

Head Design for Novel Ink-Jet Printing using Electrostatic Force

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Abstract

The authors developed a printing head with multiple ink ejecting apertures based on novel ink-jet technology, which was reported at the last NIP14 conference. A 4-inch wide printing head was made with this head structure. This ink-jet technology uses electrostatic force and ink containing charged colorants dispersed in a highly resistive solvent.

The developed printing head comprises a control substrate and an ink-guide. The control substrate consists of a printed circuit board, and has apertures and control electrodes arranged around each aperture. The ink-guide has a tapered shape with a narrow slit in the tip, like a fountain pen, and is positioned inside the aperture. The ink is carried from the aperture to an ink droplet emitting position by capillary action. The printing head structure makes it possible to stabilize ink ejection and print images at high speed.

The 4-inch wide head has 384 ink ejecting apertures which are arranged by 100 dpi and can print 6 pages per minute with a 4” x 6” image with 800 dpi resolution.

The authors present a detailed description of the printing head structure, the printing characteristics of the head structure, printed samples, and specifications of the 4-inch wide head, in this paper.

Introduction

The authors proposed a novel ink-jet technology with electrostatic force for high definition ink-jet printing and presented the features of this technology at the last NIP14 conference[1)]. In that conference presentation the possibility of high definition printing was investigated by using a printing head with a single ejecting nozzle. For the next step, the development of a head device with multiple ink-ejecting apertures was required.

The authors concluded that the following functions were important, to eject ink from the multiple ink ejecting apertures, based on the experiment with a single nozzle.

- To supply ink at the tip of an electrode, without using electrostatic force
- To make the electric field maximum at the ink emitting position

Considering the above, the authors designed the printing head comprising a control electrode and an ink-guide. In this paper, the authors will present a detailed description of the printing head structure.

New Printing Head Structure

Experiment

Figure 1 shows the schematic of the developed printing head structure. The printing head comprised a control substrate and an ink-guide. The control substrate was made of a printed circuit board, and had apertures and control electrodes arranged around each aperture. The diameter of the aperture was 200 µm. The ink-guide was made of a 75 µm thick polyimide sheet cut by an excimer laser. The ink-guide had a tapered shape with a narrow slit in the tip like a fountain pen, and was positioned inside the aperture. The ink was carried from the aperture to an ink droplet emitting position by capillary action. The width of the ink-guide was 160 µm and the height from the aperture was between 300 and 600 µm. The spacing of the ink-guide was 0.508 mm. The ink contained charged colorants dispersed in a highly resistive solvent, and the resistivity of the ink ranged from 1 x 10e8 to 1 x 10e9 Ω–cm.

The authors tried four types of ink-guide to investigate the stability of the ink ejection and the printing speed, as shown in figure 2. Type A and B were the basic shape and the top angle was 50 degrees for type A and 90 degrees for type B. Type C had a flat portion on the tip, 40 µm wide, and the top angle was 90 degrees. Type D had a narrow slit in the tip, 40 µm wide.

Moreover, the width of the slit and the height of the ink-guide were changed to investigate the size of printed dots and the margin of the gap length between the printing head and recording material, for the ink-guide with the slit.

Figure 3 shows the schematic of the experimental setup. The recording material (paper) was put on the rotating drum with an insulating sheet between. The rotating drum was attached to the X-stage which moved vertically in the rotation direction. The X-stage moved one resolution step in one rotation of the drum, and the image was recorded on the paper two-dimensionally.

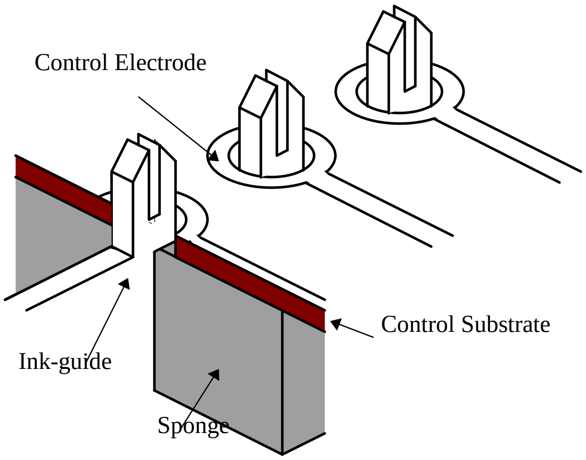

Figure 1. Schematic of the developed printing head

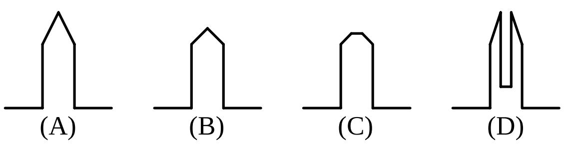

Figure 2. Configuration of four kinds of ink-guide

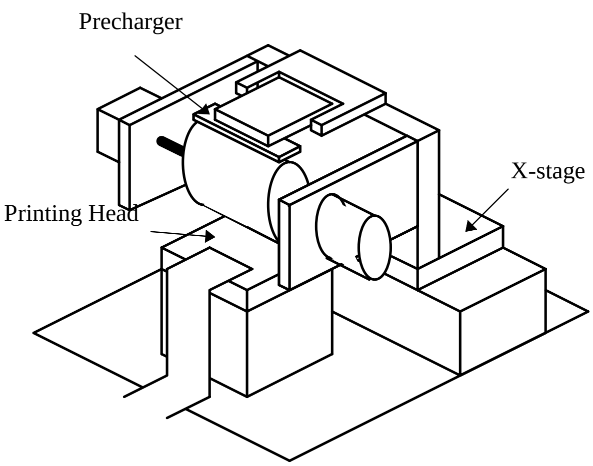

Figure 3. Schematic of the experimental setup

Figure 4 shows the principle of the ink ejection. The precharger was the source for applying the bias voltage (Vb) to the paper. The signal voltage (Vs) was supplied directly to the control electrode according to the information to be recorded. The positively charged ink droplets were emitted towards the paper by the electrostatic force between the electrode and the paper when the signal voltage was added to the bias voltage.

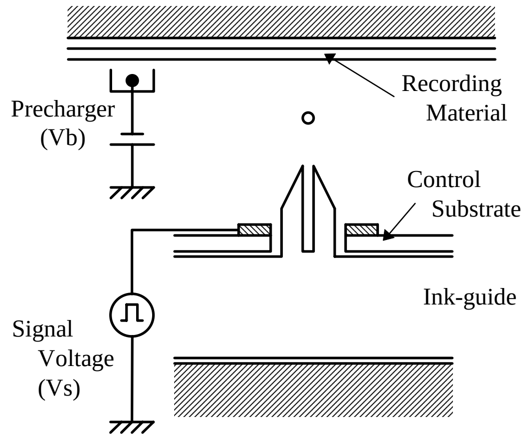

Figure 4. Principle of ink ejecting

Results

Table 1 shows the ink-ejection characteristics for different ink-guide configurations. Type D, an ink-guide with a narrow slit, was superior in stability and recording speed, and the other three types did not differ greatly. For type C, there was no effect of the flat portion at the tip. The meniscus was not limited to the flat portion, and spread to the slope of the ink-guide. In type D, the meniscus was restricted to inside the slit. In type A, it was difficult to control the ink ejection by the signal voltage, the ink droplet being ejected by only the bias voltage. Thus, the characteristics of the dot on demand were quite bad. The authors calculated the electric field at the tip portion of the ink-guide. There was little difference in the four types of ink-guide. The characteristics of the ink ejection were mainly based on the differences in the fluid condition.

Table 1. Ink ejection characteristics for different ink-guide configurations

	A	B	C	D
Stability	poor	poor	poor	good
Printing Speed	1.5kHz	1.5kHz	1.5kHz	5kHz
Dot On Demand	bad			good

Next, the dependence of the dot size on the slit width of the type D ink-guide was investigated. Figure 5 shows the relationship between the pulse width of the signal voltage and the dot size. The recording frequency was 1kHz. The

60-µm slit width ink-guide was suitable for multilevel printing, because the dot size could be controlled over a wide range by the pulse width of the signal voltage. On the other hand, the 20-µm slit width ink-guide was suitable for binary printing, since the dot size did not change with the pulse width.

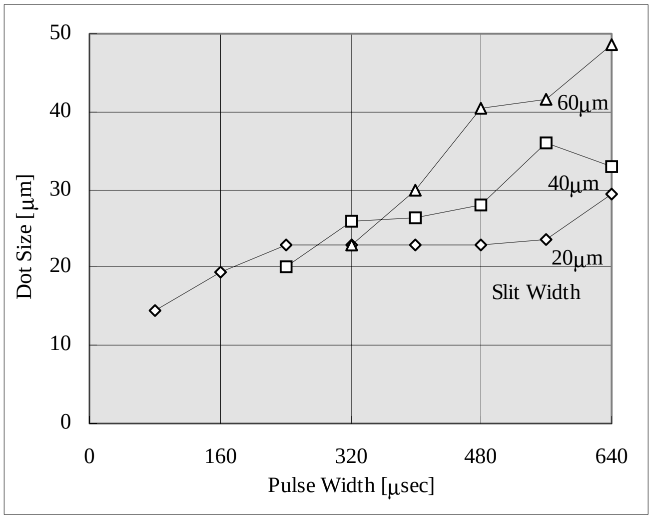

Figure 5. Relationship between diameter of printed dots and the pulse width of signal voltage

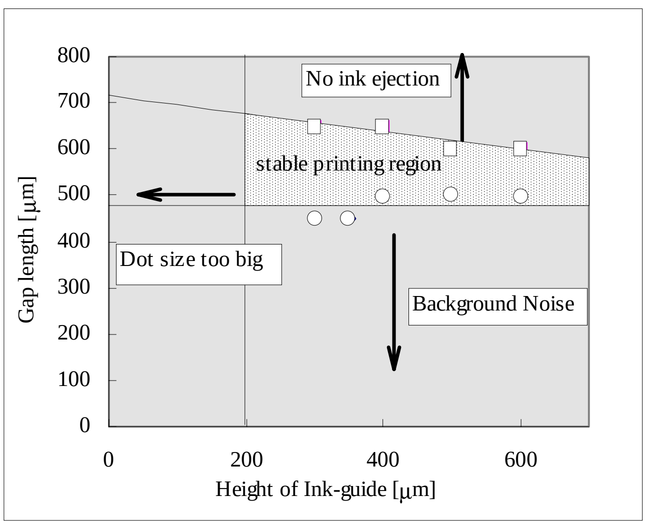

Figure 6. The stable printing region when changing the ink-guide height and the gap between the tip of the ink-guide and the printing material

The ink ejection is affected by the gap length between the printing head and the printing material in the ink-jet system using electrostatic force, because the gap length changes the electric field.

Figure 6 shows the stable printing condition when changing the height of the ink-guide and the gap length between recording material and the tip of the ink-guide. The circles and squares in figure 6 mean the lower limit and upper limit, respectively, of the gap length to eject ink in response to the signal voltage.

When the height of the ink-guide was too short, the printed dot became too big because the meniscus spread to the slope of the ink-guide. The range for the stable printing condition became narrower as the ink-guide became longer, because the ink ejecting position was far away from the control electrode. Background noise occurred when the gap was shorter than about 400 µm, because the ink droplet could be ejected by only the bias voltage. The optimum height was around 300 µm and for gap length was 500 µm, as in figure 6.

Printing Samples

Figure 7 shows the printed sample of a Japanese character pattern and microstructure letters. The pattern resolution was 1600 x 1460 dpi. The size of each Japanese character in a, b, and c was 0.5, 1.0 and 2.0 mm square, and each character pattern was formed by 32 x 32 dots, 64 x 64 dots and 128 x 128 dots, respectively. In the experiment, the recording frequency was 2.0 kHz, the bias voltage was 1.2 kV, the signal voltage was 500 V, and the signal pulse width was 400 µsec. The dots were measured at 25 - 30 µm.

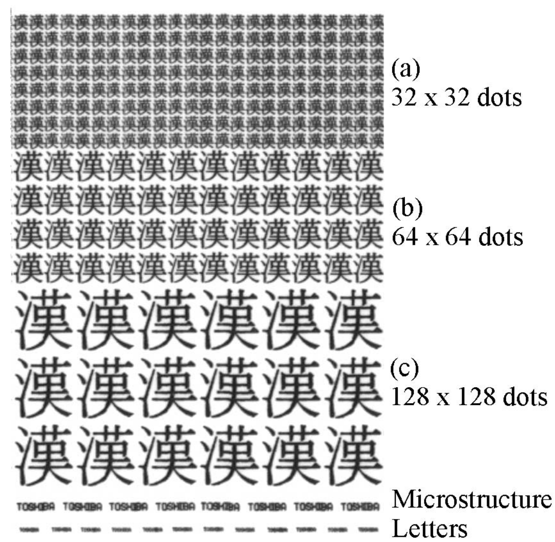

Figure 7. Printed sample of a Japanese character pattern and microstructure letters

Figure 8 is the magnification of the 0.5 mm square printed letter. We can see that even such a small Japanese character pattern of 0.5 mm square was printed clearly on the paper.

The authors printed microstructure letters, each letter of which was formed by 5 x 7 dots with a size of about 0.1 mm square. The magnified microstructure letters are shown in figure 9.

Figure 8. Japanese character of 0.5mm x 0.5 mm size

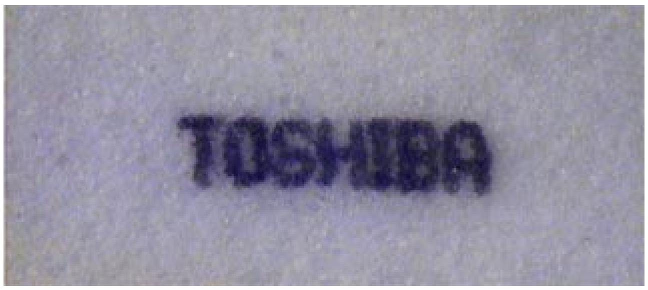

Figure 9. Microstructure letters of 0.1mm size with 5 x 7 dots

4-inch Wide Printing Head

A 4-inch wide printing head was developed based on the head structure described in this paper. Figure 10 shows the control substrate with the two rows of apertures with 0.508-mm spacing.

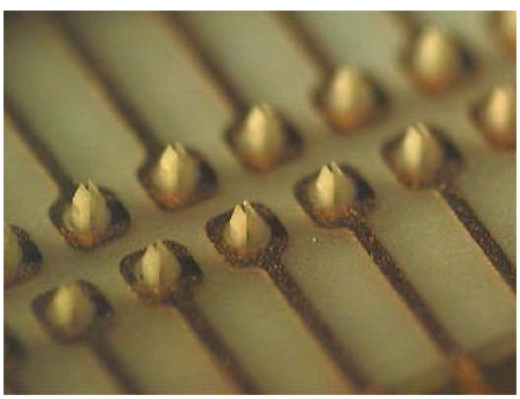

Figure 10. Top view of the control substrate in 4-inch wide printing head and its two rows of apertures

The specifications of the prototype printer with this printing head are shown in table 2. The printing head comprised two sheets of the ink-guide each of which had 192 ink-guides. The ink-ejecting aperture density was 100 dpi, so an 800-dpi image was recorded by rotating the drum 8 times. Figure 11 shows a printing head which has 384 ink-ejecting apertures with an aperture density of 100 dpi.

Table 2. Specifications of the Prototype Printer

Number of Nozzles	192 x 2 rows
Resolution	800dpi
Recording frequency	4kHz
Printing	6ppm(4" x 6")

Figure 11. Prototype of a new printing head

Conclusion

The authors developed a printing head with multiple ink-ejecting apertures based on novel ink-jet technology. The developed printing head comprised a control substrate and an ink-guide with a narrow slit.

This printing head structure made it possible to eject ink drops stably and to print images at high speed.

The authors believe that this printing head structure has the potential to develop into a practical line head covering the full width of the paper.

In future work, the authors intend to investigate the uniformity of printed dots and higher definition printing.

References

1. T. Murakami, S. Hirahara, H. Nagato and Y. Nomura, High Definition Ink-Jet Printing: 10-20μm Dots Eject from an Injection Needle, Proc. IS&T's NIP14 Int. Conference on digital Printing Technologies, pg.36. (1998).

Biography

Hideyuki Nakao received his B.S. and M.S. degrees in electronic engineering from the University of Tokyo in 1984 and 1986, respectively. Since 1986, he has worked at the Research & Development Center of Toshiba Corporation in Kawasaki. He has been engaged in the development of non-impact printing technology. Presently, he is a research scientist for the Toshiba Research & Development Center. He is a member of the Imaging Society of Japan(ISJ).