Robot Arm Printer of Electrostatic Inkjet

Shigeto Kawata[1], and Shinjiro Umezu[1]; 1)Tokai University, Hiratsuka-shi, Kanagawa, Japan,*

Abstract

We have been investigating fundamental characteristics of electrostatic inkjet and developing the inkjet for bio-technology and green-technology. It is not unusual that size is small and shape is complex in the field of these technologies. When the target is complex shape, robot arm printer is suitable to print because the gap between the printer and the target is easy to control. In this paper, we developed robot arm printer of electrostatic inkjet. Electrostatic inkjet module is set on commercial robot arm. Target is set on xy- linear stage. We can control the voltage application of electrostatic inkjet and motion of the robot arm and the xy- linear stage by PC. We investigate printing characteristics of the robot arm printer of electrostatic inkjet when the robot arm is running.

Introduction

In recent days, digital fabrication (fabrication utilizing inkjet technology) is highly focused because digital fabrication is suitable to print complex design. The application is bio technology, green technology, printed-electronics, and so on. Artificial organ, biosensors, and investigation of biochemical characteristics in 3D cell structures are hot topics in bio technology [1-7]. Several kinds of solar cells and flexible batteries are hot topics in green technology [8-17]. The products of these technologies will be large, complex, and flexible. We have been developing electrostatic inkjet technology [18] for fabrication of 3D cell structures in bio-technology and fabrication of dye-sensitized solar cells in green-technology. When high voltage is applied between nozzle and target, electrostatic inkjet takes place. Diameter of ejected droplet depends on electric field around tip of nozzle. The electric field is changed when the gap between nozzle and target is changed. We should move z-stage to keep the electric field. When the shape of target is very complex, it is difficult to print withxy-z-stage because of print head size. In this paper, we develop robot arm printer that syringe of electrostatic inkjet is installed.

Experimental Set-up

Experimental set-up of robot arm printer of electrostatic inkjet is shown in Fig. 1 and 2. Small droplets were ejected by electrostatic force when high voltage is applied between nozzle that is filled with conductive liquid and plate electrode. We already reported the fundamental characteristics of this inkjet technology. The merits of the inkjet technology were high resolution and ability to eject highly viscous liquid. The electric field is controlled by the amplitude of applied voltage and the air gap between the electrodes. Print samples are patterned by the control of robot arm and xy- stage. The target shown in Fig. 3 is not flat but valley shape. Target is aluminum plate that thickness is 0.3 mm. This target is set on xy- stage that is next to robot arm printer. Electrostatic inkjet module is installed at hand of robot arm that is shown in Fig. 2. The syringe is filled with paste of titania. Titania paste in this experiment is made as follows. Titania particles (1.85 g) and water (1.0 g) is mixed. Acetylacetone (0.2 ml), Triton-X (1.0 ml) and polyethyleneglycol (0.185 g) are mixed into the paste. Voltage is applied to syringe. The shape of target is like valley that is shown in Fig. 3. Robot arm is moved over the target. The shortest gap between nozzle and target is 20 mm. Applied voltage is 2.0 kV.

When high voltage is applied, titania paste is ejected like spray because of balance between charge and evaporation of the ejected droplet. The ejected droplet is separated into relatively small droplets because of balance between charge and evaporation of the ejected droplet when flight of the droplet is long.

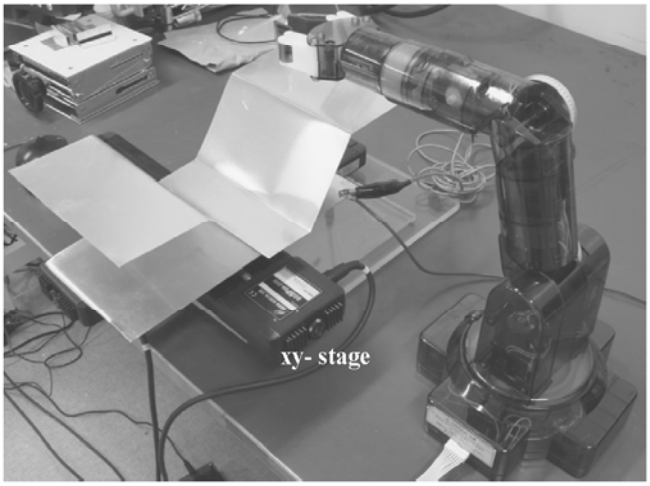
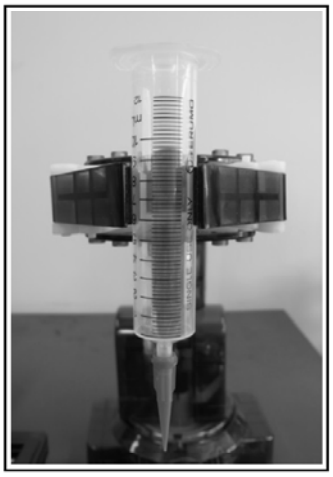


Figure 1. *Experimental set-up of robot arm printer.*



Syringe V: 10ml
Nozzle ID: 0.25mm

Figure 2. *Syringe is installed at the tip of robot arm.*

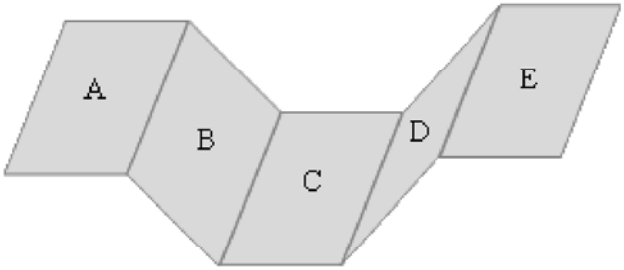


Figure 3. *Shape of target.*

Results

Fig. 4 shows photographs while printing. Fig. 5 shows printed target when only xy-stage is moved. When the air gap is changed, mode of droplet ejection is changed because the electric field around the tip of nozzle is changed. When we print C of the target that is shown in Fig. 3, little drop is formed because of long air gap. When the robot arm trace the shape of target, the mode of droplet formation will be observed. Fig. 6 shows printed target when the robot arm trace the shape of target, the gap between target and syringe is kept to be 2 mm. These results indicate that relatively stable droplet ejection is observed when the air gap between the target and robot arm printer is controlled to be constant.

Electric field is calculated by voltage and shape/ gap of target. So, shape is important parameter of electrostatic printing. When the target is complex shape, the electric field around tip of nozzle will be affected by the complex shape. We investigate printed results when the inclination angle of target is changed. The inclination angle of the target is 30 deg, 45 deg, and 60 deg. Taylor cone [19] is formed at the tip of nozzle. The cone is inclined because perpendicular between the tip of nozzle and the target is smallest gap and the perpendicular line is different from the extended line. The printed sample is like ellipse.

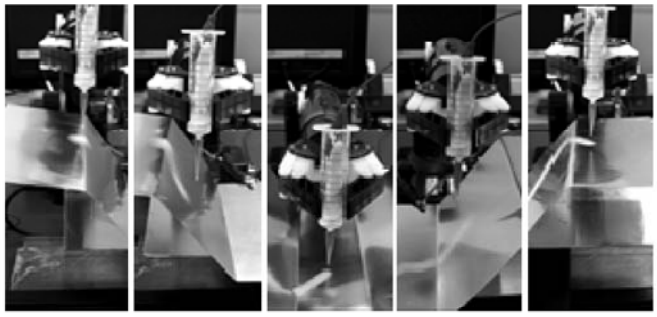


Figure 4. *Photographs of printing titania on valley-shape target*

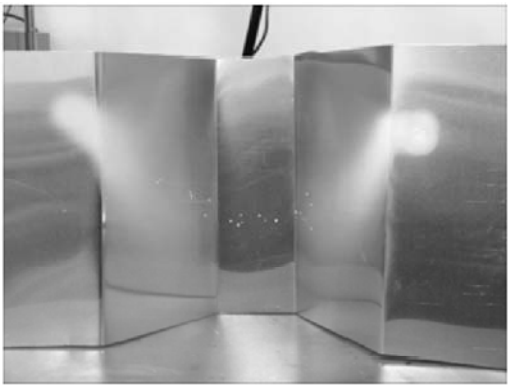


Figure 5. *Printed target when only xy-stage is moved.*

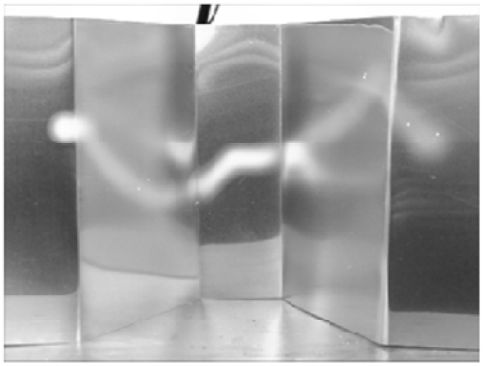
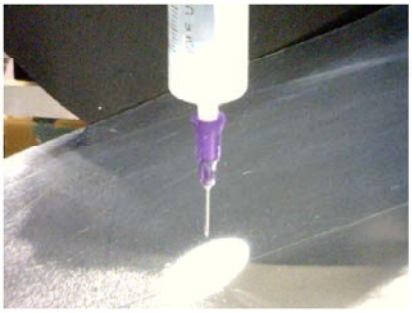


Figure 6. *Printed target when xy-stage and robot arm are moved.*

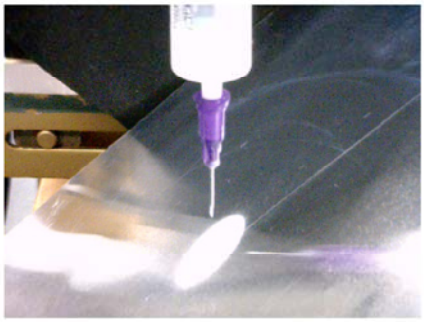
When the robot arm is moved, the gap between target and syringe is constant.



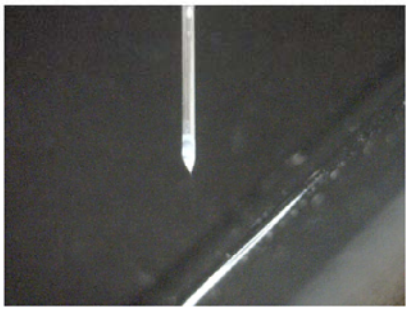
(a-1) printing when the inclination angle is 30 deg.

(a-2) enlarged view of tip of nozzle

(a-3) printed sample on target



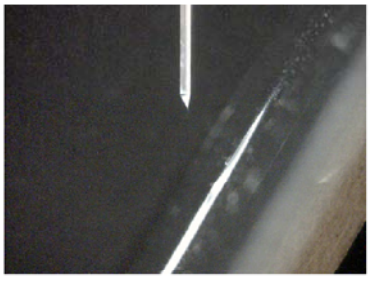
(b-1) printing when the inclination angle is 45 deg.



(b-2) enlarged view of tip of nozzle,

(b-3) printed sample on target

(c)printing when the inclination angle is 60 deg



(c-2) enlarged view of tip of nozzle,

(c-3) printed sample on target

Figure 7. *Photographs of Printed target when the inclination angle of target is changed. (a: 30 deg, b: 45 deg, c: 60 deg)*

Conclusions

3D printer is developed to fabricate 3D structures. Recent days, complex structure should be fabricated and print target will be complex. Commercial printing module is moved by xyz-stage. Robot arm is suitable to handle printing module precisely. We develop robot arm printer of electrostatic inkjet. Following fundamental characteristics of electrostatic printing are investigated. When gap between the nozzle and target is kept to be constant by movement of robot arm, mode of droplet ejection is same. When the target is inclined, Taylor cone and angle of droplet ejection is inclined. This inclination angle depends on the inclination angle of target.

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Author Biography

UMEZU, Shinjiro received the BE (2001), MS (2003) and Ph.D (2006) degrees in Mechanical Engineering from Waseda University. He was a research associate at Waseda University since 2003 to 2007. He was a special postdoctoral researcher at Riken since 2007 to 2009. He is now Jr. Associate Professor at Tokai University. He was awarded many times. His research interests include imaging technology and biomechanical fabrication utilizing inkjet technology.