Study of Thick Film Thermal Head Structure

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Abstract

The protective layer for a thick--film thermal printhead is formed usually by the conventional screen-printing method. The curvature of the protection layer is dependent on the formation of the heater nib. If the cross-sectional structure of a heater nib is thin or wide, the curvature of the protection layer is large. Though the platen pressure becomes small, the printing characteristics is uneven due to larger contact area. On the other hand, if the cross-sectional structure of a heater nib is thick or narrow, the curvature of the protection layer is small. The contact pressure with media is large and may generate sticking, and intense wear result. A new approach of protective layer formation by means of a direct dispensing system to realize a convex cross-sectional structure with a desirable curvature is studied. It possesses the following advantages over the conventional screen-printing method: (1) Forms of various curvatures can be studied, independent of the form of a heater nib structure. This is critical in manufacturing a high-resolution printhead where the heater nib is usually very thin, and high reliability and long life expectancy are desirable. (2) Reduction in manufacturing cost since screen masks are not required and the waste paste used in screen-printing is saved.

Introduction

The thermal printing technology is based on the principle of transferring heat from a high-resistance nib line to the thermal-sensitive media being contacted, and has the advantages of fast throughput and ease of maintenance. There are two technologies in manufacturing thermal printheads: thin film by vacuum technology and thick film by screen-printing and firing process. Utilizing thick film technology, the dual-line wide-format 1200dpi thick film thermal head has been developed[1]. Several wide-format (up to 54" width) products based on the 1200-dpi thermal print head have been designed and are capable of printing half-tone images.

Since the cross-sectional structure of a thick film thermal head is of curvature, contact with media is firm to provide sufficient printing efficiency. However, it does depend on the characteristics, such as viscosity, surface tension, etc., of paste material used for the nib line as well as the protection layer. In the case of requiring a high heat response, the heater nib line should be thin, thus the curvature becomes large, resulting in an undesirable contact characteristics with media. Also, the variation in resistance of a nib line becomes large. To improve contact characteristics with media, it is necessary to make the curvature small. However, when the contact pressure becomes too high, media sticking would occur and wear of the protection layer becomes large. On the other hand, in the case of large curvature, contact with media may become unstable. In order to investigate these problems, formation of the protective layer by means of a direct dispensing system is studied and experiments are performed to obtain insight in the influence of different forms (curvature).

Study of Protective Layer Structure

The top view of the heater nib line on a typical thick film thermal head and the cross-sectional view of the structure are shown in Fig. 1.

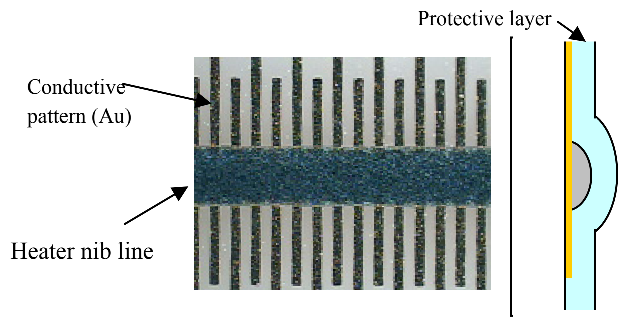


Figure 1 *Top view of the heater nib line on a thick film thermal head and the cross-sectional view of the structure.*

A conductive pattern made of gold is formed by means of photolithograph and etching technology on the glazed ceramic substrate. Then the heater nib line is formed utilizing a direct dispensing system, and the protective layer is formed by screen-printing[1]. The cross-section curvature of the protective layer on the heater nib line is influenced by the form of the heater nib line. This curvature can be approximated with a second-order curve with a hill-foot spread-out which is the characteristics of screen-printing. The curvature of the protection layer depends on the width as well as the height of the heater nib line. The profiles of the protection layer on the heater nib line and the approximation of the second-order curves are shown in Figures 2 for 600dpi and 400dpi nib lines.

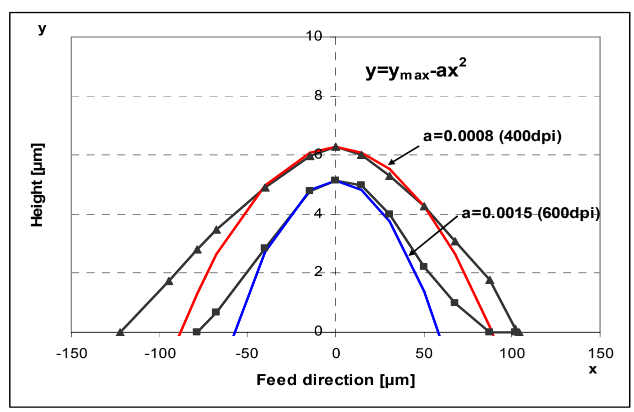


Figure 2 *Cross-sectional profiles of the protection layer on the heater nib line*

The sketch diagram of a thermal printing system, that the feeding mechanism uses a platen roller, is shown in Figure 3.

The pressure applied to the protection layer atop the nib line may be estimated by the force and the contacting area which is a function of the elasticity characteristics[3][4] of the material as follows:

$P_0 = f/b$ (1)

where

P_0: Pressure on the protective layer [g/mm^2]

f: Force per unit length in the direction of nib line [g/mm]

b: Contact width in the direction orthogonal to the nib line

$b=\sqrt{4f(K_1+K_2)R_1R_2/(R_1+R_2)}$ [mm] (2)

$K_1=(1-v_1)/\pi E_1$ (3)

$K_2=(1-v_2)/\pi E_2$ (4)

$_1$: Poisson ratio of platen rubber

$_2$: Poisson ratio of protective layer

E_1: Young's modulus of platen rubber

E_2: Young's modulus of protective layer

R_1: Radius of the platen roller

R_2: Curvature of the protection layer

Note that $R_2 = 1/2a$ for a second-order curve $y= ax^2$

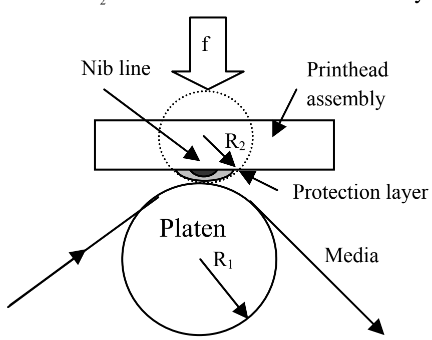


***Figure 3** The diagram of the mechanism of a thermal printing system*

Shown in Fig. 4 is the calculated P_0 as a function of R_2 which is the curvature of the protection layer and is approximated as 1/2a. The pressure curve is normalized to 100% for the profile of a 600dpi printhead.

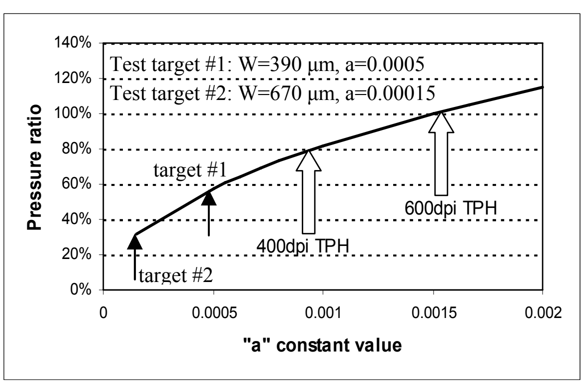


***Figure 4** Changes of pressure due to variations of the curvature of contact area, with a=0.0015 for 600dpi and a=0.0008 for 400dpi*

Due to a smaller curvature (i.e., smaller R_2, larger 'a' value), P_0 for the case of 600dpi is about 1.37 times of P0 for 400dpi, and is about twice of P_0 for 200dpi.

The problem and a solution

For the structure of the current thick film thermal head the pressure at the contact area between the protection layer and the media is a function of the curvature which differs with resolution of the nib line. Therefore, the following problems arise:

1) Wear of the protection layer
   A higher pressure results for a nib line of higher resolution, hence wear of the protection layer becomes larger.
2) Foreign objects and contaminations
   When foreign objects or contaminations are involved in, a heater element will break more easily under a higher pressure.
3) The printing mechanism needs to be changed to adapt to the protective layer profile (curvature) on a heater nib of different resolution.

To solve the above-mentioned problem, a new structure of protection layer is proposed as shown in Figure 5. The protection layer is formed by means of a direct drawing system so that the contact portion may be of a desirable curvature. The optimal condition of the characteristics of the material of the protective glass paste and the dispensing parameters are studied in this development.

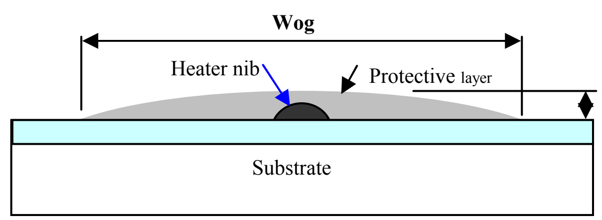


***Figure 5** Cross sectional structure of the proposed protective layer*

Present data analysis, and experiments

Test samples are made by maintaining the same height (t) and only varying the width of the protection layer so that the curvature is changed. With P_0 of the existing 600dpi printhead as a reference for 100% nominal pressure (Fig. 4), effort is made to generate the desirable curvatures for 75% and 50% on 400dpi nib lines. The target height ranges between 14 and 16 μm, and the target widths are 1) 400 μm for 75% pressure, and 2) 650 μm for 50% pressure. The following experiments estimate:

(1) Measurement of dimensions
(2) Wear characteristics
(3) Printing characteristics
   (3-1) Optical density versus applied energy
   (3-2) Variation of optical density along the moving direction

Experimental result

(1) Measurement of dimensions

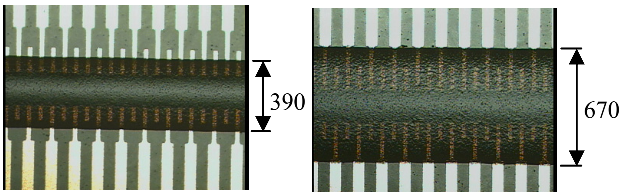
The result of the width and the height of trial heads are shown in Table 1. The top views of two trial thermal heads are shown in Fig. 6. The profiles and the approximation second-order curves are shown in Fig. 7.

The estimated pressures P_0 are shown in Figure 4.

- Narrow width (W=390 μm) "a" constant=0.0005
  Pressure ratio; 58%
- Wide width (W=670 μm) "a' constant=0.00015
  Pressure ratio; 32%

Table 1 Form of a protection layer

Test sample	Width, W (μm)		Thickness t (μm)	const ‘a’
	Target	Actual		
Narrow	400	390	17	0.0005
Wide	650	670	18	0.00015



Narrow width (W=390) *Wide width (W=670)*

Figure 6 *Top view of the protection layer formation*

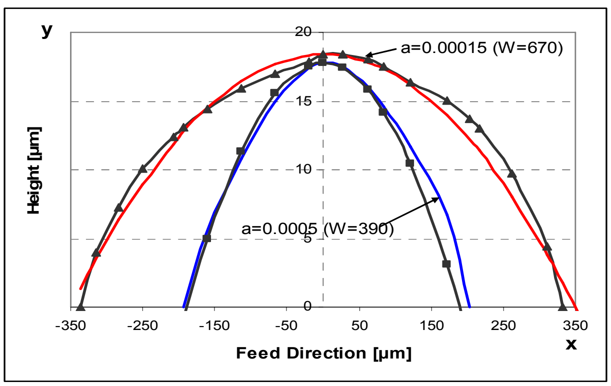


Figure 7 *Cross-sectional profiles and approximation second-order curves*

(2) Wear characteristics

The lapping sheet of #3000 is twisted around the platen roller in Fig. 3, and the running test is performed under the following condition:

Platen diameter: 40mm
Force applied on platen: 4Kg
TPH length: 60mm
Feed speed: 25mm/sec
No applied energy on TPH
Measuring samples: 400dpi, W=390 and W=670

The result of wear-out versus running length is shown in Fig. 8. The photographs after 100m run of the current 400dpi thermal head and the wide OG (W=670) thermal head are shown in Fig. 9 with the photographs of initial state of the surface for each case also shown. Both profiles are shown in Fig. 10.

The amounts of wear of the current 400dpi thermal head and of Narrow OG (W=390) are almost the same as seen in Figure 8. In the case of W= 670, due to a gently-sloping curvature (a much smaller "a" constant of 0.00015), the wearing is at a slower rate than the current 400dpi or narrow OG (w=390).

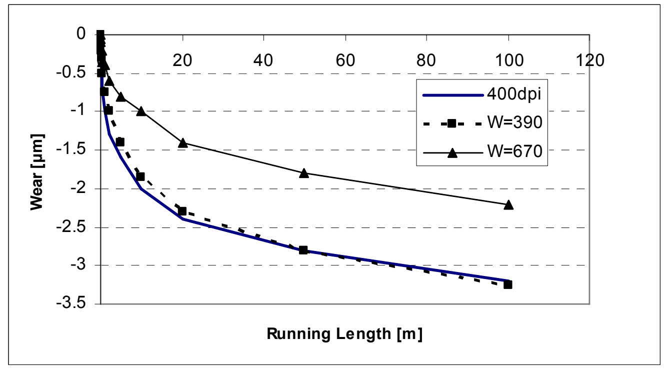
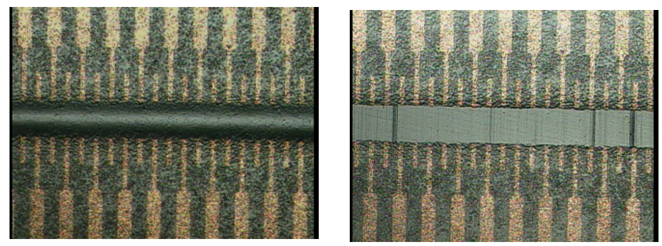
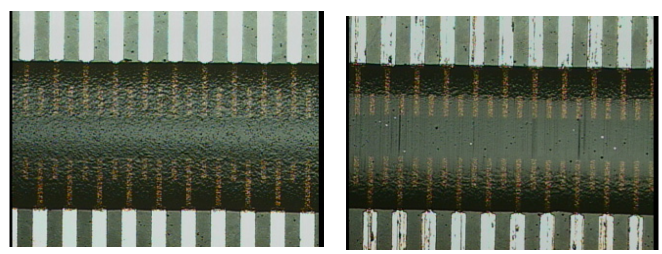


Figure 8 *Result of wear characteristics test*



(a) Initial state (0m) *(b) After 100m*

Current 400dpi thermal head



(c) Initial state (0m) *(d) After 100m*

Wide (W=670) partial OG type

Figure 9 *The surface states of thermal head in wear-out tests*

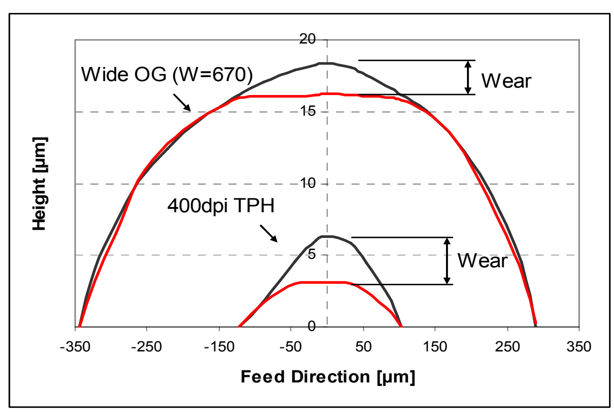


Figure 10 *The profiles before and after 100m running test*

(3) Printing characteristics

The spec of the thermal heads used for testing are as follows:

- Printing width: 360mm.
- Resolution: 600dpi,
- Partial protective layer width:
  1) W=390 µm
  2) W=670 µm
  note: SiN of 2 µm thickness is used for protecting conductor.
- Printing equipment: TechStyler (OYO Instruments)
- Printing media: GSP film (OYO Instruments)

The tests are performed by varying applied energy levels, and transmission optical density is measured by a Macbeth TD904. The result is shown in figure 11. The energy required to obtain saturation optical density is as follows.

Current 600dpi thermal head: 0.175mJ
Narrow OG (W=390): 0.172 mJ
Wide OG (W=670): 0.192 mJ

The standup (-Gamma) characteristics of printing optical density:
Narrow OG (W=390) is steep.
Wide OG (W=970) is gently-sloping

Note that about 10% more energy is required for the wide OG (W=670) type to achieve the same optical density. This is due to the influence of the thickness and the volume of a protective layer enclosing the heater nib.

The averaged optical density along the moving direction is measured at intervals of 10mm on the applied energy conditions at optical density 3.4 and is shown in Fig. 12.

Variations in the optical density:
Current 600dpi thermal head: 4.0% (3-)
Narrow OG (W=390): 2.4%
Wide OG (W=670): 4.5%

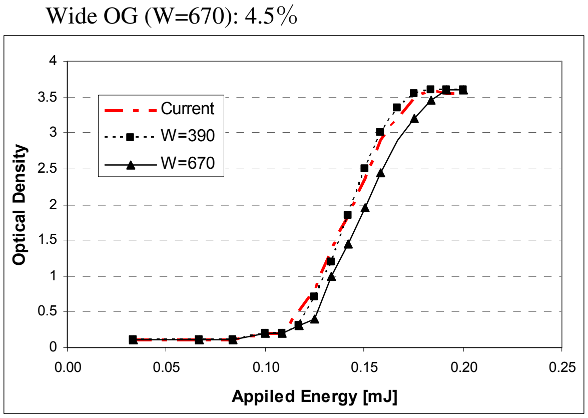


Figure 11 The characteristics of optical density versus printing energy

The variation of the narrow OG (W=390) type is the smallest although the curvature of the protection layer is the largest. This is because the protection layer is formed by means of a direct dispensing system and it's easier to make a uniform form for a larger curvature, resulting in a smaller variation.

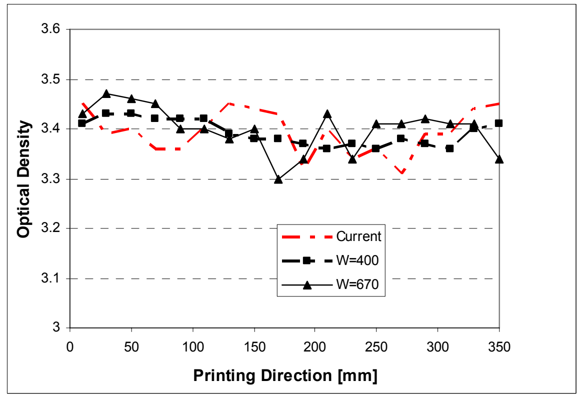


Figure 12 Measured optical density along the moving direction

Summary and future direction

Formation of the protection layer of a thick film thermal head is made by means of a direct dispensing system. Since it is the same equipment used for forming a heater nib line, there is no additional cost involved and it can form a protection layer of high precision on a heater nib line. The protection layer has a form of curvature which can be approximated with a second-order curve. Experiments have been performed on different types of protection layer of the same height but with different widths. In the case of wide OG (W=670 µm), both the amounts of wear and the wearing rate are smaller the current 400dpi or narrow OG (w=390 µm) nib line. However, it requires 10% more energy to achieve the same optical density. The variation in printing optical density is about the same as a current type. In the case of narrow OG (W=390), it exhibits almost the same wear characteristics as a current thermal head, so is the printing characteristics. The variation in optical density is small compared with a current one. When the protection layer of a thick film thermal head is formed by means of a direct dispensing system, it consumes about 1/10 or less protection layer material as compared with the current forming approach of screen-printing. Besides, the screen-printing mask is not required. Therefore, it also brings in the benefit of cost reduction

References

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Author Biography

Takeshi Toyosawa obtained his B.S. in Chemistry from Akita University, Japan in 1979. He worked at GRAPHTEC Corporation Research and Development from 1979 to 2004. Since 2005 he has been with OYO Geospace Corp, and is continuing R and D in wide format high resolution thermal print head.