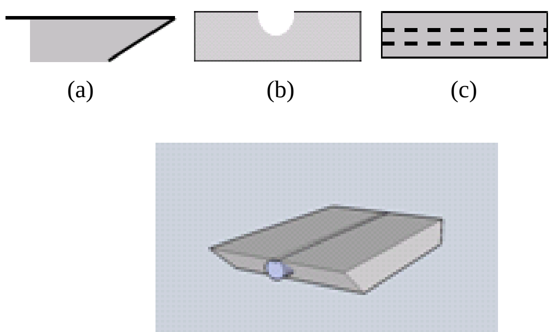


Figure 2: (a) side view of the ground shape where the black line representing the electrode line (b) the cross-sectional view of the ground (c) the top view of the ground where dotted line indicated the cable and (d) shows the 3D overall schematic of the ground electrode.

The schematic 2-D and 3-D diagram of the side ground is given in the figure 2. The model is built on the thick layer of epoxy plate. The epoxy plate is curved out from the center of the plate as shown in the figure 2a. The conductive wire is inserted to act as the ground and to make it stable it's glued on the surface of the epoxy plate.

For observation purpose, ITI drop watcher® with modified structure is used. The zooming magnification of lens is 0.75X to 4X or with high-magnification option 2.5X to 10X with frame rate of 30 frames per second. And for drop on demand analysis a high speed camera is also attached to further investigate the behavior of the meniscus and drop shape.

For experiment purpose, commercial available natural mineral water being used. The properties of the water used as ink composed of Calcium (Ca) , Potassium (K), Sodium (Na) and Magnesium (Mg) contents with a ratio of 2.2~3.6, 1.5 ~ 3.4 mg/L, 4.0 ~ 7.2 mg/L and 1.0 ~ 2.8 mg/L respectively. The liquid pressure is controlled by using the pressure injection pump. The inlet flow rate is an important parameter to maintain the uniform static pressure in the ink chamber when the reservoir head is changing due to the ejection of ink during the printing process. After developing the meniscus, the result is analyzed to find the optimal values for the given nozzle. This is done by applying different voltages and different freqeuncies unitl optimal position of the jetting volatge point is determine.

3. Experiment

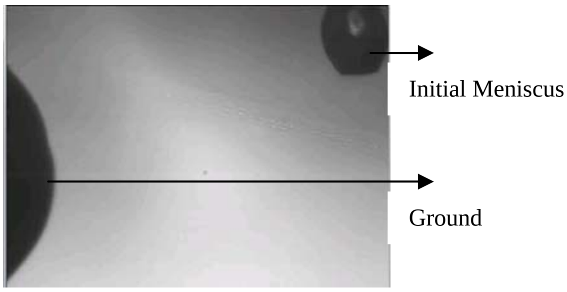


Figure 3: The initial meniscus and electrode position.

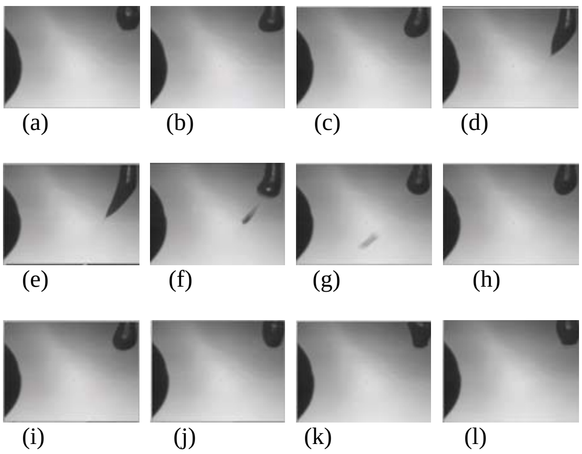


Figure 4: Time line of ejection of droplet.

In the experiment the focus was kept to the drop on demand generation of droplet and the shape of the meniscus before and after the droplet generation. The initial shape of the droplet is given the figure 3. The complete behavior of the droplet generation is also summarized in the figure 4. The figure 4 (a) represent the initial conditions when the applied voltage is zero. Figure 4 (b) shows the starting behavior of the droplet when the initial charging is taking place. It's important to mention here that for providing the electrostatic voltage a square wave of 500 volt is used with the offset voltage of 1.1 kV DC offset voltage for the charging of the ink and stabilization of the meniscus before making drop ejection. The duty cycle of the wave kept around 50%. After the application of applied voltage the meniscus change the shape as shown in the figure 4(b) to figure 4(d). As the applied electric pulse stabilize the drop ejection process also get stable and the drop ejected as the figure 4 (e) to figure 4(g) represents. Figure 4(h) to figure 4(k) shows the stabilization of the meniscus. The recoil process of the meniscus is also given in the figure 4(k). It can be seem that even after recoil of the meniscus and vibration of the meniscus no satellite drops emerges. The time required for the drop generation and the stabilization of the meniscus is almost the same which also indicates the stabilization of the process on the specific input to output. The other results of the study will be disclosed somewhere else. The angular voltage parameters also reduce the satellite drops to reach the surface of the substrate, as if the smaller drop is charged then due to less mass it will approach the ground instead of the substrate and if the satellite drop is uncharged, then it will move straight towards the collector direction where a gutter is being used to stop it to reach the surface of the substrate as shown in the figure 1 (a). The two effects mentioned above can also be used to enhance the quality of the drop on the surface of the substrate.

4. Conclusion

In this paper, a new approach for electrostatic drop on demand electrostatic inkjet s studied and experimentally verified. The idea is to make positive potential nozzle and ground integrate to each other so that it can be use in a single package. This study will help in development of the integrated electrostatic inkjet head. For electrostatic inkjet, the major problem is to reduce the satellite drops and deposited the drops on the required surface. This technique will help in deposition of the drops on specific position and the drop position can also be control by using providing different level waveform to the active meniscus. More study on the above mention technique can help in developing a precise nozzle head.

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