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Study of a Thin Film Thermal Print Head for High Definition Color Imaging Use

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Abstract

This paper describes the process of development of a thin film thermal print head that provides 600dpi resolution.

In order to achieve high definition printing using thermal transfer technology, it is essential for the print head to have fast thermal response, high thermal resistance and uniform contact pressure on print media. Subtle adjustment of the head is also required. With this point of view, we have evaluated a new structure and an optimum form for the print head.

At first, we developed a thin film thermal head which has a new structure composed of a high-thermal-diffusion substrate made of single Si crystal and a low-thermal-diffusion layer formed through sputtering process. This permits the 600dpi thermal print head to be driven at high speed and print at high density.

Secondly, we have succeeded in controlling edge distance, the distance from the center of heating elements to the edge of the head to approximately 130µm with tolerance of ±5µm or less by anisotropic chemical etching of the single Si crystal substrate. The optimum form of the specially developed print head allows resin ink to be stably transferred to plain paper. We call this print head Micro DOS (Deposition on Silicon) head.

Introduction

Thermal transfer printers have been used widely as the printing unit of word processor or an output device for personal computer because of its low price and compactness, both which are characteristic features approved by consumers.

However, in recent years color print quality in inkjet and electrophotographic technology has been quickly improved, which has enabled the former to increase market share in the low-price field and the latter in a high-quality-on-plain-paper field.

In this current, we have stuck to thermal transfer; 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 name this new technology Micro Dry ™ technology. We envisage that the provided image quality has the potential to become very close to that of offset printing. This paper will introduce Micro DOS head, one of the key parts of Micro Dry ™ technology, uniquely developed to achieve high definition printing at 600dpi using thermal transfer printer. Micro DOS head is installed in Micro Dry Printer MD-5000 launched at the end of last year. Figure 1 shows the appearance of the printer.

Figure 1. MD-5000

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 0.4inch width during every carriage movement. Dimensions of the head are 18mm x 8.5mm x 0.8mm.

Single Si crystal is adopted as a head substrate instead of conventionally used alumina ceramics.

The heat insulation layer is a silicon-based-alloy reactive sputtered film with a low-density columnar structure approximately 20µm thick, used instead of a conventional glass glazed layer. 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. It is known that ink-release characteristic in thermal transfer printing is easily affected by the edge distance of the head. Edge distance of Micro DOS head is therefore designed to approximately 130µm.

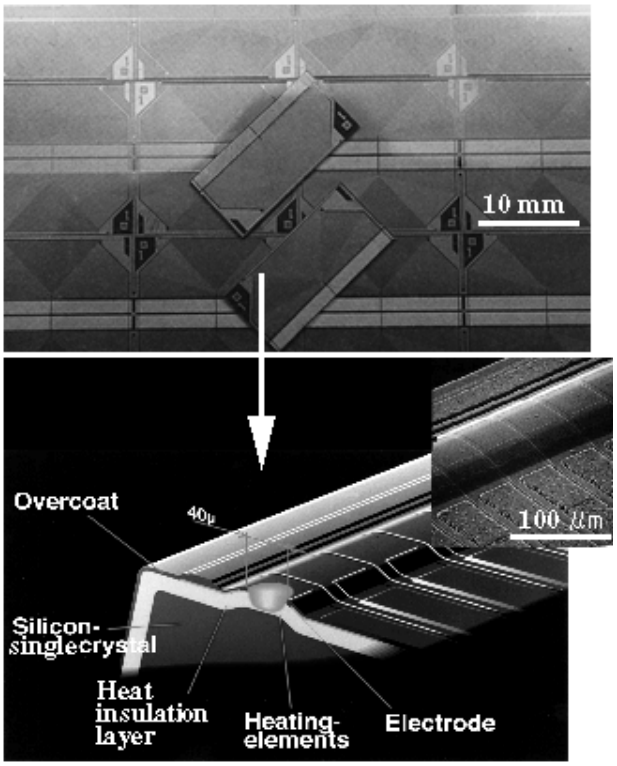

Figure 2. Micro DOS Head

Technical Issues in Development of High Definition Thermal Transfer Head

Thermal Response

The first technological issue in development of high-definition thermal transfer head is thermal response.

Required driving frequency to achieve 600dpi at print speed of 10 inches per second is computed as 6kHz. However, fast switching-on and -off of the heating elements at this frequency cause the substrate to retain heat; as a result, overheated elements fuse resin ink superfluously and ruin image quality as seen in Figure 3. Temperature of the print head also can not be controlled properly with this frequency.

To solve these problems the heat radiation characteristic of the substrate must be efficiently improved. Yet if the substrate radiates too much heat, it would not regenerate heat easily. On the contrary, it needs enormous energy to regenerate heat quickly at the elements. Furthermore, conventional glazed alumina ceramics substrate does not allow stable wiring of heating elements at 600dpi, because countless numbers of holes from a few to tens μm in diameter on the surface of the substrate, which look like pores, cause short circuit or disconnection easily.

Consequently heat insulation layer with low thermal diffusivity formed on a high thermal diffusion substrate needs to be developed to attain quick alternation of heating and cooling with less energy.

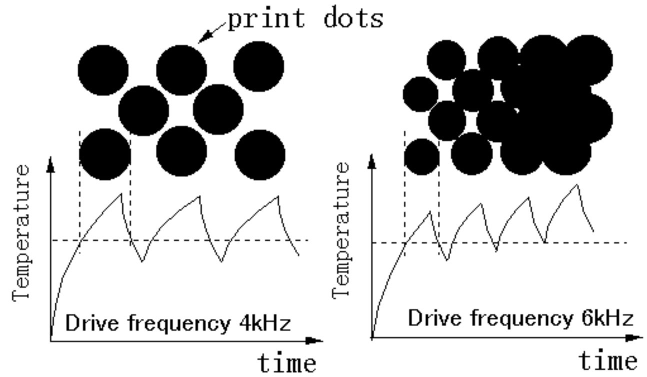

Figure 3. Relation between driving frequency and print image

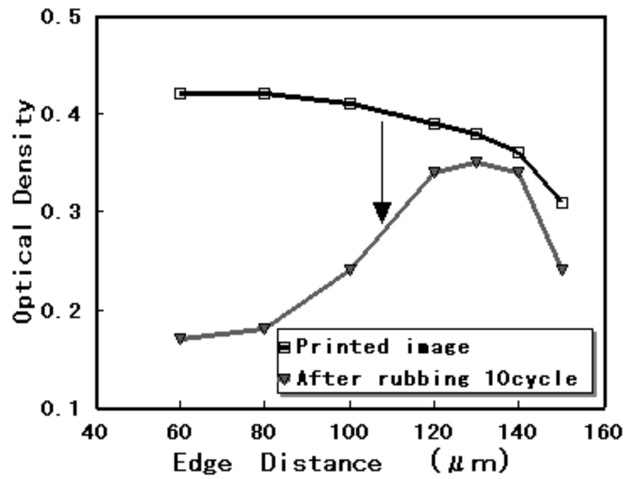

Figure 4. Relation between edge distance and printing density or and rubbing-resistance

Head Form

The second technological issue is the print head form.

Improvement in head design is an essential requirement for better transfer and fixation of resin ink on plain paper. Especially for the edge distance, striking a balance between the efficiency of ink transfer and that of fixation is important. Figure 4 shows the relation between edge distance and printing density or and rubbing-resistance. We have figured out that the range of favorable edge distance is quite narrow. The tolerance is approximately ±5μm against the optimum edge distance of 130μm.

Evaluation of Technical Issues

Adopting Silicon Substrate

As stated in the previous chapter, with the aim of achieving fast thermal response of the print head, both a substrate that shows higher thermal diffusivity than the alumina ceramics substrate and a thin heat insulation layer that shows lower thermal diffusivity than the conventional glazed layer are required.

Table 1 shows the thermal diffusivity of various materials. After examining these materials, we have adopted single Si crystal for the substrate. The reason for this is that the substrate made of Si single crystal has 6 times higher thermal diffusivity than an alumina ceramics substrate. Another reason is that its smooth surface makes it possible to form stable wiring pattern at 600dpi.

Table 1. Thermal diffusivity of various materials

Material	Thermal Diffusivity(mm^2/s)
Alumina ceramics	2.1
Single Si crystal	72.6
Glaze	0.45
SiO_2 sputtered film	0.89

Development of Optimum Heat Insulation Layer

Now the major problem here is how we manage to find and obtain the intended heat insulation layer formed on the Si substrate. We have adopted oxygen reactive sputtering method, which the heat insulation layer is formed by sputtering process targeting a metal in the oxygen filled atmosphere. This is a sputtered heat insulation layer made of silicon-based-alloy reactive sputtered film, while conventional one is glazed. Its thermal diffusivity is shown in Table 1. We can see that it is 15% lower than the glazed layer.

We have proved that we can form films with wide range of density by changing sputtering conditions. Figure 5 shows the structural differences affected by varied conditions. The higher sputtering pressure it is given, the lower density columnar structure it tends to have. The change in density also affects thermal response of the print head. Figure 6 shows the change of head temperature against the sputtering gas pressure. The higher sputtering gas pressure it is given, the more heat the print head generates. We have taken thermal response characteristic and productivity of print head into consideration and set sputtering pressure at approximately 1Pa.

The reason we have adopted oxygen reactive sputtering method is that forming speed can be significantly increased. Standard sputtering method has slower speed in forming films, which results in delivering dissatisfied productivity as compared to other methods such as thick film print method or wet coating method. Especially when insulators such as SiO_2 are used as a targeted material, it desperately decreases the forming speed. Adopting oxygen reactive sputtering method makes the speed three times faster than a standard sputtering method that uses SiO_2 as the targeted material.

Improvement of Head Form

As for the accuracy of head forming, it is improved by utilizing anisotropic of single Si crystal substrate against etching. Especially pursuing high accuracy in forming required edge distance with ±5μm tolerance is fairly difficult, since it has been conventionally done by grinding process.

We have finally succeeded in controlling the shape of sensitive parts such as the projection and edge distance of the substrate with the tolerance of ±5μm or less by adopting anisotropic chemical etching. Therefore Micro DOS head exhibits the optimum form and stable characteristics.

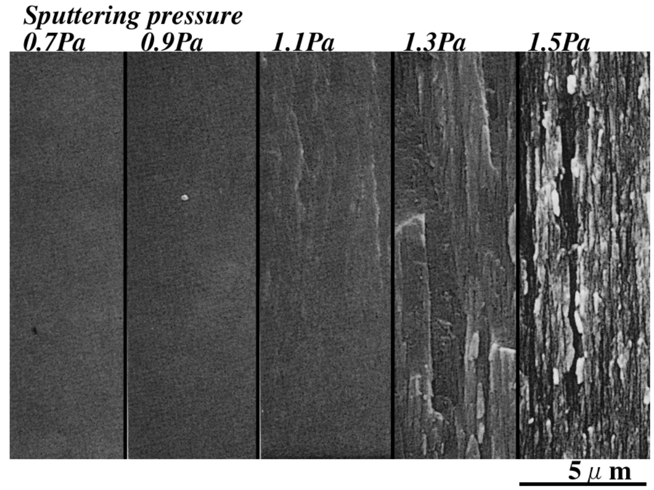

Figure 5. SEM image of heat insulating layer

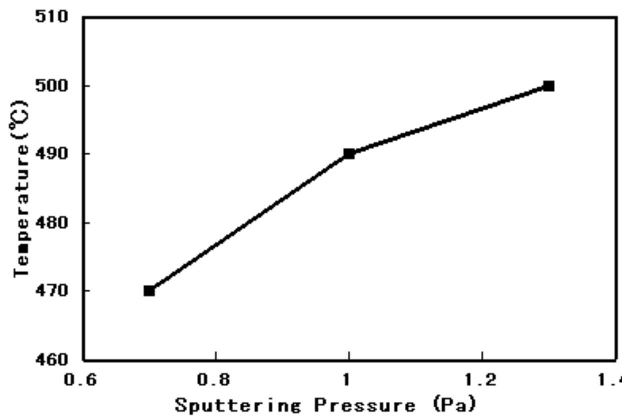

Figure 6. Relation between sputtering pressure and head temperature

Conclusion

In order to achieve high definition printing at 600dpi using thermal transfer method, the print head needs fast thermal response, high thermal resistance, uniform contact pressure on print media and subtle adjustment in the forming process.

Therefore we have evaluated the optimum new print head form and its structure that consists of the single Si crystal substrate with high thermal diffusivity and the low thermal diffusion layer formed on the substrate by oxygen reactive sputtering. As a result we have succeeded in driving 600dpi thermal print head not only at a high speed but also at a high density, which has realized high definition thermal transfer printing.

Application of Micro DOS Head

Micro Dry printer with Micro DOS head introduced in this paper is being continuously on developed and has resulted in the following features in the Micro Dry printer.

Firstly it has realized Variable Dot Photo ™ printing on plain paper, the technology for controlling printed dot size in 16 levels. This innovative print technology is applied to plain paper by MF (Media Flexible) ink applied on the surface of print media prior to color printing. The image quality attained by Variable Dot technology is extremely close to that of aimed offset printing.

Secondly it has made transference of metal foil, what we call "flush-metallic," available.

Finally we predict that it will realize almost the same image quality as offset printing and also printing on various kinds of print media that other technologies would never manage to handle.

Thus newly developed Micro DOS head has broadened the application range of Micro Dry printer.

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Biography

Hirotoshi Terao received his BS degree in materials engineering from Mining College at Akita University in 1991. 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.

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