

Study of a Thermal Print Head for Multi-level Tone Printing

Hirotoshi Terao, Toshifumi Nakatani, Noboru Tsushima, and Ikuo Hibino
Alps Electric Co.,Ltd.
Tokyo,Japan

Abstract

We studied the thermal print head to achieve the multi-level tone in thermal transfer printing, which required appropriate heat control of heating elements on the head and variations in the amount of resin ink melted by the energized head edge, that is, varying dot diameter as needed. After a series of examination, we came to the conclusion that head form especially the part between the heating elements and head edge is deeply related to the property of the tone. This meant that optimization of the head form was the key to the solution. Thus we have attained multi-level-tone printing by varying dot diameter in 16 levels with the enhanced print head. We call this unique printing method Variable Dot Photo(VPhoto) print technology.

Introduction

Color print quality to various output devices has been quickly improved, which has enabled inkjet technology to increase market share in the low-price field and the toner method in a high-quality-on-plain-paper field. In this vain, we have stuck to thermal transfer using resin ink, as a result we have attained high definition printing at the resolution of 600dpi and have improved some of the basic performance such as running cost and sharpness of the printout. We call this new technology Micro Dry technology. We envisage that the image quality produced has the potential to become very close to that of offset printing.[1–3]

In the recent pursuit of better image quality to various output devices, there is a strong demand for multi-level-tone printing that is formerly impossible to perform for printers supporting only binary mode. This paper will introduce Micro DOS (Deposition on Silicon) head, uniquely developed to achieve multi-level-tone printing in high definition printing using resin ink. Micro DOS head is installed in Micro Dry Printer MD-5500 launched at the end of last year. Figure 1 shows the appearance of the printer. MD-5500 has attained multi-level-tone printing with variable dots on plain paper. We call the unique printing method Variable Dot Photo (VPhoto) print technology.

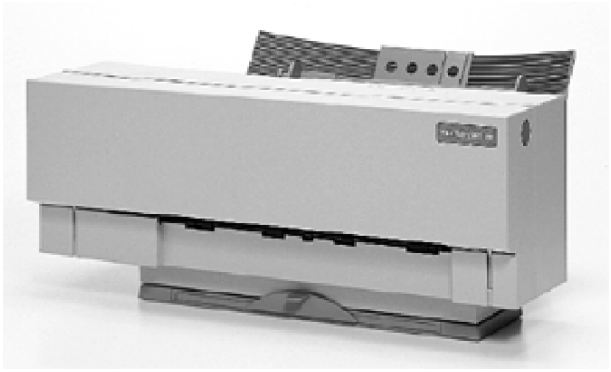


Figure 1.MD5500

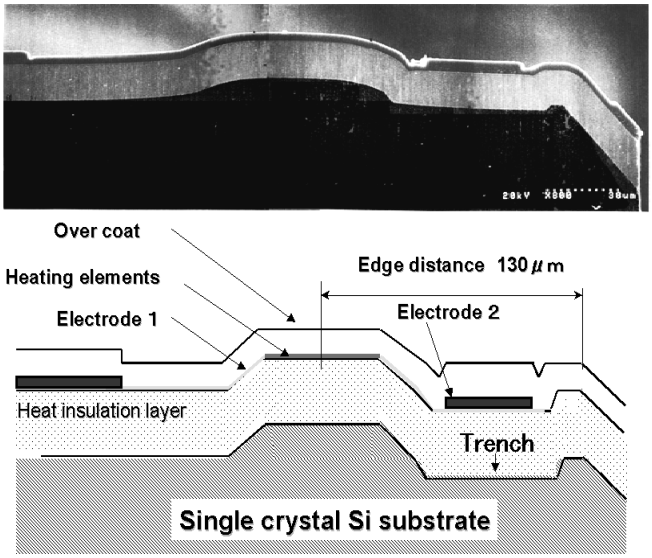


Figure 2. Structure of Micro DOS Head

Structure of Micro DOS Head

The structure and SEM images of Micro DOS head are shown in Figure 2. The print head consists of 240 heating elements lined up at 42µm intervals and achieves 600dpi print resolution. It is designed for a serial thermal transfer printer that prints bands of 0.4 inch width during every carriage movement.

Dimensions of the head are 18mm x 8.5mm x 0.8mm. Single crystal Si is adopted as a head. The heat insulation layer is a silicon-based-alloy reactive sputtered film with a low-density columnar structure approximately 20µm thick. The heating elements are formed on a protruding part of the substrate with the aim of concentrating the load applied to the thermal head on them. Thus, resin ink can be transferred and fixed to plain paper. Although this head form with a projection has been conventionally adopted so far, heating elements of Micro DOS head are located at 1.5 times higher position than conventional print heads and slope angle of the protruding part is also 1.5 times steeper.

Ink-release characteristic in thermal transfer printing is easily affected by the edge distance of the head, the distance from the center of heating elements to the edge of the head. Edge distance of Micro DOS head is therefore designed to approximately 130µm. As shown in the cross section of SEM images of Micro DOS head in Figure 2, a trench is formed between the heating elements and the head edge, and a common electrode is buried there. Also, a flat part of approximately 20µm is formed on the edge part where resin ink is fixed.

Technical Issues in Development of Multi-Level-Tone Printing

Technical issues in development of multi-level-tone printing are making dot diameter smaller by heat control of heating elements and controlling dot diameter. Also, transfer stability of small dot is essential to continuous tone. In order to get stable ink transfer, ink must be fixed on the paper.

Figure 3 shows ink transfer process. Figure 4 shows the relation between dot diameter and head temperature or ink temperature when dot diameter varies.As shown in Figure 3, transfer process of resin ink in thermal transfer consists of 4 steps. Required time and distance for the process is 500_sec and 130_m at print speed of 10 inches per second [4] and at driving frequency of 6kHz. When resin ink of the edge part is transferred from base film on the paper as shown in Figure 4, lowering the temperature of resin ink by lowering head temperature can make dot diameter smaller.

However, conventional head with low temperature produces unstable ink transfer such as having tail as shown in (a) of Figure 5.

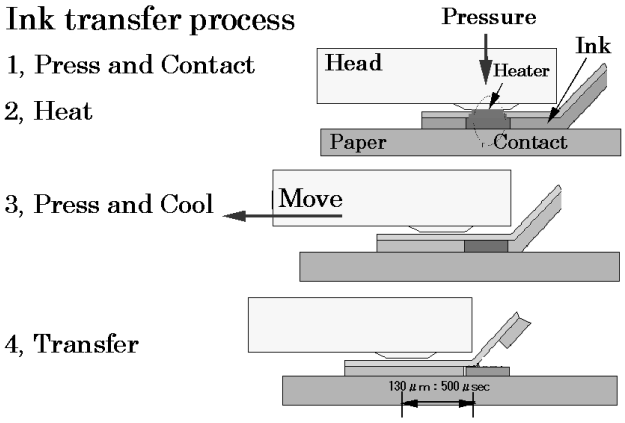


Figure 3. Ink transfer process

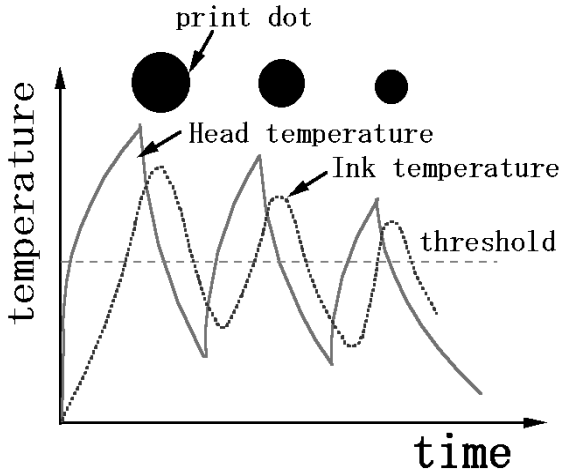
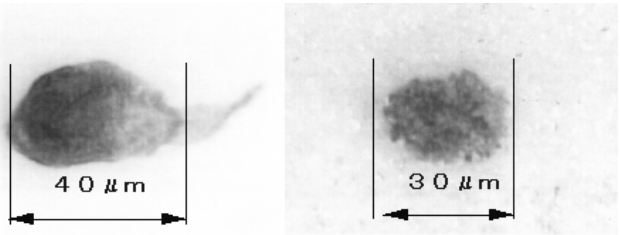


Figure 4. Relation between dot diameterand Head temperature or ink temperature



(a)Conventional Head *(b) New Head*

Figure 5. Image of print dot

Evaluation of Technical Issues

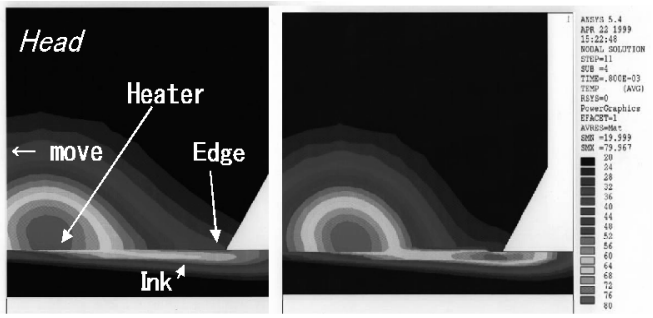
Analysis by FEM (Finite Element Method)

As stated in the previous chapter, ink transfer of small dot by lower temperature of ink is unstable. Therefore, we have analyzed temperature change of ink, between heating elements and the head edge where ink is transferred, with both conventional head and simulated new head by FEM in order to confirm potential cause of unstable transfer. Figure 6 shows the results of simulated thermal distribution in head and ink by FEM analysis.

First, we have performed analysis with conventional head and Figure 6 (a) shows the results. According to the Figure 6 (a), ink temperature with conventional head peaks between the heating elements and the edge part. In ink transfer of small dot, heat of ink at contact part of the head and paper between the heating elements and the edge part conducts to the head, and this lowers the ink temperature at edge part. Therefore, it is considered that ink temperature lowered by heat conduction from the ink to the head causes unstable transfer in highlight part.

Based on the results of analysis with conventional head, we have simulated the head structure with the common electrode buried in the trench in order to prevent heat conduction from the ink to the head between the heating elements and the head edge, and then have performed analysis. The result is shown in Figure 6 (b).

As shown in Figure 6 (b), ink temperature peaks at the edge part where ink is transferred from base film on the paper, because heat of ink with the simulated structure does not conduct to the head over the necessity in the process of press and cool. Therefore, we have proved that the optimum head form is that heat of ink between the heating elements and the head edge does not conduct easily in order to attain multi-level-tone printing.



(a)Conventional Head *(b) New Head*

Figure 6. Simulated thermal distribution

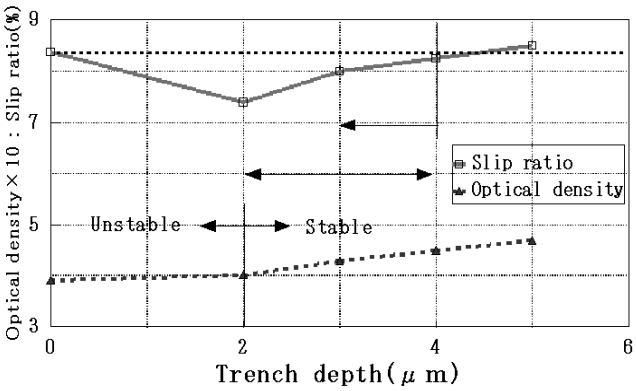


Figure 7. Relasion between trench depth and optical density or slip ratio

$$\text{Slip ratio}(\%) = 100 - \frac{\text{Ink spent length} \times 100}{\text{Print length}}$$

Designing Structure of Micro DOS Head

As we have proved optimum head structure, we have evaluated to actually bury the common electrode located at the edge part of head in the trench. This enhanced form eases contact of the ink and the electrode between the heating elements and the head edge, and secures heat of ink to the edge of the substrate. Print results with the enhanced head is shown in Figure 5 (b). As shown in Figure 5 (b), resin ink using new head is transferred stably compared with that using conventional head. Also, pattern reproduction in shadow part has been improved.

Figure 7 shows relation between trench depth and optical density or slip ratio. According to the evaluation, it has been proved that required trench depth is 2μm or more from the point of stability of transferred dot. However, it has been also proved that trench depth of 4μm or more increases slip ratio and causes ink ribbon feed failure.

As a conclusion, required accuracy of trench forming is 3μm±1μm.

Head Forming

As for the trench forming which requires high accuracy, it is achieved by utilizing anisotropic of single crystal Si substrate against etching. We have succeeded in controlling the projection and the trench of the substrate with the tolerance of ±1μm by adopting anisotropic chemical etching. Therefore Micro DOS head exhibits the optimum form and stable characteristics.

Property of the Tone

Figure 8 shows tone reproduction curve. And it shows improvement of the tone. Transfer sensitivity of new head is higher than that of conventional head, and pattern reproduction of shadow part is improved.

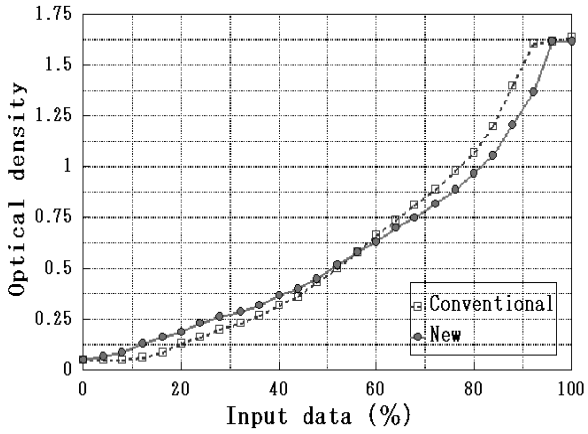


Figure 8. Tone reproduction curve of new head

Conclusion

After a series of examination for attaining multi-level-tone printing, we came to the conclusion that head form especially the part between the heating elements and head edge is deeply related to the property of the tone. Thus we have attained multi-level-tone printing using resin ink with the optimum head form by varying dot diameter in 16 levels.

Image quality using Micro Dry printer with Micro DOS head introduced in this paper is extremely close to that of aimed offset printing by having attained multi-level-tone printing. Thus, we believe that Micro DOS head with higher definition will attain almost the same image quality as offset printing.

References

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Biography

Hirotoshi Terao received his BS degree in materials engineering from Mining College at Akita University in1991. He has worked at Alps Electric Co., Ltd. System Devices Division since 1991 and is currently a researcher in the R&D department. His interests are in research and development of thermal transfer technology and thermal print head. He received a technical award from The Society of the Electrophotography of Japan in 1996. He is a member of The Japan Society of Mechanical Engineers.

E-mail address:teraohit@alps.co.jp