A Review on Thermal Inkjet Printing System for Micro Fabrication

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Abstract--- Inkjet printing is an alluring patterning technology, which has become progressively acknowledged for a variety of scientific and industrial applications. Among all the inkjet printing technologies, Thermal Inkjet technology has extensively flourished from the day it came into the bigger picture. This present study is an overall review of the recent advancements of the thermal inkjet(TIJ) printing technology and it also illustrates the diverse applications of this printing technique like in electronics printing, textile printing, micro-fabrication of solar cells, etc. This study also takes a glimpse of the history of TIJ, its working principle and the recent findings in the chronological order.

Keywords--- DOD, Inkjet printing, Thermal inkjet, TIJ

I. INTRODUCTION

Inkjet printing, as a brilliant digital material dissemination technique, has become an increasingly extensive additive manufacturing technique due to its quick & fast printing speed, broad choice of materials, scalability, and compatibility for multi-material printing. It is very much trendy for various applications, such as printed electronics, organic and polymeric semiconducting materials and devices, thin-film transistors, optical elements, organic light-emitting diodes, photonic crystals& DNA microarrays, textile printing and solar cells.

Inkjet printing has an idiosyncratic characteristic, as it has the expertise of direct writing without any predefined master pattern; it can drop ink to any random positions on the substrate by the aid of precisely controlled movable nozzles and a plate on which substrates are loaded. At the core of inkjet printing, is droplet generation, which is a common component for all different applications of inkjet and controls the productivity and quality of the prints.

If we look traditionally, two practically different methods have been developed: Continuous inkjet and Drop-On-Demand (DOD) inkjet. In a continuous inkjet system, high pressure is applied to a fluid reservoir to generate a continuous fluid stream of approximately the diameter of the nozzle, which splits into droplets after departing from the nozzle due to Plateau-Rayleigh instability [22]. Whereas, a DOD inkjet produces a short-duration jet that reduces into a single droplet of the required diameter. Due to its uncomplicatedness and precise control of droplets, DOD has turned out to be the mainstream inkjet technique. Many diverse approaches have been discovered for DOD inkjets, including thermal jetting, piezoelectric jetting, electrohydrodynamic jetting, focused ultrasonic jetting, liquid spark jetting, etc.[23].

Thermal jets and piezo jets are the two extensively used DOD jetting techniques by commercial inkjet printers. Thermal jet, headed by Canon and Hewlett-Packard, operates electrical pulses to heating elements in order to vaporize a small amount of liquid to produce bubbles in the fluid that generate pressure pulses to eject droplets [24]. Piezoelectric jet, steered by Epson, on the other hand, depends on the mechanical deformation of a piezoelectric element to create the required pressure pulse.

II. HISTORY OF THERMAL INKJET TECHNOLOGY

In 1979, Toshitami Hara & Ichiro Endo of the Canon Company re-invented the drop-on-demand (DOD) printhead, which is activated by a water vapour bubble, called bubblejet. They were both performing their work on a piezo-based drop-on-demand printhead. Inadvertently, Endo observed a spray of ink from a needle when the needle came in contact with a hot soldering iron. The first BubbleJet printer was unveiled in 1981 and was the first side-shooter device. The droplet was discharged in a perpendicular direction away from the evaporating bubble. At the same time HP also developed their thermal inkjet technology. John Vaught and Dave Donald, operating on a squeeze mode piezoprinthead, both got motivated by the working principle of a coffee percolator. This led to the first efficacious low-cost inkjet printer in 1984. The jetting direction was aligned with the evaporating bubble, the so-called top-shooter design. The ThinkJet fired 180 picoliter (pl) drops from 12 nozzles at a highest repetition rate of 1.3 kHz. In 1985, Canon launched the BJ-80, which contained a printhead with 24 nozzles.
The invention of the thermal inkjet (TIJ) profoundly changed inkjet research. By the substitution of the piezoelectric by a thermal transducer, the main blockage concerning miniaturization was resolved. The thermal transducer became a simple, cheap and small resistor. Canon and HP coupled their forces and safeguarded themselves with a wall of patents. The actual inkjet revolution began in 1988 with HP’s DeskJet, which fired 85 pl drops at a repetition rate of 3.6 kHz. Canon engrossed in 1990 with their BJ10, which comprised of 64 nozzles at a resolution of 360 dpi, and in 1992 with the BJ200. In 1991, HP introduced the first full color TIJ. Their PainJet, launched in 1986, was a three-color printer. Lexmark, turned off from IBM in 1991, enrolled the top three of thermal inkjet vendors in 1993 with the ExecJet IJ 4076.

III. THERMAL INKJET PRINTING: WORKING PRINCIPLE

A standard thermal inkjet (TIJ) printhead is comprised of a thin-film heater driven by a power-input controller and an ink nozzle for keeping the ink. The operation cycle of the TIJ printhead can be simply divided into these sequential steps. In the first step, the thin film resistor of the heater is rapidly heated by an electrical pulse of numerous microseconds. Such a pulse can produce power densities in the order of several megawatts per square meter. As a result, a sharp temperature rise in the ink develops from the high heat flux coming from the thin-film resistor. The ink temperature near the heater-ink interface rapidly reaches the threshold temperature, above which homogeneous nucleation takes place in the ink. Once the homogeneous nucleation occurs, a vapour bubble with high pressure (>10 atm) is then developed in the ink. The second step of the operation cycle starts from the moment that a vapour bubble is formed. As the vapour bubble grows, it causes ink flow in the nozzle and ink ejection at the exit. Due to the fast growth of the vapour bubble and the evaporation of ink, the temperature and pressure in the vapour bubble quickly decrease. At the end of the second step, a droplet then breaks away from the ejected ink. The break-off of the droplet from the ejected ink occurs nearly simultaneously with the collapse of the bubble. In the next step, the nozzle is refilled with ink after the collapse of the bubble.

IV. LITERATURE REVIEW

This section provides an overview of what has been done in thermal inkjet printing process, including: reviews of the physics, waveform design, experimental investigations, and numerical models. Ping-Hei Chen et al. (1997) [1] investigated bubble growth and the ink ejection process of a thermal ink jet (TIJ) printhead with a thin-film heater on the bottom-wall of the ink nozzle. Numerical predictions were presented for bubble volume, temperature, and pressure, and ink jet ejection length under various heating conditions. An inexpensive optical system was set up to visualize the transient ink ejection process.

Ping-Hei Chen et al (1998) [2] presented numerical results to show the pressure response curves in the vapour bubble after homogeneous nucleation in the ink, the droplet formation process, the break-off and separation time instants of ink droplets. Effects of gravity, ink property, and operating voltage of electrical pulse on the droplet formation process were also investigated. Christian Rembe et al. (2000) [3] derived a model for detection and simulation of dynamic phenomena in the thermal pneumatic microactuator of a thermal ink jet. Using that model they calculated the pressure transmission in the bubble by detecting the mathematical model with position measurements extracted from cinematographic image sequences which were taken with their visualization equipment.

T. Lindemann et al. (2004) [4] presented 3D simulation model of a thermal ink jet printhead which provided a valuable approach to optimise thermal bubble jet printheads regarding droplet volume, droplet velocity, droplet quality and print frequency also including the consideration of 3D sensitive problems. Hsuan-Chung Wu et al. (2004) [5] developed a 3D computer-aided analysis system to simulate the formation, ejection, and impact of a liquid droplet in a squeeze-type piezoelectric inkjet printing device. The computer simulation system was based on a solution algorithm (SOLA) scheme for the solution of velocity and pressure fields. L. Setti et al. (2004) [6] explained that it was possible to exploit inkjet printing for ejecting microdots with different functionalities (for example biological or electronic), in very precise positions and on any surface.

Tao Xu et al. (2005) [7] grabbed the idea of thermal inkjet and took it to the heights of printing biomaterials, showing that the Chinese Hamster Ovary (CHO) and motoneuron cells were successfully printed through the nozzles of a thermal inkjet printer. L. Setti et al. (2005) [8] showed that thermal inkjet printing could be a viable technology to realize biosensors depositing active proteins and conductive polymers on electronically active substrates, through the formulation of specific biological and electronic water-based inks.
T. Aernouts et al. (2008) [9] demonstrated the use of ink-jet printing for the deposition of the active layer of a bulk heterojunction solar cell, consisting of a poly 3-hexylthiophene (P3HT): fullerene blend. Alison J. Lennon et al. (2008) [10] described an inkjet method for patterning a resist layer that enabled a single resist layer to be used for multiple patterning steps. That method had immediate applications in silicon solar cell fabrication. Emine Tekin et al. (2008) [11] highlighted that both experimental and theoretical investigations showed droplet size was not totally dependent on the printhead's nozzle diameter. Voltage had a direct effect on droplet size and speed, with both properties being linearly dependent on it. Jolke Perelaer et al. (2008) [12] prepared a silver nanoparticle ink that had a critical curing temperature as low as 80°C. Good to excellent conductivity values of 10 to 56% of bulk silver had been reached by using a very small amount of organic additives without any strong adsorbing groups such as amines, amides or mercapto groups. Dan Soltman et al. (2008) [13] demonstrated that by varying drop spacing and temperature, it lead to several different printed line morphologies and offered a simple geometric explanation for those various forms. Also, by controlling the evaporation profile of drying drops and lines, control of the coffee ring effect was demonstrated.

Daehwan Jang et al. (2009) [14] investigated the inter-relationship between ink-jet printable and the print fluid's physical properties. Alison J. Lennon et al. (2009) [15] stated that the direct etching method for patterning Si-based dielectrics was a novel, low-cost, low-waste method that could be implemented more safely than existing immersion etching processes.

Abdolrahman Dadvand et al. (2011) [16] carried out the numerical and experimental analyses of the spark bubble droplet formation and breakup dynamics by using the boundary element method (BEM) approach and high-speed photography technique, respectively. Alexander Lange et al. (2012) [17] produced solar cells with inkjet printed polymer: small molecule active layers or inkjet printed hole transport layers.

Wenyong Liu et al. (2013) [18] gave a brief idea on the application and performance of the 3D Printing (3DP) in nanobiomaterials along with an investigation of currently available literature to support each 3DP technique and application performance. Mau Chien Dang et al. (2013) [19] presented the conductive ink development, study of printed patterns, as well as application of these to the realization of radio-frequency identification (RFID) tags on flexible substrates.

Changhai Ru et al. (2014) [20] investigated that nano- & micro-scales printing techniques have found many applications in biotechnology, electronics, materials synthesis and patterning. Hua Tan et al. (2015) [21] carried out the 3D numerical simulation of droplet-ejection process in TJ printing.

V. CONCLUSION

Conclusively, a number of printing technologies are prevailing in the market, though the thermal inkjet printing is predominantly leading in this patterning business. The main reason behind the thriving success of TJ is due to its quick & fast printing speed, broad choice of materials, scalability, and compatibility for multi-material printing. This review is an overview of the past and current progressions of the research work carried out by the renowned scientists and researchers in this booming field. This study highlights its omnipresent applications such as in electronics, biotechnology, fabrication of organic light-emitting diode (OLED) displays, thin-film transistors, photonic crystals, etc. Several researchers from the science and engineering background have worked on the numerical and experimental simulation of this technology, and they have succeeded also in the micro and nanometre scales. So, the coming years will witness the further expansion of the prevailing printing technological methods to higher altitudes and also the emergence of improvised methods & techniques in this prospering field of patterning technology.

REFERENCES


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