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Analysis of meniscus less electrohydrodynamics-patterning of metallic ink through standard tapered tip needle

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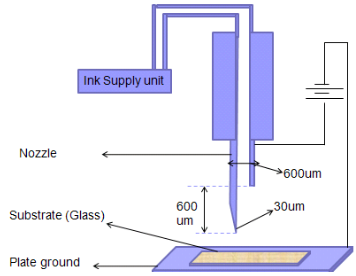
1. Introduction

Contactless drop-on-demand deposition method of different materials is very appealing technique to fabricate different nano and micro level electronics and electrical patterns on any substrate. This technique has advantages over conventional photolithography technique in source dissipation and energy level. It requires no physical mask, less environmental issue, low fabrication cost and provides good layer-to-layer registration [1, 2]. Most commercial and industrial drop on demand deposition schemes use piezoelectric element or tiny electrically driven thermal chambers to produce the drop-on-demand droplets to generate desired image or printed lines. But the aforementioned manufacturing technologies have certain commercial bottlenecks with regard to printing frequency, clogging, maintenance, steps and resolution in terms of device manufacturing. Electrostatic inkjet technology seems to be a promising technology as electrostatic inkjet printing system has advantages over other types of the inkjet (piezo, thermal) printing techniques in size of fabricated device and precision in extraction. The electrostatic forces enable the system to overcome the mechanical actuation which often requires high fabrication cost, actuation limitation and integration problems to produce printed electronics and electrical patterns at higher frequency rate. Thus, the direct fabrication process using electrostatic inkjet printing can be expected to be one of the dominant tools for both nanotechnology research and electronic applications such as microelectronics [3]. With the inception of printed electronics and microfluidics, the electric force has been exploited as one of the leading mechanisms for driving and controlling the movement of the operating fluid (electrohydrodynamics) and the charged suspensions (electrokinetics) [4]. Electrostatic mechanism also prevents the absorption, density loss, and colorant-related stability problems found in other contactless fabrication apparatus [5]. 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.

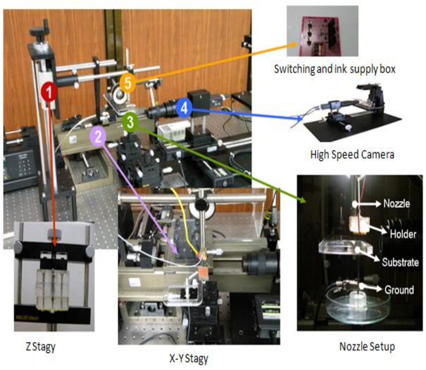
This paper analysis and shows the results of standard tapered tip needle head. The experiment setup and head design section will elaborate the experiment setup and head parameters. Experiment analysis section highlights the experiment conducted and the results obtain through it. And it's found that this type of head breaks surface tension and reduces the effect of applied force.

2. Experiment setup and Head design

For experimental purpose, pin to plate electrostatic inkjet nozzle head was fabricated. For the charging of ink meniscus, a commercially available tapered metallic capillary is used. The difference between the charged meniscus and ground electrode depends on the ink properties like surface tension, viscosity and number of metallic pigments. The paper is focused on the jetting behavior and pattering through head.



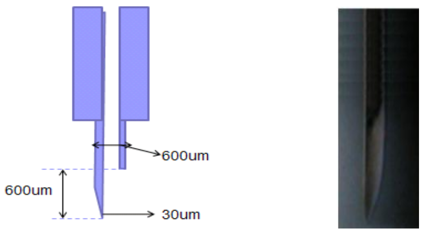
(a)



(b)

Fig. 1 (a) Schematic diagram of the electrostatic contactless printing system (b) shows the physical setup.

The experiment setup and print head driven by on-demand electrostatic forces are specifically designed for this study. The apparatus consist of X-Y stage, electrodes, a high voltage source, an observation system, ink supply system and nozzle holder with Z-axis control. Schematic diagram of the electrostatic contactless printing system is shown in the figure 1. The ground electrode is connected to the negative potential of the high voltage source and the positive potential is connected to the nozzle head for activating the ink and providing the necessary potential to the ink in the nozzle head for the drop extraction. To evaluate the stable wetting after meniscus, DC waveform is applied. After developing the wetting layer, the result is analyzed to find the optimal values for the given nozzle. This is done by applying different voltages until optimal position of the voltage point is determined. After obtaining the optimize DC waveform for stable meniscus, the square (rectangular) wave form is applied between the nozzle head and the ground electrode to develop extraction potential for controlled droplet ejection. For experiment purpose, dielectric, particle based conductive and non particle based conductive solution is used. The properties of the inks are listed in table 1. 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, to stop the back flow in the ink chamber and to maintain the ink status in the reservoir of the head, when it is changing due to the ejection of ink during the printing process. For observation purpose, ITI drop watcher® with modified structure is used. For observation purpose, high speed camera having 5000 frames rate is used. The lens magnification is kept 11X.



(a) (b)

Fig. 2 (a) Schematic diagram of the electrostatic contactless nozzle (b) shows the physical model of the nozzle head

Table 1. Ink Properties

S/N	Properties	Values
1	Glycerol (wt%)	37.5
2	Conductivity (μS/cm)	58
3	Surface tension(dyn/cm)	33.7
4	Viscosity (cp)	12.3

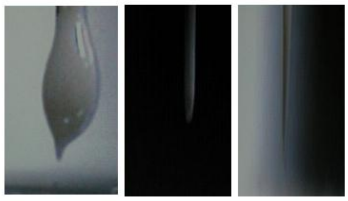
The print head driven by on demand electrostatic forces is shown in the figure 2. The one side of metallic capillary is longer than the other one. The extension is 600um is longer. And the tip of the nozzle is 30um. For experiment purpose, ink is used. the properties of the ink are given in table 1. 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.

Table 2. Testing parameters

Properties	**Values**
Voltage range (kV)	0.5 to 5
Setup configuration	Pin to plate
Voltage form	DC
Flow rate (μl/hr)	50
Distance between Nozzle tip and electrode	>200 um
Temp	Room Temp
Substrate	Glass

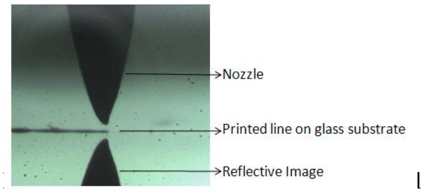
3. Experiment analysis

In the experiment the focus was kept to the jet generation and the shape of the meniscus before and after the droplet generation. The initial shape of the droplet is given the figure 3. The pattern behavior is also summarized in the figure 4. The figure 3 (a) represent the initial conditions when the applied voltage is zero. Figure 3 (b) shows the starting behavior of the droplet when the initial charging is taking place. It's important to mention here that for jetting, DC wave of 2.8kV is used by maintaining flow rate of 50 μl/hr. The head is also tested on glass substrate as shown in figure 4 and figure 5 on a speed of 1mm/sec.



(a) (b) (c)

Fig. 3 Initial meniscus and printing wetting



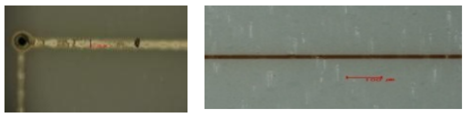


Fig. 5 Printed metallic lines.

4. Conclusion

The paper shows a new approach for electrostatic printing by using wetting behavior for electrostatic inkjet, experimentally. In meniscus based electrostatic inkjet system, due to backflow, it's very hard to print for longer time with uniformity and meniscus is highly sensitive to any external noise. This study will help in development of the 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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