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Effects of nozzles array configuration on cross-talk in multi-nozzle electrohydrodynamic inkjet printing head

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ABSTRACT

This paper presents the analysis of a triangular array of nozzles in a multi-nozzle electrohydrodynamic (EHD) inkjet printing head. A methodology has been proposed to minimize the “end effect” by changing the traditional linear array of nozzles to triangular array of nozzles in multi-nozzle EHD printing head. Interaction (cross-talk) between the electrically charged neighboring jets is investigated and analyzed both numerically and experimentally using three glass nozzles with independent voltage connections and independent ink supply to each nozzle. In order to scrutinize the performance of triangular array multi-nozzle EHD inkjet printing head, comparative study of triangular array multi-nozzle EHD inkjet printing head to the linear array multi-nozzle EHD inkjet printing head has been made on the basis of electric field simulations and experiments. Experimental results illustrate that in triangular array multi-nozzle EHD inkjet printing head, the over potential requirement is low and individual capillaries are operating with more independence as compared to linear array multi-nozzle EHD inkjet printing head.

1. Introduction

Electrohydrodynamic atomization is a well-established phenomenon, applicable to many areas, such as mass spectroscopy [1], micro colloid thrusters [2,3], automobile painting [4], thin film deposition [5] and inkjet printing technology [6]. When a liquid having sufficient conductivity is supplied to a nozzle, where it is charged to a sufficiently high electrical potential so that the liquid meniscus forms the shape of a stable cone, whose pinnacle emits a small jet as compared to the nozzle orifice. This stable cone is known as Taylor cone. Electrohydrodynamic inkjet printing is a printing method using this small emitted jet from the apex of Taylor cone [7]. Though deposition by electrohydrodynamic inkjet printing process offers various advantages in fine patterning because blockages are prevented and the highly viscous colloidal solutions containing solid particles can be easily processed [8,9]. However, since electrohydrodynamic jet exhibits a monotonic reliance of droplet size on flow rate [10–12], therefore if small droplets or jets are desired then this low production speed of electrohydrodynamic inkjet printing is a severe drawback that has hampered its widespread applications in printed electronics industry [13].

In order to surmount the limitation of low throughput and attain a large-area electrospray deposition process for industrial production, a multiplexed electrospray deposition process has been primarily investigated by many scientists [14–25]. Similarly for development of high production efficiency EHD inkjet printing process in printed electronics industry, recently various researchers have centered their attention on multi-nozzle EHD inkjet printing head design [26–30]. In order to apply multi-nozzle EHD inkjet printers to industrial printing tasks such as in printed displays, printed circuit boards (PCB) and printed solar cell fabrication, a multi-nozzle electrohydrodynamic array of jets must be precisely controlled for simultaneous printing. However, the interaction between the neighboring jets is the main encumbrance to this objective. This interaction breeds the asymmetric electric field at the tip of the nozzles, eventually destabilizing the resulted jets [19,20]. While operating the multi-nozzle EHD inkjet printing head, two problems were commonly encountered by many scientists. First is the “end effect”, which represents the meniscus deflection at the boundary nozzles of a linear array due to asymmetric electric field and repulsive forces between adjacent jets [12,18–20,26,27]. It defectively affects the accuracy and repeatability of multi-nozzle EHD Inkjet printing head, making it impracticable in printed electronics industry. Number of researchers [12,19,20,21,26] tried to resolve this problem by inserting dummy nozzles at the ends of a linear array multi-nozzle head. Though they were able to reduce the

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Table 1
Types of fabricated multi-nozzle EHD inkjet printing heads.

No.	Array configuration	Nozzle-to-nozzle distance (mm)
1	Linear	5
2	Linear	3
3	Triangular	5
4	Triangular	3

deflection of meniscus up to some extent, yet this technique is only valid when metallic capillaries are used, which itself enhances this "end effect" [26]. Secondly due to the electric shielding, the center nozzles require high electric potential to craft a specific form of cone-jet as compared to the end nozzles i.e. the onset voltage is not the same for all the nozzles [22,31]. Moreover in case of multi-nozzle EHD inkjet printing process, the required onset voltage for stable cone-jet formation is high as compared to the single nozzle EHD inkjet printing process. This over potential requirement increases with the decrease in space between the adjacent nozzles [19].

In order to resolve the above mentioned issues and minimize the over potential requirement, a novel nozzles array has been proposed by introducing a triangular array of nozzles instead of using conventional linear array of nozzles in multi-nozzle electrohydrodynamic inkjet printing head. The performance of triangular array of nozzles is investigated both numerically and experimentally by comparing it with linear array of nozzles. For comparison of both array configurations, 3-D electric field simulations and different sets of experiments were performed keeping all the operating parameters constant except the array configuration. Paper is divided into different sections. Sec.2 is further divided into two subsections; first it describes the steps involved in fabrication of multi-nozzle EHD inkjet printing head and then the experimental setup. Sec.3 is about the electric field simulation. Sec.4.1 elaborates the "end effect" and analyzes experimental results as well as numerical results. Sec.4.2 discusses the effects of array configuration on onset voltage and over potential requirement in multi-nozzle EHD inkjet printing head.

2. Experimental details

2.1. Multi-nozzle EHD inkjet printing head fabrication

In all the experiments, laboratory fabricated nozzle holders of poly di-methyl siloxane (PDMS) were used. Following the soft

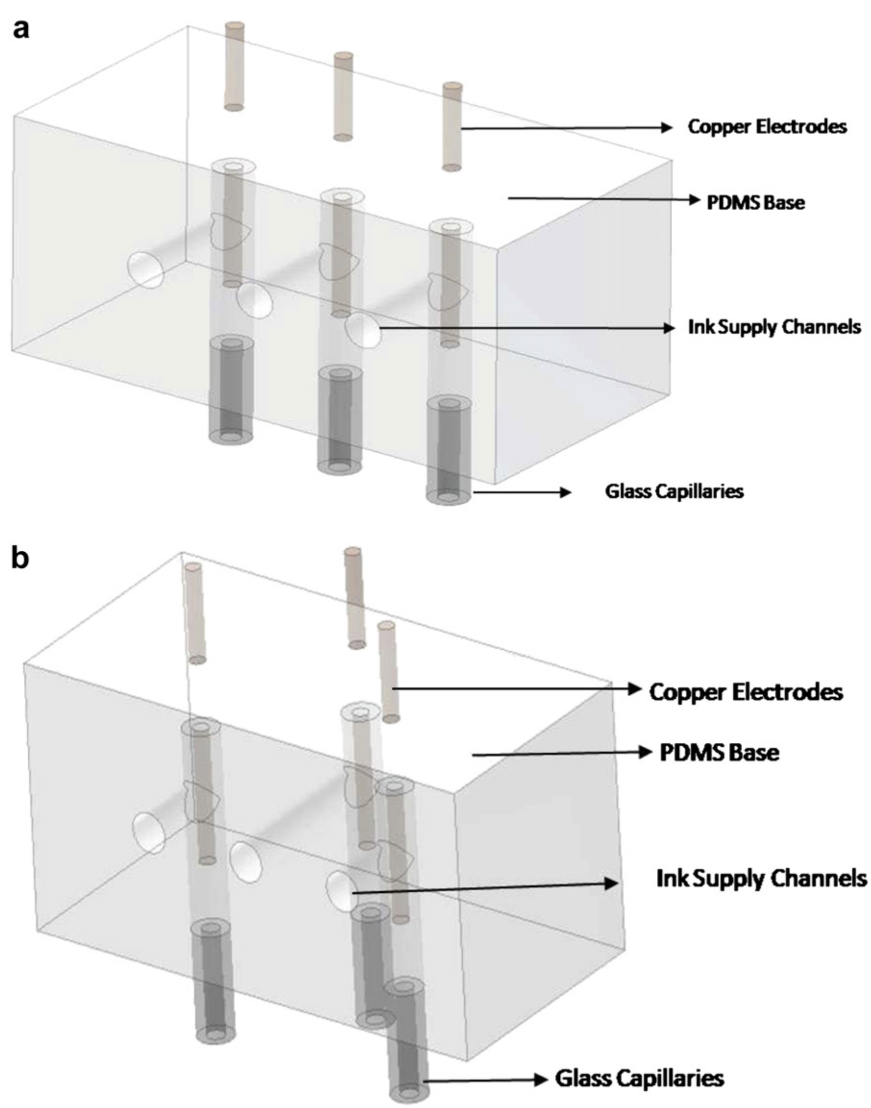

Fig. 1. (a) Schematic of linear array multi-nozzle EHD inkjet printing head. (b) Schematic of triangular array multi-nozzle EHD inkjet printing head.