Improvement on Heating Head Performance

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Abstract

We have been improving the heating head structure for thermal printing processes. The major structural change is that the heating element is on the back side of ceramic substrate in a conventional sense. There are several advantages in this configuration such as the increased thermal capacity of the heating head, much higher mechanical anti-abrasion and scratch resistance ability, simplified substrate manufacturing process.

We will discuss how the new heating head functionality can be improved from an application point of view. There are two areas we are addressing in this report: Heating head driving method and heating surface coating.

The first area is maintaining the heating temperature constant. The heating head has the temperature sensing element alongside of the heating element which is made of resistive material having a large positive temperature coefficient of resistance. The temperature change is reflected in the resistance change of sensing element which is fed into the heating element control circuit. The heating element energy can be controlled by varying the driving voltage with continuous on-time or varying the on time with constant supply voltage. We employed the later control method for this paper with the pulse width modulation circuit for a simplified way of maintaining the desired process heating head temperature.

The second area is the ability to overcoat the heating surface with a material suitable for the heating process. Unlike the existing heating heads where the heating surfaces are overcoated by an insulative material such as glass which gives a limited freedom for the coating process on top, the new heating surface is ceramic and various coating materials which can be conductive and/or lower coefficient of friction can be used for overcoating. This capability enhances the width of heating process application range as the wider variety of media can be heated as well as the applications beyond printing field.

Thermal Heating Head Background

Thermal printing technology became popular with the needs of data output from the fast developing consumer electronics devices such as hand-held calculators, typewriters (aka word processors), facsimile machines, and printers of various types stating in the late ’70s. The industry requirements for faster and better printing quality from newly developed applications such as barcode labels and receipts printing, color printing and specialized printing like ID cards. The common denominator for the industry is the thermal printhead which heats up the media to form an image. Improvements of printhead capabilities and functionalities are major contributors for the thermal printing technology.

The heating head was developed as the extension of the thermal printhead technology, having a very similar product materials and production methods. The functionality and applications are very different, however. The printhead has an ability to address individual dots in order to mark the print media while the heating head is energized as a whole or section. So the thermal printheads are used to create images by heating up each dot and the heating heads are for used for post-printing processes, be it a thermal re-transfer process, protective overcoating or lamination.

Needs for Heating Heads

The typical thermal process before the heating head’s time was performed with the heating roller. Though heating rollers have a long and established history in the electronic printing industry, there have been several major issues such as slow power-on time from cold start, difficulty to maintain the constant temperature and wearing of the roller material. Heating heads were developed in order to remedy the shortcoming of the heating rollers[1].

Some examples of specific advantages of heating head over the roller are:

1. Easier temperature control

   The real-time temperature monitoring capability makes the temperature control of the heating head much easier than the roller.

2. Heating on-demand

   The heating head temperature reaches the processing level in a matter of seconds while the heating roller will take minutes to reach the temperature from starting in the cold state.

3. Energy saving

   If the “sleep mode” is used on heating roller to keep it warm during the standby phase, the energy is simply wasted. The heating head is an on-demand device which does not require pre-heating process.

4. Safety and less degradation

   Since the heating head becomes hot only when it is in use, it is less likely to cause health hazard situation such as a burn injury and also less chance for components thermal degradation.

5. Smaller size

   The heating head is smaller in size compared with the heating roller unit for more efficient space usage.

First Generation Heating Head

The heating head we developed originally was very unique and awarded patents in several counties including Japan and US[2]. One of the major differences between our first generation heating head (sometime referred to as erase head as it was developed for erasing purpose of the thermal rewritable media) and the existing heating heads available on the market then was the temperature sensor element material and location. It was placed along the heating element on the ceramic substrate as shown in Fig. 1. The heating element and temperature sensor element were made of the material with a large positive Temperature Coefficient of Resistance (TCR). So the temperature change is reflected to the resistance change of sensing element which can be utilized to control the heating element driving energy.

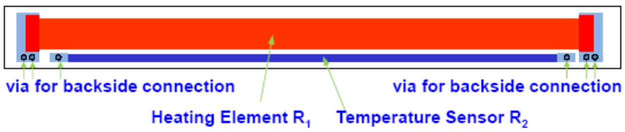

Figure 1
Top View of First Generation Substrate

Second Generation Heating Head

The current heating head is the second generation, although the basic concept of our first generation heating head remains the same -- heating element and temperature sensor element have a large positive TCR for fast heat-up and temperature sensing capability. The current head, however, has a different heating and sensor element pattern as shown in Fig. 2. Another difference is that the heating surface is on the other side where the elements are located as shown in Fig. 3. The structural change of the second generation heating head contributes several advantages over the first [3]. Some examples are:

1. Even heating profile (temperature stay constant from edge to edge with the heating element pattern)
2. Higher heat capacity
3. Higher processing temperature
4. Simpler product structure and manufacturing process
5. Heating surface stronger anti-abrasion ability
6. Maintenance-free heating surface
7. Possibility to connect multiple units (daisy-chain fashion)

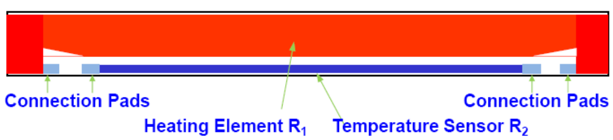

Figure 2
Top View of Second Generation Substrate

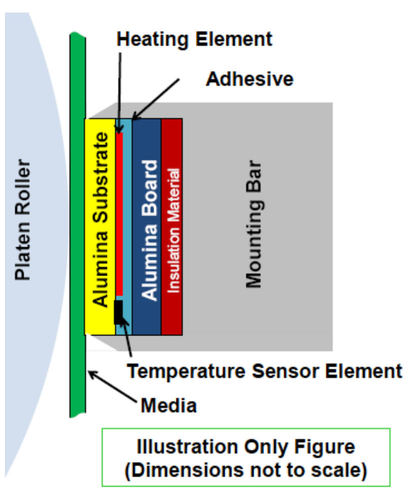

Figure 3
Cross-sectional view of second generation heating head assembly

Heating Head Structure

The current heating head is designed for simpler structure and easier assembly than the first generation unit. This is due to the new ceramic substrate on which the heating and sensor elements are placed and ceramic board are bonded with the adhesive. The 2-inch version of the second generation heating head is shown below.

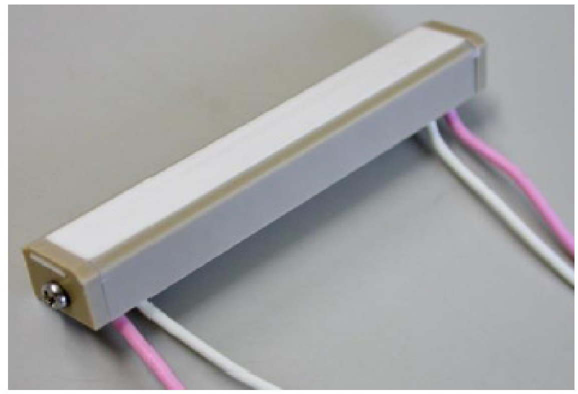

Figure 4
2-inch version of second generation heating head

Since the heating surface is ceramic and heating and temperature sensing elements are on the other side of the substrate, only a white strip of substrate can be seen from outside. Internally, two elements are connected to the 4 leads similar to the first generation head.

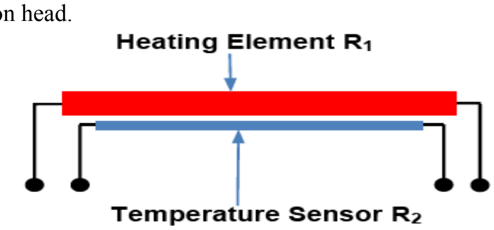

Figure 5
Heating head internal connection

Temperature Measuring

Uniqueness of our heating head is that the real-time temperature change can be monitored though the sensor as the media goes through. Figure 5 shows the graphical representation of two elements on the substrate. They are very close (a few tenths of a millimeter) to each other physically and length-wise, so what sensor sees is very close to the heater temperature.

On the other hand, existing conventional heating heads on the market are equipped with single discrete thermistor usually mounted on the opposite side of heating element on the ceramic substrate. So the thermal response of the thermistor to the heater temperature is much slower and less accurate at higher media speed.

The temperature measurement calculation process is done with the reference voltage and external standard resistor as shown in Figure 6.

Sense voltage V_S and Sensor R_2 relation is as follows:
Reference voltage V_{REF} = +5 V DC
Sensor material TCR = +1500 PPM/°C
Sense voltage $V_S = 5.0V \times R_S / (R_S + R_2)$
Where $R_2 = R_{2INITIAL} \times (1 + TCR \times T_{DIFFERENCE})$

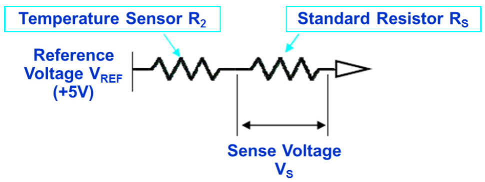

Figure 6
Temperature measurement via sensor

Usage Temperature Sensor

Maintaining a constant (or stable) temperature while the heating process is in progress is a difficult task, especially if the process speed is higher than 10 mm/second in conventional heating devices. In fact, there is no heating device available on the current market which can measure the heating element while the media is in contact and in motion in real-time.

In our heating head, the Sense Voltage V_S is used to measure the temperature as described above. The voltage change across the resistance is small, so it needs to be amplified before it is fed into the temperature controller.

The heating head temperature can be varied by changing the driving energy. The heating head energy can be controlled by varying the driving voltage with continuous on-time or varying the on time with constant supply voltage. The head can be driven with an AC voltage and the energy can be controlled by adjusting the AC duty cycle. We employed the DC power and the pulse width modulation (PWM) circuit to maintain the desired process heating head temperature in this paper. In real life application, this function may be accomplished through the printer controller circuit. We, however, decided to make a small stand-alone heating head controller for evaluation so that the heating head can be tested and employed without involving the full scale development effort by the new user if needed.

The driver circuit block diagram is shown in Fig. 7 and the control is accomplished via PC with the proprietary control software which can preset the desired temperature.

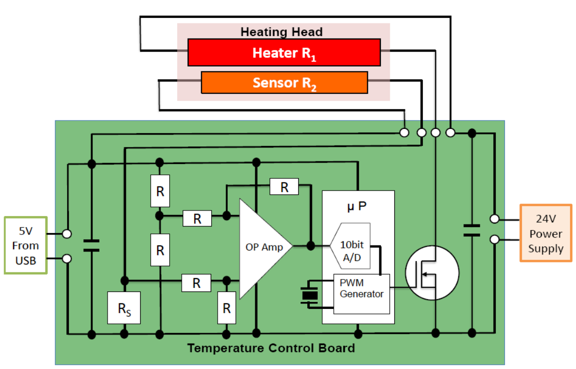

Figure 7
Temperature control circuit board block diagram

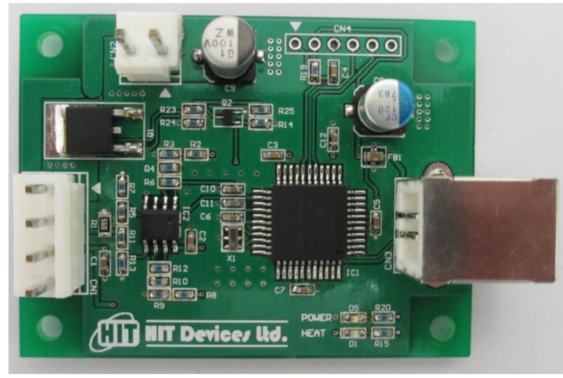

Figure 8
Picture of temperature control circuit board for evaluation

The Fig. 8 is the actual heating head evaluation temperature control driver board. There is nothing special about the circuit shown in Fig. 7 per se as it is basically a straight forward combination of an amplifier, microprocessor based PWM unit and a power transistor. However, the combination with the heating head makes the setup so special.

Control Unit Output

Fig. 9 shows the actual temperature plot of the control unit output on the PC screen. This plot shows the temperature transition as 3 plastic cards are fed through the heating head. For this experiment, the process speed was set to 15 mm/sec and the temperature was set to 150 °C. The upper curve is the temperature which fluctuates within 10 °C once it reaches the preset level, while the duty cycle of PWM (middle curve) and average power (lower curve) goes from the maximum to minimum based on the sense voltage (i.e. temperature of the heating head). As seen from the graph, the temperature response is extremely fast and this type of control based on the PWM method is very effective.

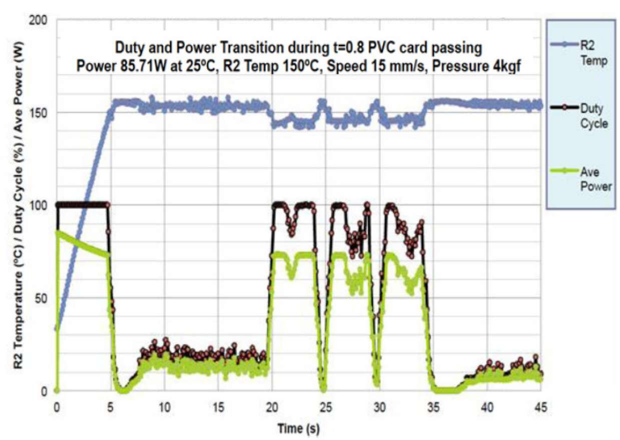

Figure 9
Temperature response of heating head with PWM circuit

Thermograph and Thermal Image

Fig. 10 shows the thermograph of the 2-inch version of the heating head surface.

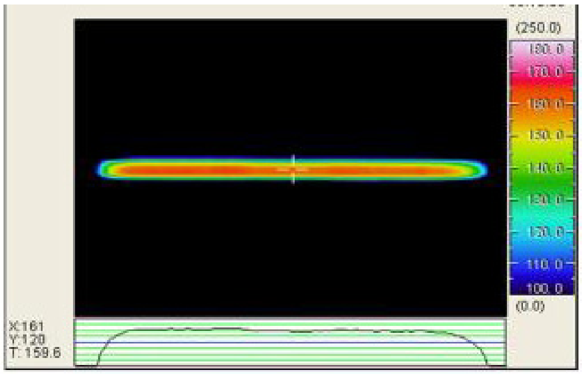

Figure 10
Thermograph of heating surface

Fig. 11 is a static thermal image of the heating head. It shows the temperature distribution within the heating surface when it is placed on the thermal sensitive paper. It is interesting that the thermograph is not exactly the same as the static imaging of heating head.

In practice, the media is moving in the Y-direction and the media will be heated vertically, so the thermal characteristics will be different. The image shows, however, the complete heating surface temperature is elevated.

Figure 11
Static thermal image of heating head

Overcoating the Heating Surface

In general, thermal heating devices, may they be thermal printheads or conventional heating heads, the heating surface is coated with the hard coating (often insulative) material to protect the heating element.

Since our heating head's structure is different from the general heating devices that the heating surface is made of ceramic and does not require the protective coating. This gives the freedom of choice to select different materials if the surface needed to be coated or treated with different materials. The coating material can be conductive, for example, if the application requires such material.

There are some applications such as heat curing gel-like material or fusing power ingredient which have to be heat-treated, but not to smear the materials. For applications such as that, one way to deal with can be to use the continuous intermediary film looping around the heating surface.

We have been experimenting both organic and inorganic coating materials, such as polytetrafluoroethylene (Teflon), polyimide (Kapton), glass, diamond-like carbon (DLC), for various usages. Other potential method is to sandwich a film in between the heating surface and the media.

Although there are benefits of coating or placing a layer of material on the heating surface, there are some issues such as losing the heat due to the insulating effect and the durability of the material and we have not found a single material which will fit all occasions and applications so far.

Conclusions

Our objective for the paper was to improve the heating head performance and we approached from "software" and "hardware" viewpoints.

The software approach was to utilize the voltage from resistance change of the temperature sensor element fed to the external driver circuit board to maintain the process temperature. The test result shows the temperature control was maintained during the heating process.

The hardware approach experiments did not yield a satisfactory result and the work has to be continued as the future challenge.

References

[1] H. Taniguchi, S. Sunada & J. Oi, "Novel Approach to Plastic Card Overcoating Process", Proceeding 2012 IS&T's NIP28, pg.85
[2] U.S. Patent # 7206009
[3] H. Taniguchi, S. Sunada & J. Oi, "New Development of Multi-Purpose Heating Head", Proceeding 2013 IS&T's NIP29, pg.130

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.

Mark Tatsuya has worked for HIT Devices Ltd as a marketing manager since 2012 to develop new markets. Prior to joining HIT Devices, he worked for Rohm Ltd for over 15 years, and then worked at Torex Semiconductor Ltd specializing in power management ICs for another 15 years. His expertise is marketing and sales engineering with extensive experience in global sales. He received his Bachelor of Science in Physics from Kyoto Sangyo University.

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.