Study of Thermal Print Head for High-Speed Print

Hirotoshi Terao and Toshifumi Nakatani
Alps Electric Co., Ltd.
Tokyo, Japan

Abstract

We studied a thermal print head featured high-speed print. In the former paper, we reported renovated head design and structure of a thin layer showing low thermal diffusivity formed on a substrate with high thermal diffusivity to attain 1200dpi high definition print. And we have developed such print head consisted of single crystal silicon substrate and sputtered film. We also conducted FEM analysis to the newly developed print head to evaluate the possibility of high speed print. As a result, we came to a conclusion that 40IPS (inch per second) using 300dpi head was technically achievable and print test using 600dpi head proved reliable print quality.

Introduction

Printers, from office use to individual home use, have been enhancing its print speed day by day and ones featuring 100ppm or more are almost the mainstream in the market today. We have so far achieved the first goal of 1200dpi in thermal transfer printing by improving various factors such as head structure and ink material.[1-6] Besides, in pursuit of better image quality on various output devices, it is urgent for printers providing only binary mode to realize multi-level tone printing. This current made us add further improvement to thermal head with the aim of multi-level tone printing employing resin ink, which let us gained the new technology called Variable Dot Photo (VPhoto).[5] Recent strong demand for higher speed, however, forces thermal printers, often applied as a proofer thanks to its similarity in printing process and ink property to commercial print, to attain higher speed, too. In addition wide spread of digital still camera reproducing high pixel-density images makes it more important for output devices to reach photographic print quality by attempting higher resolution. Therefore, adopting thermal analysis, we examined high speed print without changing the present structure of Micro DOS head in respect of whether it can realize satisfactory print speed.

Head Structure

Thermal print head used in a series of analysis and experiments has the structure as shown in Figure 1. It is a 600dpi-head consisted of 240 heating elements lined-up at 42 micron intervals and designed for a serial printer that prints a band of 0.4-inch width at every carriage movement. Driver IC chip is mounted in TAB (Tape Automated Bonding). Dimensions of the head are 18 mm × 8.5mm × 0.8mm. TAB and the head are soldered at terminal pitch of 70micron. Single crystal Si is employed as material of the substrate and the heat-insulation layer is a silicon-based-alloy reactive sputtered film with a low-density columnar structure approximately 23micron thick. This is the same structure as Micro DOS (Deposition on Si) head already in practical use. The heating elements are formed on a protruding part of the substrate with the aim of fixing resin ink firmly onto even plain paper, which contributes to concentration of the load applied to the head on the heating elements. When it comes to ink releasing from base film and transferring it onto print medium, ink transference characteristic is highly influenced by edge distance, the length from the center of the heating elements to the head edge. Edge distance of Micro DOS head is approximately 130micron. In this head structure, the influence of the thickness of the heat insulation layer on the thermal response was simulated, and the possibility of a high-speed print was examined.

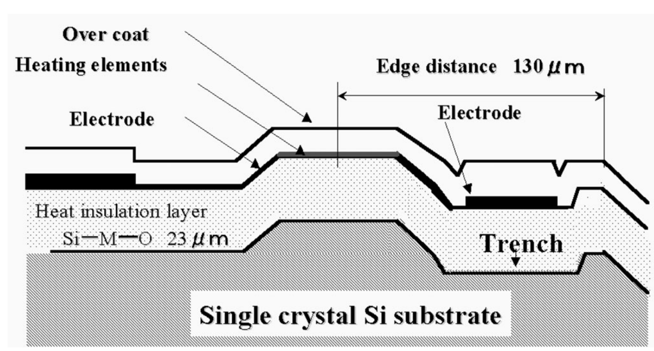

Figure 1. Head Structure

Evaluation of Technical Subjects: Analysis by FEM (Finite Element Method)

We applied FEM to the evaluation of technical subjects on high-speed print. Figure 2 is the FEM analysis model and

Table 1 shows material properties of the head, ink ribbon and print paper. We used ANSYS6.1, FEM analytic software, as the means for two-dimensional analysis. Assuming a model simulating relative motion of the head and media (ink and paper), the analysis employed Mass Transport function of the software. In the analysis of the head, we first analyzed condition of three continuous dots which two of them energized and one in the middle not energized and then evaluated the relation between shift in ink temperature and amount of relative motion of the head and ink. We evaluated ink-transferring condition from the relation of threshold of printing to peak and valley ink-temperature, and then found out required minimum head temperature after the head peak temperature.[6]

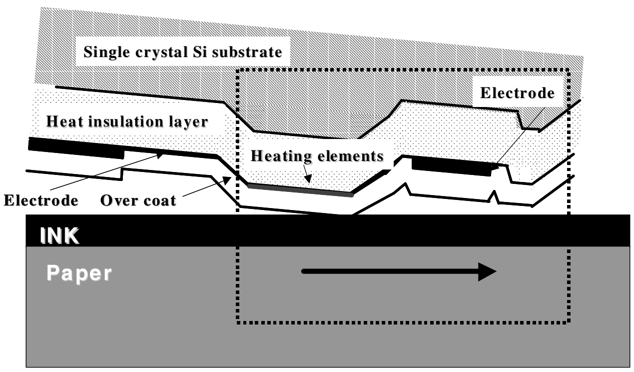

Figure 2. FEM analysis model

Table 1. Materials Property

Materials	Thermal conductivity (W/mK)	Specific heat (J/kgK)	Density (kg/m3)
Si substrate	170	800	2.33E-06
Heat insulation layer	10	750	2.33E-06
Heater	57	152	2.00E-06
Over coat	3	3.00E+03	1.66E+04
PET	1.40E-01	1.34E+03	1.40E+03
Paraffin	3.20E-01	2.52E+03	9.40E+02
Ink	3.49E-0	2.44E+03	9.80E+02
Paper	6.00E-02	1.17E+03	1.05E+03

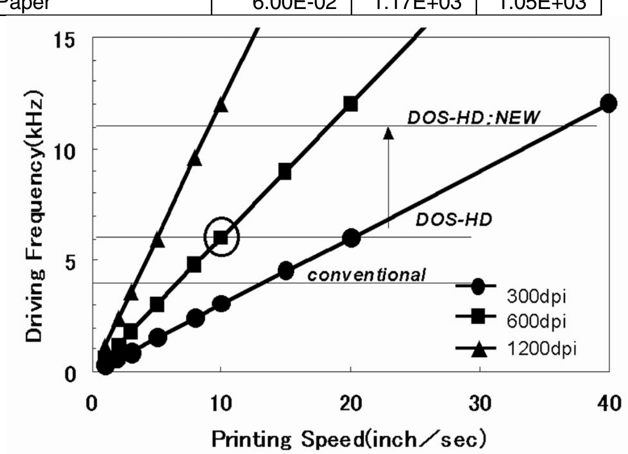

Figure 3. Relationship between driving frequency and printing speed

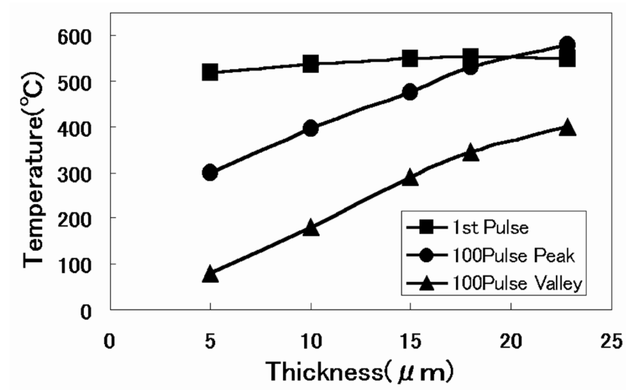

Figure 4. Relationship between thickness of heat insulation layer and head peak temperature

Driving Frequency and Print Speed

The relation between a print speed and driving frequency in each resolution is shown in Figure 3. The limit of driving frequency was 4kHz for the conventional head. Therefore, 11IPS was a limit speed at the print speed for 300dpi. As for driving frequency, 6kHz are possible for the DOS head, which we made a product in the past. 20IPS becomes in 300dpi in this structure. In this paper, the head structure was changed, and where the print speed could be raised was examined.

Transition Response Characteristic

The heat response characteristic of the head when the thickness of the heat insulation layer of the DOS head is changed to Figure 4 is shown. As for the temperature of 1st pulse, the correlation with the thickness of the heat insulation layer was not seen. It is understood that the temperature when continuously energizing lowers when the film thickness is thin. The temperature of the valley of 100 pulse energizing decreases with the peak temperature. It is thought that this reason is to have come to radiate heat easily by the thick nesses of the heat insulation layer having thinned.

Electric Power and Heat Radiation Characteristic

An electric power necessary to adjust the 100th pulse to 500degrees centigrade is shown in Figure 5. When the thickness of the heat insulation layer is thin, a necessary electric power grows. 1.75 times energy are needed in thickness 5micron of the heat insulation layer compared with the conventional. Therefore, Power consumption is a subject when the future. The relation between the thickness of the heat insulation layer and the temperature of the valley when the temperature at the time of a continuous energizing is 500degrees centigrade is shown in Figure 6. It is understood that the thinner the thickness of the heat insulation layer is, the lower the temperature of the valley is. When the thickness of the heat insulation layer is thin, the time that reaches the temperature of the valley of a conventional thickness of the heat insulation layer becomes early. Therefore, raising driving frequency becomes possible.

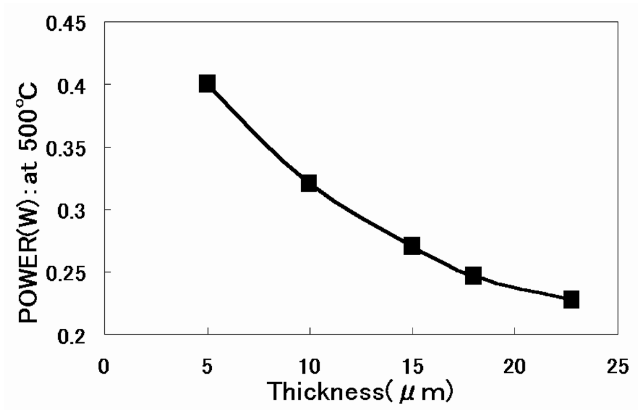

Figure 5. Relationship between thicknesses of heat insulation layer and head pea power

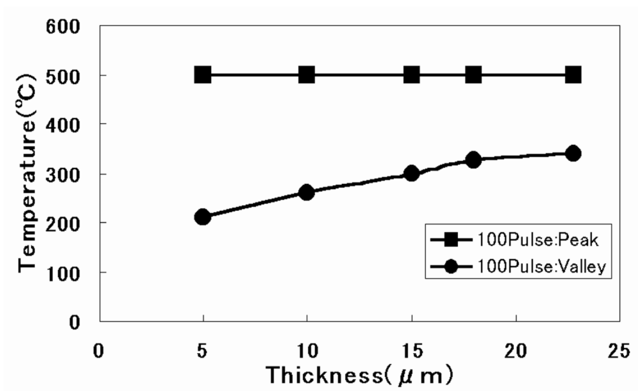

Figure 6. Relationship between thickness of heat insulation layer and head peak temperature

Relation Between Thickness of Heat Insulation Layer and Driving Frequency

The relation between a thickness of the heat insulation layer and driving frequency is shown in Figure 7. It is understood that driving frequency can make even 11kHz early when even 5micron thins the thickness of the heat insulation layer. About this relation, the head was actually made a prototype, and the experiment confirmation was done. The experiment result was shown in Figure 7. It is understood to become almost the same result as the simulation result.

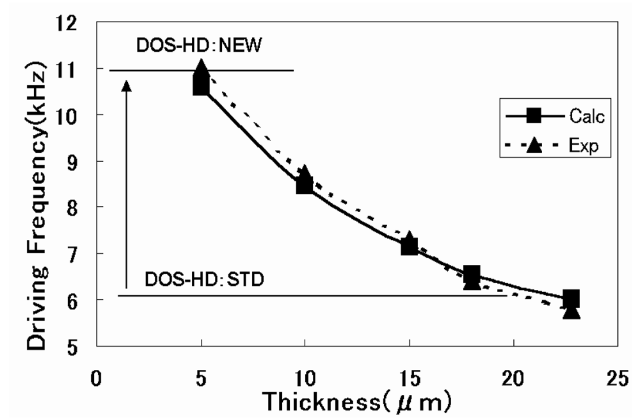

Figure 7. Relationship between driving frequency and printing speed

Head Surface Temperature

It has been understood for the DOS head, which thins the heat insulation layer to be able to make driving frequency early up to 11kHz. About 20IPS is possible by 600dpi, and it is understood that about 40IPS is possible by 300dpi. The relation between a print speed and driving frequency in each resolution is shown in Figure 8. And, the relation of a head surface temperature necessary for the print is shown in Figure 8. When the print speed becomes early, it is understood that a necessary head surface temperature rises. A heat resistant temperature is about 500degrees centigrade for the conventional head. Therefore, 20IPS is a limit for 300dpi conventional head. There are 700degrees centigrade or more heat resistant temperature for the DOS head. So that because, the Si substrate is adopted, and the heat insulation layer formed with sputtering is used. Therefore, the DOS head is early driving frequency, and understands the possibility of speed-up is very high because heat resistance is high.

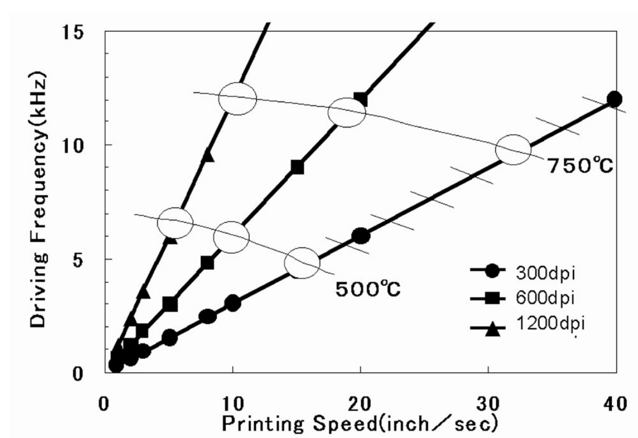

Figure 8. Relationship between driving frequency and printing speed and head peak temperature

Testing of Prototype

The head was made for prototype based on this analytical result, and the characteristic of a high-speed print was confirmed. The thickness of the heat insulation layer of this head is 5micron. The result is shown in Figure 9. Using the head of 600dpi compares 10IPS and 20IPS. Instability remains a little in the ink transfer of the outline in 20IPS. However, it is understood to be able to print almost equally to 10IPS.

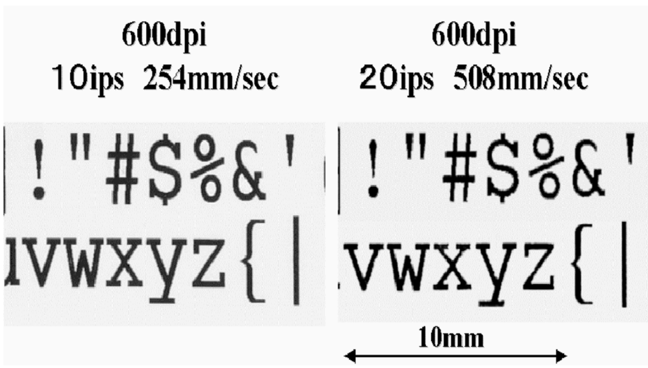

Figure 9. Comparison of print quality

Conclusion

It was confirmed to be able to high-speed print 20IPS with 600dpi, and to be able to high-speed print 40IPS with 300dpi from the FEM analysis, which used the structure of the DOS head. It has been understood to have to make the head surface temperature when high-speed printing a high temperature from the temperature of the head used so far. And, the possibility that a high-speed print could be achieved in an excellent DOS head in heat resistance was found. The head was actually experimentally made for prototype, the print examination was done, and the possibility of a high-speed print was confirmed.

Afterword

We have found that thermal response of Micro DOS head consisted of Si substrate and Si-alloy reactive sputtered heat-insulation layer contributes to materialization of high-speed print. And at the same time we strongly believe that printers for commercial use equipped with Micro DOS head will surely provide almost the same image quality as offset printing and the same photographic quality approaching that of silver halide imaging.

References

1. I. Hibino, “High Resolution Thermal Transfer Technology”, Proc. PICS, p100. (1998)
2. I. Hibino, J. Technical Report of IEICE, EID95-95,7 (1996)
3. H. Terao, N. Tsushima, T. Shirakawa and I. Hibino, “Study of a Thin Film Thermal Print Head for High Definition Color Imaging Use”, IS&T’s NIP15:1999 International Conference on Digital Printing Technologies, p227 (1999)
4. I. Hibino, S. Ono, T. Uchida, IEICE. Vol. J81-C, No. 6, pp. 566-573 (1998)
5. H. Terao, T. Nakatani, N. Tsushima, and I. Hibino, “Study of a Thermal Print Head for Multi-level Tone Printing”, IS&T’s NIP16:2000 International Conference on Digital Printing Technologies, p227 (2000)
6. H. Terao, T. Nakatani, N. Tsushima, and I. Hibino, “Study of 1200dpi High Resolution Thermal Print Head”, IS&T’s NIP17:2001 International Conference on Digital Printing Technologies, p504 (2001)

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