New Development of Multi-Purpose Heating Head

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Abstract

The majority of existing thermal printers are made so that the print media is sandwiched between the drive roller and heating element of the thermal head. Our new heating head is an extension of the thermal printhead concept with the exception of heating a whole section of the head rather than a portion of it. The heating head utilizes the thick-film heating element on the ceramic substrate. The new design prevents energy diffusion by heat accumulation and retention. Also, the new structure makes it possible for the device to be miniaturized and the heat transfers to the media easily. Another distinction of the new heating head is that the heating/contacting surface is on the opposite side of the heat generating side of the ceramic substrate. This improves the heat dispersion throughout the heating head. The best benefit of this structure, however, is there will be no life problems on the heating surface such as abrasion, scratch and chemical corrosion which is a serious concern for any contact heating device. The temperature sensor is located very close to the heating element on the same side of substrate and temperature monitoring can be done very fast, easily and accurately. The unique heating element construction makes it possible to join multiple ceramic substrates making the head heating as long as required.

Background of Thermal Heating Head

Thermal printing technology came into the main stream in the late 70's starting with applications like the calculator printers and typewriters (referred to as "word processors" in Japan), followed by the facsimile machines, barcode label printers and the POS (point of sales) receipt printers. Later, color printers for digital images and card printers became very popular. The technology branched out to various markets, but the common component is the thermal printhead. Thermal printhead consists of tiny resistive heating elements often referred to as "dots" placed in line. Popular printheads today are made with 200 or 300 dots per inch (or DPI) dot density.

The heating head is on the extension of printhead in manufacturing material wise. However, the major operational difference is that the heating head resistive element is not a dot, but a continuous line and it heats up an entire line. So, the control methods for both products are different, though the principle, a resistive element is heated as the electrical current goes through, is the same. The significance of the heating head is the ability to monitor the actual heating temperature real-time while the media is in contact with the heating head. The thermal rewritable media on the market required a narrow window of erasing temperature (typically within 20°C), the heating head can maintain the pre-determined temperature through feedback from the sensing element.

The heating head application is expanding into other usages than thermal rewritable media erasing, namely the applications traditionally the heating roller have been used.

Heating Roller and Heating Head

The heating rollers have been used for card applications in putting the overcoat such as the protective layers and holograms. Other usages are erasing application for the thermal rewritable media and thermal re-transfer printing process.

One of the major drawbacks of heating roller is the "warm-up time" required to get up to the operating temperature at starting. This is due to the roller material mass being heated. Although there are ways to shorten the standby time such as to keep the roller at warmer temperature while waiting for the process, the problem is the waste of energy while on standby and potential heat-related hazard due to constant heating. Also, the unused excess heat has to be dissipated typically through some cooling method such as exhaust fan which requires space and power.

Another issue related to constant heating is the component life shorting. Wear and tear of roller material increase when the roller is heated with the standby temperature continuously, for example. The maintenance becomes more problematic for heavy usage when the roller is worn out unevenly as the process quality gets degraded especially around the card edges.

The printer industry is moving toward a smaller, lighter and more efficient product design today and using the component which wastes the energy and requires the cooling system is not desirable.

The heating head new development, on the other hand, addresses the above issues. Our development of heating head originally started for the thermal rewritable media erasing application. This was to address the tight heat control requirement of thermal rewritable media erasing temperature. Our heating head is an on demand device and does not require the constant pre-heating like heating roller when the printer is on standby.

This solves the biggest problem with the heat roller. The special heating element and temperature sensor make it possible to operate the heating head with quick start up time and easy temperature control.

Existing Heating Heads

There are two distinctive differences between the existing heating heads on the market and our current heating heads.

The temperature sensing element or part for the existing heating heads is usually external thermistor which is place behind the ceramic substrate or on the heat-sink. There is a time delay for the temperature change to be picked up by the sensor.

The temperature sensing element for our heating is an integral part of the ceramic substrate and is located on the same side and right next to the heating element [1]. Therefore, thermal sensing response is much faster than the devices whose thermistor is located on the other side of the substrate made of alumina/ceramic. The top view of our heating head substrate is shown in Figure 1.

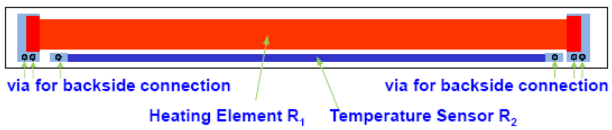

Figure 1: Top view of current heating head substrate

Another difference is the nature of heating element material. Our heating element is made with the positive temperature coefficient of resistance (TCR), while the others are using the negative TCR heating element material. The negative TCR means that the resistance goes down when the temperature increases. Although it may be a rare occurrence and can be remedied by the control software, there have been some cases that full power was kept on the heating head with the negative TCR for a couple of minutes and the head was damaged – when temperature goes up resistance goes down creating more power and heat in a vicious cycle -- phenomenon called thermal avalanche. On the other hand, our positive TCR heads have the self-regulating effect, so to speak, as the resistance goes up as the temperature goes up, hence reducing current and power.

Temperature Sensor

Uniqueness of our heating head is that the real-time temperature change can be monitored though the sensor as the media goes through. Figure 2 shows the graphical representation of two elements on the substrate.

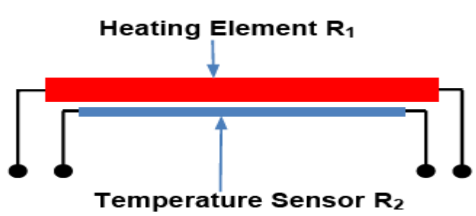

Figure 2: Two elements on the substrate

The temperature sensor process is done with the reference voltage and external standard resistor as shown in Figure 3. [2]

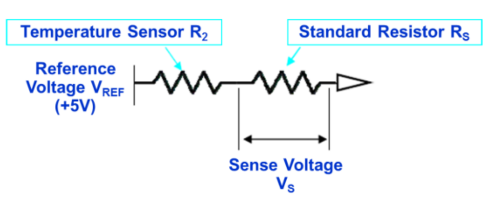

Figure 3: Temperature measurement process

Sense voltage V_S and Sensor R_2 relation is as follows:

Reference voltage V_{REF} = +5 V DC (recommended)

Sense voltage $Vs = 5.0V \times Rs / (R_S + R_2)$

Where $R_2 = R_{2INITIAL} \times (1 + 0.0015 \times T_{DIFFFERENCE})$

TCR = 1500 PPM/°C [3]

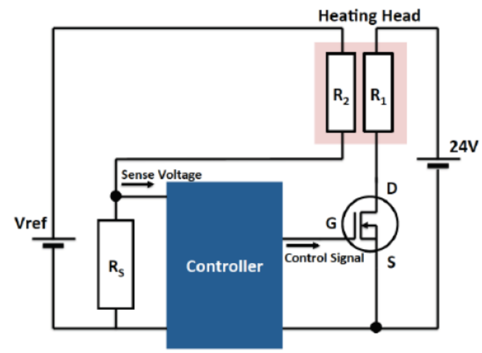

Figure 4: Temperature control unit example

Figure 4 shows an example of control circuit using the sense voltage V_S: The controller can be either analog to control the heating element driving voltage or digital to change the duty cycle of the driving power.

When the R_S resistance is equal to R_2, the sense voltage gives the maxim swing. In order to minimize the sense current, the R_S resistance value is recommended to be a little greater than the R_2 resistance. High precision resistor (preferably tolerance of 0.1% or better) is recommended for the external standard reference resistor R_S for good accuracy. +5 V DC is recommended for the reference voltage V_{REF} in order to minimize the self-heating yet enough voltage separation.

New Heating Head Development

Though the basic concept of heating element and temperature sensor element material being the Positive TCR is unchanged from the current heating head, the heating element pattern on the substrate is very different. Figure 5 shows the top view of the heating and sensor element on the substrate. The heating element pattern shape is drastically different as seen in Figures.

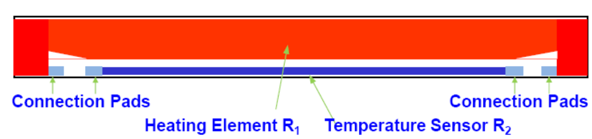

Figure 5: Top view of new heating head substrate

The unique "M" shaped heating element R_1 pattern makes it possible to heat the whole ceramic substrate from edge to edge as discussed later.

The implementation of substrate assembly into heating head is also very different as shown in Figure 6. The drawing is for the illustration of the head structure only and not to represent the actual measurements. Also the connection between the heating head substrate and circuit board/insulation board is not shown.

The heating element is sandwiched between a ceramic board and the heating head substrate. The heating surface is the back side of the substrate that has various positive effects on the product and its operation as well as the head manufacturing process.

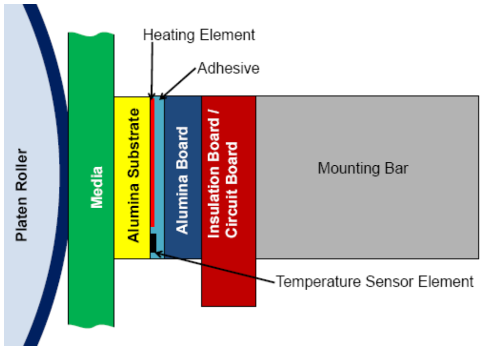

Figure 6: *Cross-sectional view of new heating head assembly (Inter-connection is not shown)*

The benefits of the new substrate construction are listed as follows:

1. Anti-abrasion ability

Abrasion is one of the main reasons that the contact heating devices such as the thermal printheads and heating heads fails, analogous the automotive tire wearing out after running on the road. Typically, the device has the abrasion life of so many inches or kilo meters as the protective overcoat on the heating element wears out. However, the new head heating surface made of ceramic it is virtually abrasion-free compared to the regular heating element protective overcoat. The abrasion related problem, therefore, will be a non-issue with the heating head.

2. Single-sided manufacturing process

Typical substrate manufacturing process including our current product involves the double-sided process operation. It involves making the through holes on the ceramic substrate using laser which is costly and creating the vias which connect the front and back side is rather complicated and expensive.

The new substrate involves only one side processing which will make the production much simpler and more efficient since making holes by laser and via making operations are not necessary.

3. No overcoat process necessary

Since the media contacting side is the ceramic material as discussed and the heating element is on the non-contacting side, the overcoat protection is not required. The protective overcoat process is not simple and costly, so elimination of this step contributes to cost and time saving.

4. Heating element surface is no issue

The surface of multi-layered product such as the heating element coated with protective layer materials tends to cause more irregularities on each process. This is a problem if the media is contacting the irregular surface as process quality degrades such as making scratching marks or lines.

Since media contacting side is the ceramic substrate for the new head, the overcoat is not required on the heating element and the surface condition of the heating element makes no difference for the performance.

5. Possible to make post-process adjustment

Because the heating element is on the other side of contacting surface, it is possible to modify the heating element with such process as mechanical resistive heating element shaping and resistance adjustment by laser trimming. If required, thermal conductive or insulative material can be applied to control the heat outflow.

6. Cost-effectiveness

Simplified new single-sided substrate translates to the cost-effectiveness of the heating head production process. Product cost has been an issue of heating head in comparison to the heating roll is the past. This process gives the competitive edge to the newly developed heating head.

7. Operating temperature control easiness

The newly developed heating head shares the same substrate construction concept as our existing models using the positive TCR heating element and temperature sensing element. The temperature control is done through the temperature sensing element with real-time temperature reading.

8. Smoother temperature distribution

The heat is conducted through the ceramic substrate to the heating surface and smaller local temperature variations tend to smooth out. This is a good characteristic for the heating head which the even temperature throughout the heating width is required.

9. Edge to edge heating

The unique "M" shaped heating element R_1 pattern is specifically designed to give the edge to edge heating capability. The drive voltage is supplied through the pads inside of the heating element length. The electrical current goes through one edge of the element (vertical part) on the substrate then goes to the middle part of the element before going to the other edge of the element.

This characteristic is important for the application which requires the over-the-edge card heating process, as the temperature profile of typical heating heads tends to run lower on element edges and the process results are not good in some cases.

10. Ability to stitch multiple heads together

The new heating head can be stitched together in order to process wider width applications. This is a new concept in the heating head industry as the existing products on market do not have this ability. This function is possible because the heating to the very edge of the head became reality.

With this capability, a basic 2-inch heating head unit can be made into an assembly of 4-inch, 6-inch or 8-inch and even one-meter for various industrial applications. The manufacturing process and cost will definitely benefit from this ability as the wider the heating width, the lower the production yield is.

11. High thermal capacity

The heating process of the new head involves the whole substrate that is touching the media whereas the conventional head is heated with a line heater. So thermal capacity of the head is much greater and it is suitable for the higher processing applications.

There is a case when heating surface covering is required in a specific application, such as a slipping layer or flexible/elastic layer. The example for this can be the media has some irregular surface conditions and the heating surface needs to conform to the media which the rigid ceramic surface cannot satisfy. Another example may be that the media sticks to the head surface when it is heated and it requires the slipping layer on the heating surface. The new head has enough thermal capacity even if the extra layer of surface covering is added for a specific application.

Implementation and Verification

The actual heating head is manufactured and implemented as show in Figure 7. The drawing is for the illustration of the head view only and not to represent the actual measurements. Also the connection between the heating head substrate and circuit board/insulation board is not shown.

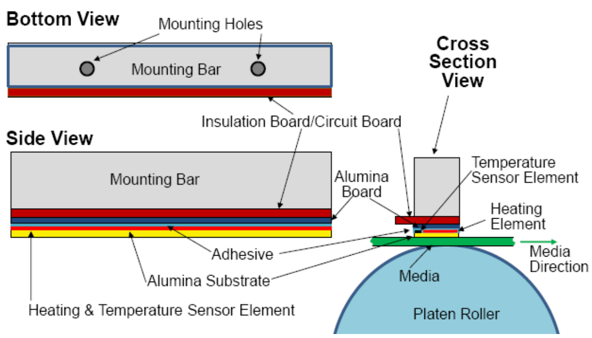

Figure 7: *Heating head views*

The heating head has been tested after the ceramic heating substrate board is incorporated.

The thermograph image comparison between the current and new substrate temperature profile of heating surfaces is shown in Figures 8 and 9. The profile of edge temperature tapering off of current substrate is clearly seen from the image indicated with the arrows in Figure 8.

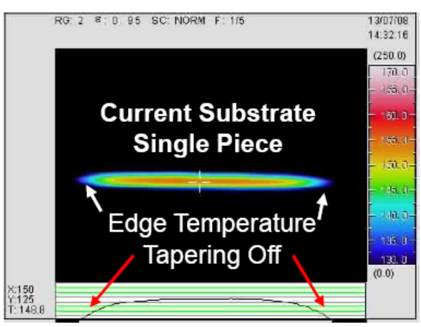

Figure 8: *Thermograph image of current substrate*

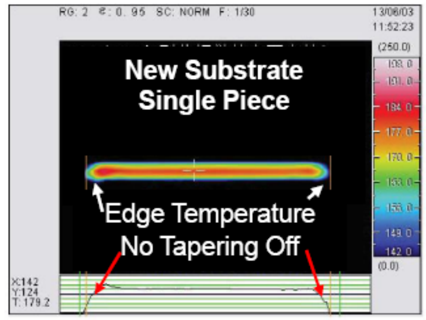

Figure 9: *Thermograph image of new substrate*

The heating profile of the new substrate, on the other hand, there is no tapering off at the edges as seen in Figure 9.

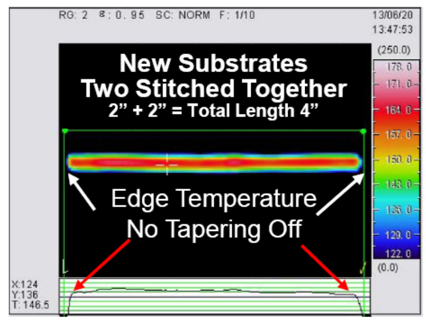

Figure 10: *Thermograph image of two new substrates stitched together*

The thermograph image was taken for the two new substrates stitched together as shown in Figure 10. Image shows no noticeable stitching gap and the edge temperature does not taper off.

Conclusions

We have successfully developed and demonstrated the new type of heating head which can be used for various purposes that is easy to use, versatile, rugged and cost-effective with the aforementioned benefits.

References

[1] H. Taniguchi, S. Sunada & J. Oi, "Development of New Multi-Purpose Heating", Proceeding 2010 IS&T's NIP26, pg.693
[2] U.S. Patent # 7206009 B2
[3] H. Taniguchi, S. Sunada & J. Oi, "Novel Approach to Plastic Card Overcoating Process", Proceeding 2012 IS&T's NIP26, pg.85

Author Biography

Before founding HIT Devices Ltd., in Kyoto, Japan, Hideo Taniguchi worked for ROHM Co., Ltd. for over 40 years where he was responsible for the products including items relevant to the printing industry like thermal printheads (printhead with partial glaze layer, development / implementation of driver ICs on substrate for printhead) and development / mass-production of LED printheads. He received his BS from Ritsumeikan University in Kyoto (in the field of Applied Chemistry) with additional study in Electrical Engineering.

Shigemasa Sunada joined HIT Devices Ltd., in 2007 and has been working in various heating head projects for design and development. Prior to his current work, he worked for ROHM Co., Ltd. in Kyoto as a design and development engineer for such products as LEDs and various diodes. He graduated in mechanical engineering at Rakuyo Technical High School in Kyoto.

Jiro Oi works for HIT Devices Ltd., a Kyoto-based electronic component manufacturer. A native of Hokkaido, Japan and now he resides in Brentwood, Tennessee. Prior to joining HIT Devices, he worked with ROHM Co. Ltd. for more than 15 years specializing in thermal printheads and other electronic components. He received his BSEE from California Polytechnic State University in San Luis Obispo, California and MBA from Thunderbird School of Global Management in Glendale, Arizona.