High Definition Ink-Jet Printing: A Study of a Printing Head Construction

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Abstract

We have developed a novel ink-jet technology using electrostatic force. This innovative ink-jet technology features high-speed printing and little bleeding print dots on plain paper.

The print head comprises a metal pipe as both the means for supplying ink and for the electrode, and an "ink-guide" which is a dielectric film positioned inside of an opening of the pipe. This print head structure makes it possible to increase the toner density of the ink on the ink-guide to a greater extent than when supplying ink and to improve the efficiency of the ink drop ejection.

The ink contains positively or negatively charged colorants dispersed in a highly resistant solvent. This paper shows that the resistivity of the ink affects the toner density of the ejected ink droplet. This highly resistant ink produces little bleeding of print dots on plain paper.

Introduction

Ink-jet printing technologies have recently been being applied over a wide range of applications. Many printing technologies on plain paper are being developed; some of these have already been applied on the market.[1] We have developed a novel ink-jet technology using electrostatic force that can print high-quality images on plain paper. This new ink-jet technology gathers charged colorants (toner) dispersed in a highly resistant solvent to an ejecting point, and then ejects ink droplets which concentrate the toner gathered at the ejecting point on a recording medium (plain paper). The toner-rich droplets give dot images with only little bleeding on plain paper.

We have studied the structure of a print head for this novel ink-jet technology. Also, we have studied how the resistivity of the ink affects the toner density of the ejected ink droplet. We would like to submit a report about this print head structure and its printing features.

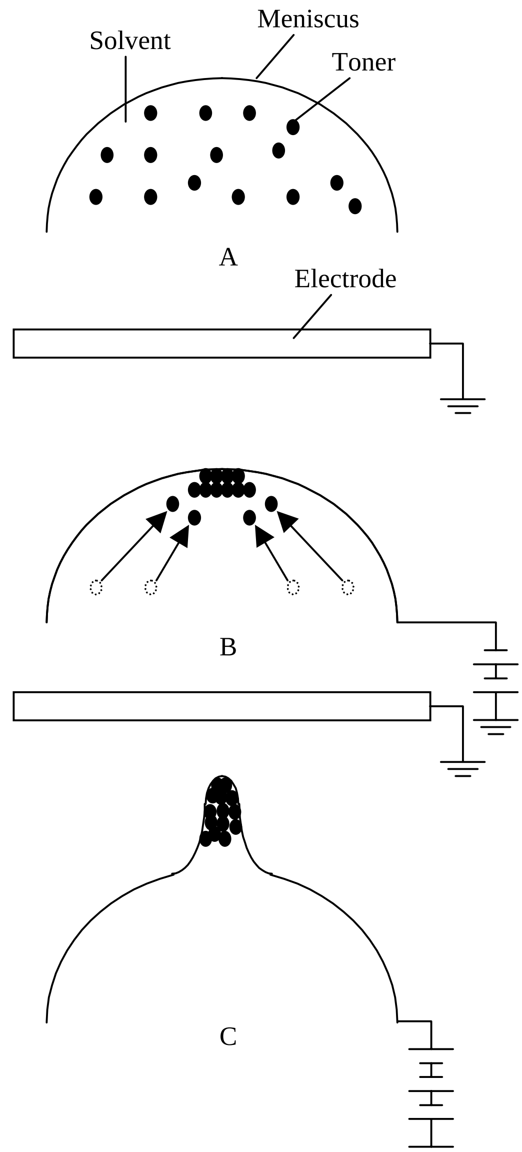


Figure 1. Schematic diagram of an ink-meniscus near the ejecting point

Design of Print Head

Principles of this Ink-Jet Printing Technology

Figure 1 shows the schematic diagram of an ink meniscus near the ejecting point in order to explain major principles of this ink-jet printing technology. When no voltage was added, the toner was dispersed in the meniscus uniformly (figure 1A). When a voltage was added to the margin of the meniscus and the electrode which was above the meniscus was set to zero voltage, an electric field was formed towards the center of the top of the meniscus from its interior. The toner dispersed in the meniscus was moved to the center of the top of the meniscus and gathered there by the electric field (figure 1B). The greater the amount of the toner gathered into the center of the top of the meniscus the better, and it is of course desirable that more toner than that included in the meniscus be gathered there. When a higher voltage was added to the margin of the meniscus, the center of the top of the meniscus where the toner was gathered expanded towards the above electrode and a toner-rich droplet was ejected. In this ink-jet printing technology, the ink has to be applied successively because more toner than that included in the meniscus is gathered at the ejecting point. The volume of the meniscus has to be increased in order to include extra toner there. The diameter of the meniscus affects the ejecting frequency and the diameter of the printed dots. [2] A longer diameter of meniscus decreases the ejecting frequency and increases the diameter of the printed dots. For realizing high-quality and high-speed printing, the diameter of the meniscus at the ejecting point has to be smaller and the diameter of the meniscus other than there has to be longer to apply more ink. Moreover the remaining ink that was not ejected has to be withdrawn to apply the new ink. Given the two requirements mentioned above, we have designed a print head element which comprised a long diameter metal pipe for supplying ink and an "ink-guide" chip with minute tip inside of an opening in the pipe.

Structure of the Print Electrode and the Ink-Guide Chip

Figure 2 shows a cross-sectional view of the print head element. It comprises a print electrode, an ink-guide chip, an ink-supply cavity and an ink-withdrawal cavity.

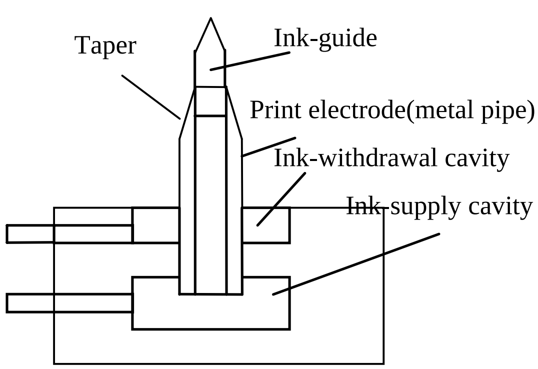


Figure 2. Cross-sectional view of the print head

The print electrode is a metal pipe with an external diameter of 1.1mm and an internal diameter of 0.7mm. The ink is supplied from the ink-supply cavity towards the top of the metal pipe as the ejecting point, through the metal pipe. The top of the metal pipe is tapered in order to make the ink flow there as the ejecting point is smooth. The overflow ink from the top of the metal pipe flows into the withdrawal cavity along the top of the tapered pipe and smoothly outside of the pipe. When the ink is supplied to the top of the pipe, a hemispherical meniscus is formed there. When a bias voltage with the same polarity as that of the toner is added to the pipe, the toner is gathered at the center of the meniscus by an electric field. Furthermore, when a signal voltage with the same polarity as that of the toner is added to the pipe, the center of the meniscus expands towards the transport roller, and the droplet is ejected from there. Since the toner is gathered at the center of the meniscus, toner-rich droplets are ejected.

Figure 3 shows the magnification of the ink-guide chip inside of the opening of the pipe. The ink-guide cut polyethersulfone (PES) whose thickness was 0.1mm by excimer laser has a top degree of 50. The projected length from the opening of the pipe is 1.3mm. The diameter of the meniscus affects the ejecting frequency. A smaller diameter increases the ejecting frequency. The ink-guide chip inside of the opening of the pipe makes the ink rise to the top of the ink-guide chip, and then a thin meniscus with a small width is formed around that area. The wide face of the ink-guide chip assures the supply of a sufficient amount of ink. Also, the size of the meniscus can be controlled by changing its projected length from the opening of the pipe. Therefore the ejecting frequency becomes higher while the diameter of the printed dots becomes smaller. Also, a bigger meniscus from the opening of the pipe to the top of the ink-guide is formed than that when the ink-guide chip is not put in the pipe for more ink is supplied.

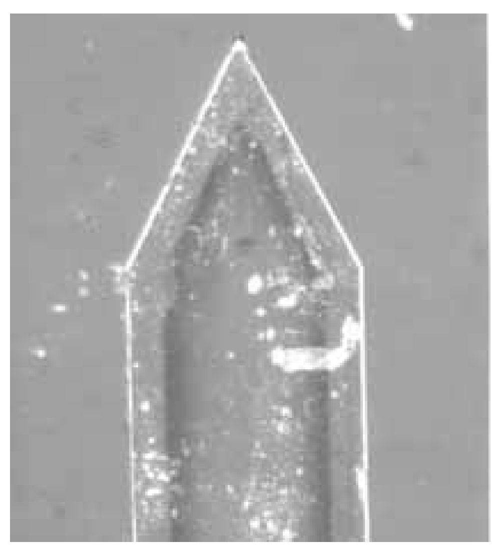


Figure 3. Magnification of the ink-guide; Thickness 0.1mm; Maximum width 0.7mm; Top degree : 50 degrees.

We have evaluated the print characteristics of this head element. Figure 4 shows the schematic diagram of the experimental setup. The ink is supplied from the ink-supply tank towards the ink-supply cavity through the connecting tube by its own weight and is supplied from the ink-supply cavity towards the ejecting point through the print electrode to its top. The amount of the supplied ink is controlled by moving the position of the ink-supply tank. The ink which has overflowed from the ejecting point is gathered into the withdrawal cavity, and is withdrawn from there in the direction of the ink-withdrawal tank through the connecting tube. Then the ink in the ink-withdrawal tank is returned into the ink-supply tank by the pump. When a signal and bias voltage with the same polarity as that of the toner are added to the print electrode, and the transport roller is set to zero voltage, an electric field is formed between the print electrode and the transport roller. The ink droplets are ejected onto the paper on the transport roller by electrostatic force between the print electrode and the transport roller.

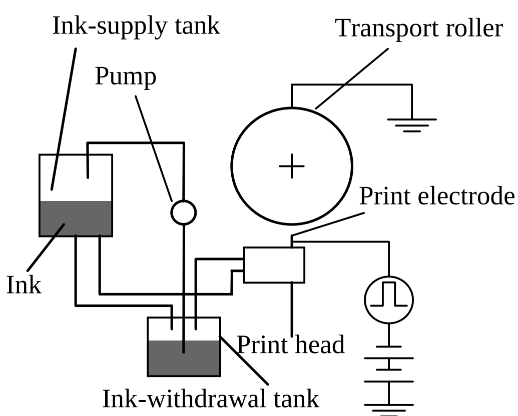


Figure 4. Schematic diagram of the experimental setup

When no ink-guide chip was put in the pipe, the diameter of the printed dot was 0.3mm and the ejecting frequency was 100Hz. On the other hand, when an ink-guide chip was put in the pipe, the diameter of the printed dot was 0.08mm and the ejecting frequency was 1kHz. Thus, due to a head comprised of a pipe and an ink-guide chip, the ink is supplied to the ejecting point efficiently, minute droplets are ejected, and the ejecting frequency becomes higher.

Effect of Resistivity of the Ink

The main feature of this ink-jet technology is that toner-rich droplets are ejected. If the ejected dot contains much toner, the smaller will be the amount of the solvent included in it, and we can consequently expect printing with less bleeding of the dot images on plain paper.

In this printing technology, the ink contains positively or negatively charged colorants (toner) dispersed in a highly resistant solvent. When electrostatic force had strong contact with the toner, the amount of the toner gathered at the ejecting point increased.

Figure 5 shows the relation between the optical density of the printed dots and the resistivity of the ink. The toner concentration in all of the ink was 6WT%. Although the toner concentration in the ink was the same, the higher resistivity of the ink increased the optimal density of the images. The fact that the optical density of the solid pattern became higher derives from the fact that the amount of the toner included in the ejected droplets increased. The reason for this is because the higher resistivity of the ink made the moving of the toner in the solvent smooth and therefore more toner was gathered at the ejecting point.

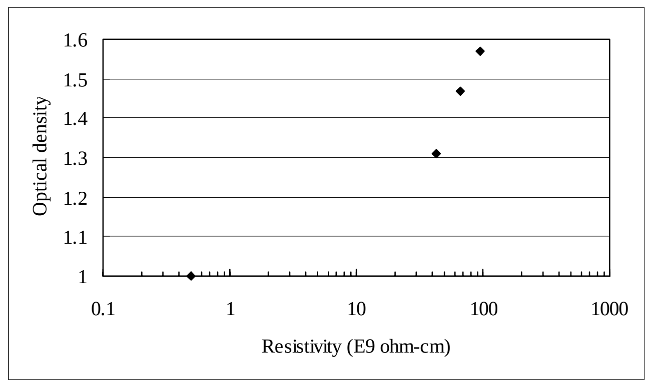
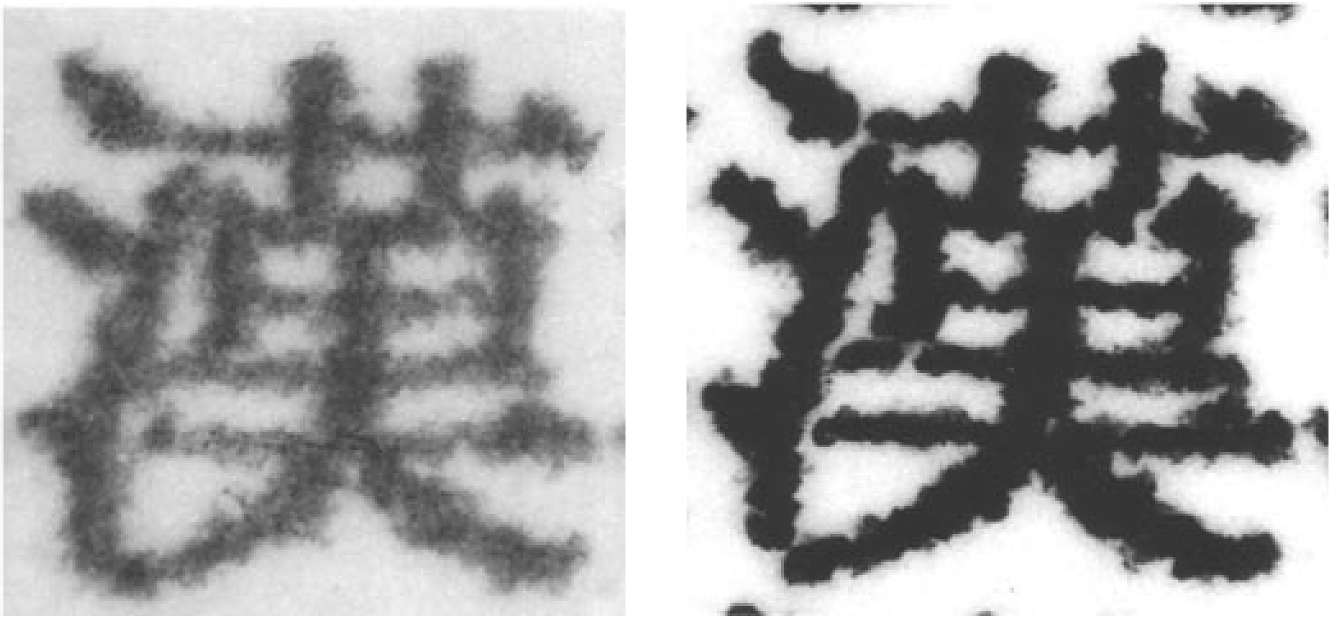


Figure 5. Relation between the resistivity of the ink and the O.D of the solid pattern

Figure 6 shows the magnification of a printed sample of a Chinese character pattern with two inks whose resistivities are different. Figure 6A shows a sample printed with ink whose resistivity was 5E8 ohm • cm. Figure 5B shows a sample printed with ink whose resistivity was 7E10 ohm • cm. We found that the optical density of the printed dots in figure 6B is higher than that in figure 6A. Also, we found that the printed dots' bleeding in figure 6B is lesser than that in figure 6A. From the experimental results above, we found that if the ink has a higher resistivity, this will increase the amount of the toner included in the ejected droplet.

Conclusion

We demonstrated that high-quality and high-speed printing were realized. Also, we showed that the resistivity of the ink which was greater than the E10 ohm • cm order resulted in very little bleeding of dot images on plain paper. The development of a head device with multiple electrodes and an increase in the speed of the printing are the next stages of this technology.



(a) *(b)*

Figure 6. Magnification of the printed sample

References

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