Maximum Performance of Thermal Printhead

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Abstract

There are two types of thermal printheads. One is a flat type which has the heater line situated on the ceramic substrate's flat surface. And the other is edge type printheads which have the heater line either on the corner edge or the edge (called "True Edge") of the head. Both corner and True edge type printheads offer straight pass capability, while flat heads do not. Using corner edge capability, an extremely high speed printhead has been developed. This is a printhead for in-line date-code printers. It has a printing speed of more than 40 inches per second. Also, a new high speed printhead for ID card printers has been developed. It has a print speed of more that three inches per second, using dye sublimation ribbons. It is a True Edge type printhead.

Thus, performance of thermal printhead speeds are maximized by edge type heads. Construction of the printheads to achieve these high speeds will be introduced in this paper.

Thermal printhead styles

There are two styles of thermal printheads. One is flat type printhead which is most popular and reasonable. The other style is edge type printheads. There are also two kinds of edge type printhead. One is corner edge and the other is true edge.

The principle feature of flat type printhead is it has a heater line is on the widest dimension of a ceramic substrate. Also, driver IC is located on that same surface. As a result, the media pass needs to have some angle to avoid touching the driver IC and it is bent along the platen surface as shown in Figure 1.

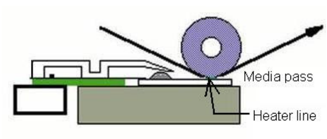
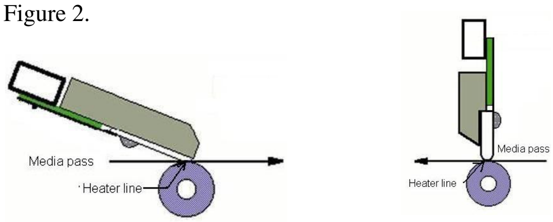


Figure 1. Flat type printhead

On the other hand, corner edge and true edge printheads have no impediment before or after the heater line. Then, a straight media pass is achievable with those edge type printheads as shown in Figure 2.



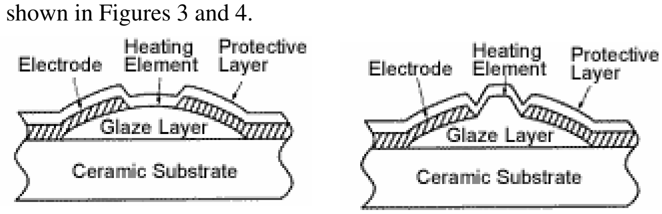
Corner edge type printhead   True edge type printhead

Figure 2. Edge type printheads

Glaze selection

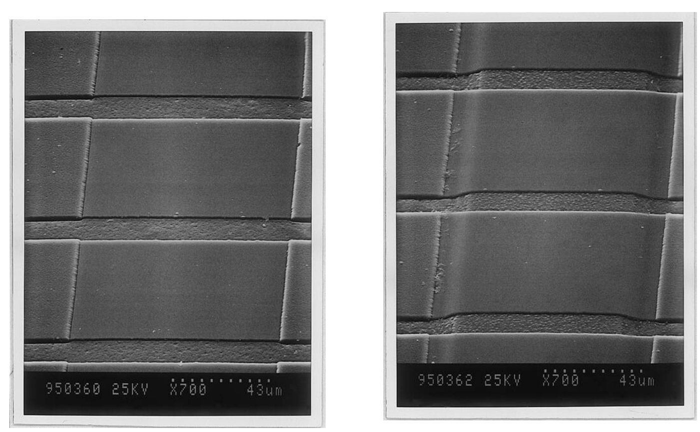
The performance of thermal printheads is directly related with type of glaze that is chosen for it. Especially, glaze thickness paramount. If the glaze thickness is thin, heat response will be good. However, maximum achievable temperature will be lower than thick glaze using the same operating conditions. Then, more energy is applied to get the same optical density. To maximize the performance, glaze thickness must be optimized.

Also there are very unique shapes of glaze. One is double partial glaze which has additional partial glaze under the heater, as shown in Figures 3 and 4.



Partial glaze   Double partial glaze

Figurer 3. Cross section of partial and double partial glaze



Partial glaze   Double partial glaze

Figure 4. Surface picture of partial and double partial glaze

This double partial glaze (DPG) makes excellent contact between heater and media. It means that localized pressure at heater line is much higher than with a Partial glaze. As a result, heat transfer is significantly improved, compared with partial glaze.

Double Partial glaze is also widely used with flat type printhead for portable printers. It uses battery for printhead operation. Printer with DPG type printhead is significantly improved to extend the battery life.

At this time, this double partial glaze is formed on the true edge substrate glaze. Purpose and evaluation results are introduced later in this paper.

Feature of corner edge glaze

Localized pressure is one of the very important factors to obtain high print quality and high efficiency. One of the methods to get high localized pressure is to apply DPG as explained in the previous section. Corner edge glaze has same effect as DPG. However, it is utilizes a different mechanical approach. Corner edge glaze has a very small radius curvature. This small radius makes the contact area between media and heater tiny.

If pressure is increased on the partial glaze of a flat type printhead, the platen will be deformed and fit to the even ceramic surface located both front and back side of the heater glaze. The result is localized pressure to the heater line will not be increased so much due to the wider contact area caused by platen deformation. And, the deformation may be a case of printing noise and sticking.

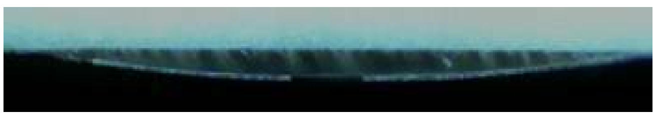


Figure 5. Cross section of flat type partial glaze

Corner edge glaze is located right on the corner of the ceramic substrate. Even though more pressure is applied to this glaze; the platen will never touch the ceramic substrate because the ceramic surface is not on the same plain as the heater glaze.

Figure 6. Cross section of corner edge glaze.

Figure 7 shows the acceptable width of heater position against platen roller to get optical density 1.1 or grater by Macbeth RD-914 using thermal paper. Corner edge printhead's localized pressure is higher than flat type printhead. As a result, corner edge printhead acceptable with for O.D. 1.1 is wider than flat type printhead.

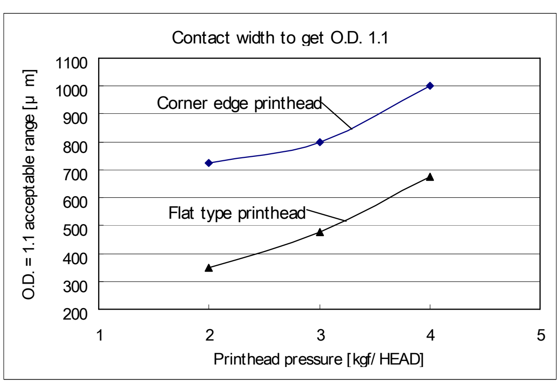


Figure 7. Contact width to get O.D.1 .1

Glaze thickness for high speed printing

The glaze thickness is the most important factor to determine heat response. When high speed printing is required, this heat response must be improved to reduce the thickness of the glaze. However, once the thickness of the glaze is reduced, the temperature of the heater surface will be reduced because a greater amount of heat will be dissipated.

The chart in Figure 8 shows the heater temperature behavior vs glaze thickness using the same pulse condition which is equivalent to 2000 mm/sec with 300 dpi resolution.

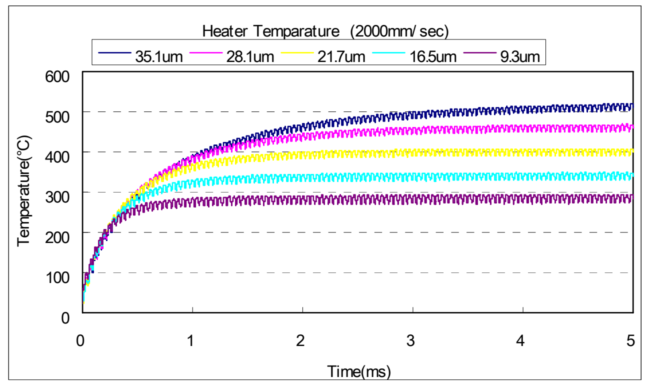


Figure 8. Temperature behavior by glaze thickness

On this chart, we can find that the temperature of thinner glaze saturates quicker than thicker glaze. On the other hand, a thicker glaze achieves a higher temperature than thinner glaze. To print quickly, a better heat response is necessary. However, a certain temperature must be achieved for printing. In this sense, best glaze thickness must be investigated by evaluation. Table 1 is showing the optimum glaze thickness and printhead type per print speed for black and white print applications.

Print speed	Printhead type	Glaze thickness
< 4 ips	Flat	55um <
4ips ~ 12ips	Flat	35um ~ 55um
12ips~36ips	Corner edge	25um ~ 35um
36ips<	Corner edge	< 25um

Table 1. Optimum glaze thickness and printhead type

Pulse durability of heater elements under high speed condition

During thermal printing, temperature of the heater needs to be raised to sufficiently to print in each line cycle time (Tcy). In high speed printing, significant power will be required to achieve the temperature required for high speed. And, after very short cooling time, power will be applied to the heater again. This cycle is quite tough on the heater. When this printing condition may exceeds the durability of the heater, a high durability type heater material should be considered.

The resistance value of the heaters declines over time of printing. If a bigger power or longer pulse width is also applied this resistance decrease will be quicker. This is from an annealing effect. Then, as the resistance value is decreased, the power is increased, from the application of the same voltage. This describes the process of resistor dot failure, due to the application of excessive energy. .

To avoid it, the resistance value of the heater should be decreased by annealing. During this process, the resistance value of the heater is decreased at the beginning. The result is longer resistor life, due to the burn out failure process being delayed and printhead life due to the pulse durability factor is extended.

Figure 9 shows the brake down test result on three kinds of heaters. The first is a standard heater material without any annealing process. The second one shows the annealing process applied to that same standard material. And, last one is the heater material to which a special annealing process has been applied. We found that simply annealing with high temperature may be a cause of damage to thin film electrodes or some other component. This is the reason why the special annealing method is required.

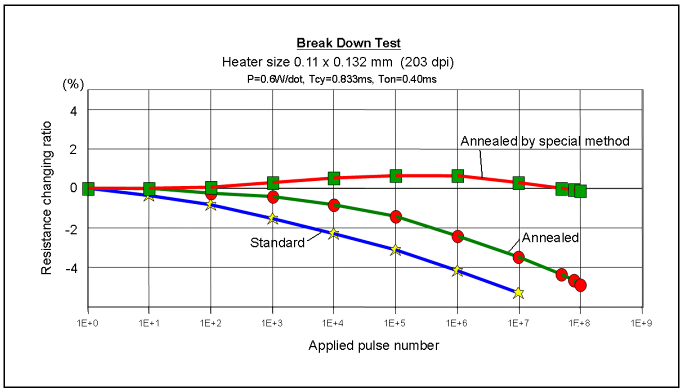


Figure 9. Pulse durability by annealing

History control

Another required technology for high speed printing is dot history control. If the print speed is sufficiently slow to permit the heater to cool, history control may not be necessary. However, in most high speed thermal printing applications, energy is applied to the heater before its temperature may decline to the original value. If the same energy is applied repeatedly with a condition that has a shorter Tcy than time to permit the heater to cool, its temperature will increase continuously until reaching the saturation temperature of thickness of the glaze. Then print quality will degrade, due to "trailing" and/ or printhead life will be threatened, due to dot durability. To avoid this, we apply history control.

There are two kinds of history control methods. One is external history control applied by the printer. The other is on-board history control provided by the driver IC on the thermal printhead. To apply external history control from the printer circuit board, more than two times the data transfer points within a Tcy will be required to select the heating elements according to history data. When printing speed becomes high, a sophisticated history control may be required which needs to have high frequency data transfer. On the other hand, higher speeds call for shorter Tcy. For example, Table 2 shows the possible number of data transfer times in a Tcy for 10 ips, 20 ips and 40 ips print speed. This printhead configuration is 4 inch 300 dpi with 13 ICs, each having 96 bits.

Clock frequency	Number of data inputs	Possible number of data transfer		
		10ips Tcy=333us	20ips Tcy=166us	40ips Tcy=83us
8 MHz	1	2	1	0
8 MHz	4	6	3	1
16MHz	4	13	6	3
16MHz	13	55	27	13

Table 2. Possible number of data transfer

From this table, higher printing speed permits fewer requirements for data transfer. Even at a rate of 16MHz with 96 bits of data transfer needs only 13 data transfer points. That however, may not be enough to apply sophisticated history control. And, whenever print speed becomes 40 ips, more may be required. However, the Tcy becomes shorter. Then, requirement for data transfer is reduced. This is the reason to have on-board history control.

Figure 10 is the example of on-board history control pattern on a Kyocera printhead. It requires two types of information. The first type is simply the printing data. The second provides the length of time on for each history pattern. Then, the printhead driver IC will chose one heating time based on history pattern. This approach is a good method to reduce printer load.

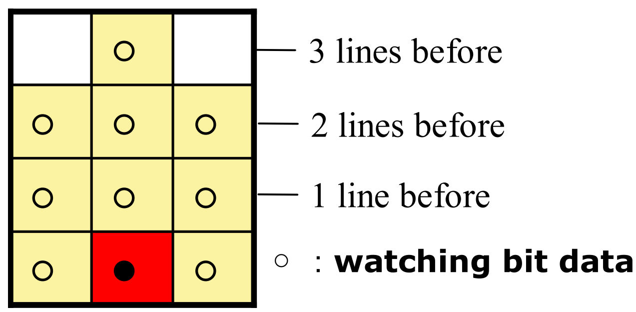


Figure 10. Example of history pattern.

While continuing to apply pulses, the temperature of the heater increases after each pulse is applied. Figure 11 shows the temperature behavior without history control when the same pulse width is given to each print line. On the other hand, after the history control is applied, the temperature is held constant following each pulse as shown in Figure12.

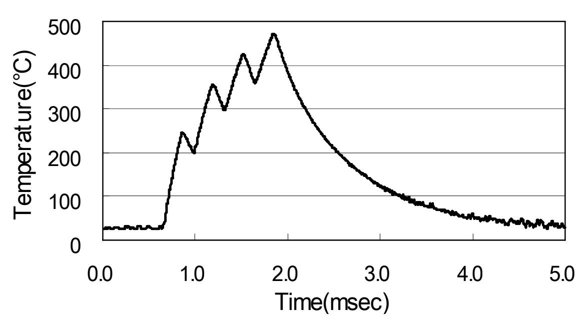


Figure 11. Temperature behavior without history control.

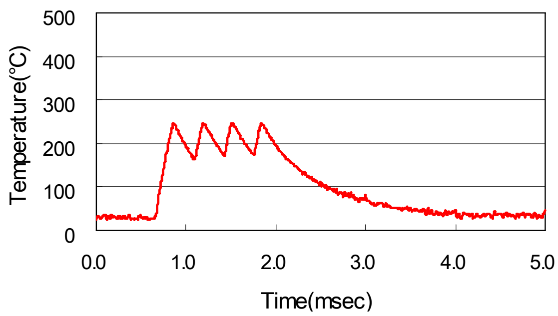


Figure 12. Temperature behavior with history control.

High print speed as maximized performance

Currently, the highest printing speed is slightly over 12 ips by flat type printheads in bar-code applications. However, 36 ips is achieved using corner edge printheads in date code printers using the thermal transfer method. To exceed the current highest print speed in both of these applications, corner edge technology will be more significant, principally because localized pressure will be more significant at higher print speed. Also, at a straight pass may be helpful to permit smooth movement of receptor media.

We are targeting the prints speed 80 ips by thermal transfer method. To achieve this print speed, improvement of media sensitivity will be required and careful determination of the optimum corner edge print head configuration.

High speed printing trial for graphics, using true edge printhead

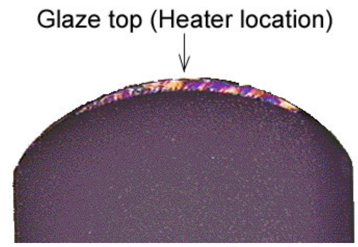
There is another requirement of high speed printing on the ID card which made by plastic using die diffusion thermal transfer (D2T2) method. Obviously, it requires straight pass printing because of printing on an inflexible and hard surface media. Required printing speed is three ips compared with the current speed about one ips. Because this is graphic printing and the print speed is relatively slower than barcode or date code applications, true edge printhead should be selected. True edge printhead glaze is smoother than other straight pass printheads which utilize either corner edge near edge (similar to flat printhead technology. This near edge technology is used for mainly digital photo applications. And, some portion of those is used for ID card printers as a low cost solution.

However, high speed requirement from the market now is currently three ips. That is three times the present card print speed which is one ips. And, as a printhead capability, the future target speed has been established at six ips.

Surface smoothness by type of printhead

For card printing, surface smoothness of the heater print line is one of most important specification. If that surface is not sufficiently smooth, the convex area makes light optical density (O.D.). To avoid this type of O.D. variation, surface smoothness must be smooth and consistent. Figure 13 is a cross section of the current true edge glaze. The reason why true edge printhead surface smoothness is better than corner edge and near edge printhead is follows below.

Figure 13. Cross section of true edge substrate



True edge glaze is utilizes flat glaze technology. This ceramic substrate is ground to make a convex shape (shown in Figure 13). After the ceramic shape has been generated, the glaze will be formed on the ceramic true edge. Then, heater line is applied on top of the glaze. Corner edge style heads use partial glaze technology. This glaze surface smoothness is relatively rougher than true edge. In the case of near edge printhead heater line is located near to side of the glaze. This heater line offset is required towards the front edge to permit an angle for the media to pass. Smoothness of this offset location is relatively worse than on the top of the glaze. The result is it may be necessary to polish a near edge surface to produce a smoother heater surface. Smoothness of near edge offset heaters and related subjects are in references [1].

Glaze selection for high speed card printing

The importance of the glaze selection has been mentioned in this paper. At this time, since target speed is six ips, the optimum glaze thickness should be considered. Additionally, technology to get higher localized pressure should also be introduced. From Table 1, primary glaze thickness is set to 40 um. A third modification, double partial glaze technology is applied. Figure 14 is showing the regular heater and Figure 15 is showing double partial heater. Obviously, we can see that the localized pressure with double partial glaze heater is bigger than regular heater.

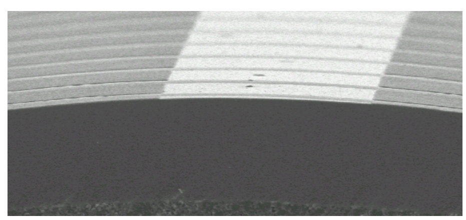


Figure 14. Regular heater of true edge printhead

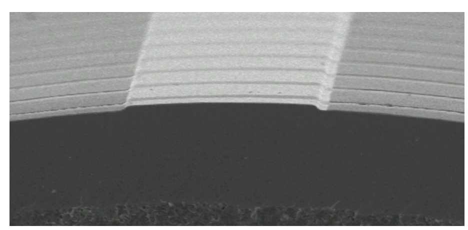


Figure 15. Double partial heater of true edge printhead

This 40 um thickness of glaze is a significant advantage of the true edge printhead. Compared to a near edge printhead heater line is located on the about 100 um offset towards front edge of a flat glazed head. Then, to maintain the media pass angle, it needs to maintain a certain glaze thickness. Figure 16 is showing Kyocera's near edge printhead surface profile from its front edge to the ICs. On this profile, to maintain the straight pass, we understand the heater offset and certain thickness requirements of the glaze. In this example as shown in Figure 16, the thickness of the top of the glaze is about 100 um. Thickness of the heater area is 85 um. To reduce it to 40 um on a near edge substrate, the thickness at the top of the glaze may need to be 50 um and less than one mm wide to have angle for straight media pass. And, it must have maintained ID card requirement level of smoothness. However, to satisfy this requirement through the use of the near edge substrate is extremely difficult. This is the one of the reason why true edge printheads are required.

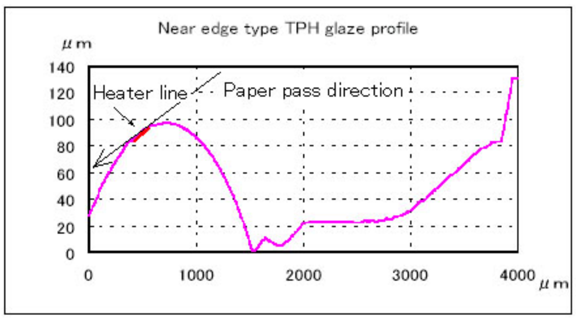
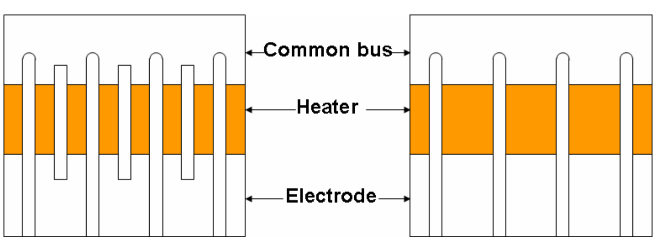


Figure 16. Surface profile of near edge printhead (front edge to back)

Slit heater construction

It is axiomatic that higher resolution printhead is improves print quality, compared to lower resolution. Slit heater construction is adopted to maximize the print quality. This slit heater is a single heater split into the slit pattern shown in Figure 17. Then, the heater resolution becomes two times that of a single heater. For example, 300 dpi single heaters become 600 dpi heaters. However, printhead operation itself is still 300dpi.



Slit heater Shingle heater

Figure 17. Sketch of slit heater and shingle heater

Due to true edge printhead having one large common bus, the customer may choose either a single or slit heater pattern. The near edge print head typically utilizes the U-shape heater construction. This heater is always split to two heaters for that slit pattern.

High speed true edge printhead sample

For a high speed printhead sample, Double Partial Glaze with 40 um thickness is utilized onto a 300 dpi printhead. The glaze and heater constructions of high speed true edge, current true edge printhead and near edge printhead are reviewed on the following. In this comparison, all printhead resolutions are 300 dpi.

	Glaze thickness	Glaze construction	Heater construction
High speed sample	40um	DPG	Split
Current true edge	75um	Full	Single
Near edge	85um	Partial	Split

Table 3. Construction of high speed, current true edge and near edge printhead.

Printout of high speed true edge sample

Figure 18 shows the printouts of letter "B" on direct thermal paper by high speed true edge sample, current true edge and near edge printhead. Printing speed for all three heads is six ips

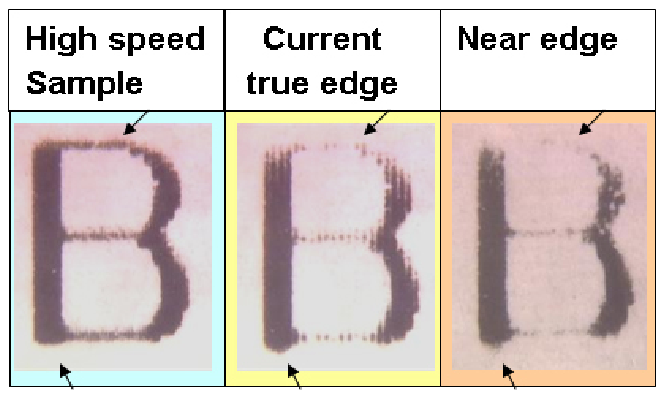


Figure 18. Direct thermal printouts comparison, print speed is 6ips

As it has been mentioned in this paper, the ultimate print speed target of the high speed development was determined to be six ips. In the printout on Figure 18, we can find a difference between three kinds of printheads at the thin line pointed out by arrows. The current true edge doesn't show a clear line and our near edge shows almost nothing. And trailing which is pointed by those three arrows at the bottom of Fig. 18, are also different. The new high speed sample shows nearly no trailing. On the other hand, current true edge and near edge printheads both show significant trailing (bulge on left of B). Obviously, these differences were from the heat response caused by glaze thickness and localized pressure by glaze construction which is double partial glaze or not. We conclude this high speed sample could achieve the six ips print speed capability as primary target.

Figure 19 shows the also D2T2 printouts of letter "B" by high speed true edge sample, current production true edge and our near edge printhead. This print speed is three ips.

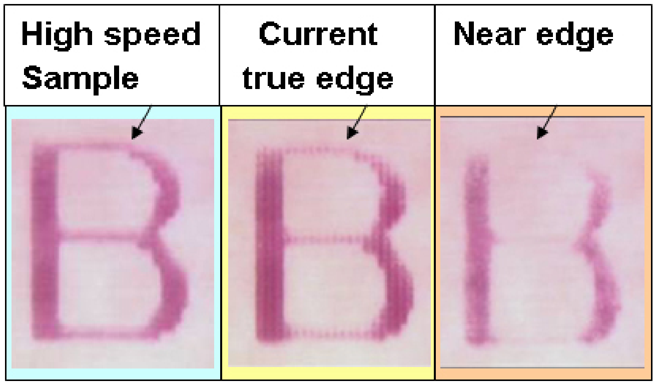


Figure 19. D2T2 printouts comparison, print speed is 3ips

Also, as already mentioned in this paper, current print speed requirement from the market is three ips. From Figure 19, we can find the difference at the thin line where is pointed by arrow. The near edge printhead has almost no print. However. our high speed sample shows clear thin line even using D2T2 ribbons. This difference is from glaze thickness and glaze construction. So , our conclusion is that this high speed sample shows better quality than the current true edge and near edge printhead at three ips which is current market requirement. However, glaze thicknesses may need to be optimized for three ips printing speed. Because, 40 um glaze thickness printhead may have too good heat response. There is a method to apply slightly thicker glaze than 40 um to get better heat efficiency if that is preferred, to the excellent heat response.

Conclusion

The performance of thermal printing method is maximized by edge type printheads. There are two kinds of edge type printhead. One is corner edge printhead. The other is true edge printhead.

Print speed is maximized by corner edge printhead. It has been achieved to 36ips as commercial printer. And, still there is a possibility to be higher printing speed. To achieve higher print speeds, it is necessary to develop media with higher sensitivity.

The True edge printhead is suitable for ID card printing with graphic quality. High speed type true edge samples which have double partial and 40 um thickness glaze achieved six ips as a potential print speed without reducing print quality. To achieve three ips as current market requirement, glaze thickness may need to be optimized to get better heat efficiency, when preferred to best thermal response..

References

[1] Hidekazu Akamatsu, Development of true edge H series printhead (IS&T, Salt lake city UT, 2004) pg. 989.

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Hidekazu Akamatsu graduated from Ehime University in 1988 with a degree in Physics. He received a Masters Degree in Science from Ehime University in 1990. His major was Magnetism. He joined Kyocera Corporation in 1990 working in the Application Engineering Department. He worked in the North America thermal printing market, living in Vancouver Washington from 1997 to 2001 and presently serves as a manager of Application Engineering 2, TPH Division, Kirishima Japan Kyocera Corporation.

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