Development of Power Saving Thermal Print Head Part 2

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Abstract

Power saving of Thermal Print Head was studied.

Since heat characteristics and thickness of head substrate are effective on power saving, as reported in NIP25, low thermal diffusivity glass have been developed.

FEM simulation was adopted to estimate the characteristics of Thermal Print Head efficiently.

Phosphate composition which satisfies the requirement on Thermal Print Head such as homogeneity, 650 Deg C or higher Tg and climate resistance was found. Thermal diffusivity 0.33mm2/sec was achieved.

Sample Thermal Head was made with substrate thickness calculated from simulation to satisfy both power saving and print quality.

The test result of Thermal Head sample showed 25% power saving and sufficient print quality.

Introduction

Thermal transfer printer such as D2T2 or DTP is widely used for embedded or mobile purpose for its compact and light characteristics.

Power saving of Thermal Head is a key subject to satisfy requirement for high speed and low battery power consumption since it takes up high proportion of thermal printer's power consumption.

Up to now, we have studied Thermal Head structure and material for power saving.

At NIP25, we introduced the finding that heat characteristics and thickness of head substrate are effective on power saving and verified with test.

This time, low thermal diffusivity glass which satisfy the requirement or limitation on Thermal Print Head have been developed.

We made the development process more efficient by estimating the characteristics in Print Head structure by simulation.

This paper will report the Thermal Head sample consist of developed glass material and evaluation result.

Thermal head Substrate

It is confirmed by CAE that low thermal diffusivity material is effective to realize power saving print head. Phosphate glass which used for bonding was selected as a candidate because of its low thermal diffusivity and was studied to apply for Thermal head.

Features required on Thermal Head substrate are below:

a. Excellent smoothness which does not produce print instability caused by bump of heat elements. (None-crystal)

b. Heat resistance which provide stable characteristics and shape under printing temperature. (Tg > 650 Deg C)

c. Climate resistance which characteristics deterioration never occurs regardless of ambient climate.

* Especially it is known the water resistance of Phosphate glass is worse than other glass material. If dissolved to water, it generates phosphoric acid which corrodes the device.

$P_2O_5 + 3H_2O \Rightarrow 2H_3PO_4$

It was required to achieve these features with low thermal diffusivity.

Thermal diffusivity and power saving effectiveness were confirmed by simulation.

Thermal Transient Analysis

At the beginning of developing material, Thermal Head characterization was simulated. This is to reduce the sample production cost and time.

ANSYS11.0 (ANSYS, Inc.) was used for simulation.

Since the purpose was to confirm materials properties and thickness effects, 2D model was adopted and modeling area was minimized to reduce calculation time. (Figure 1)

In addition to evaluating stand-alone Thermal Head, in order to evaluate thermal conduction to media while printing, phenomenon to move media relative to fixed head was reproduced by Mass Transport Option. (Equation 1)

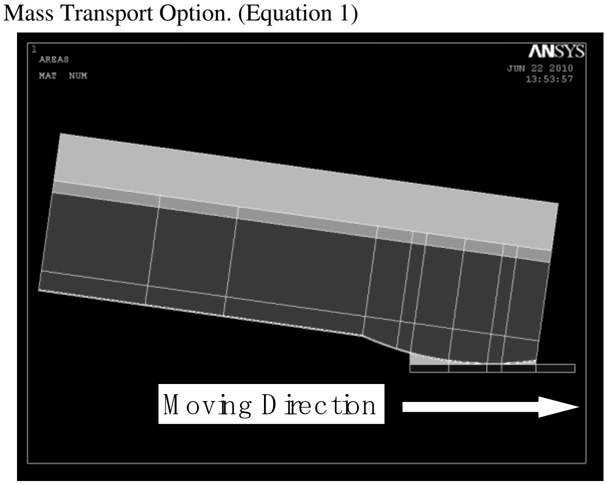


Figure 1. *FEM analysis model*

$$\rho c\left(\frac{\partial T}{\partial t} + vx\frac{\partial T}{\partial x} + vy\frac{\partial T}{\partial y}\right) + k\frac{\partial^2 T}{\partial x^2} + k\frac{\partial^2 T}{\partial y^2} = Q \quad (1)$$

ρ	Density
c	Specific heat
T	Temperature
t	Time
Vx,Vy	Velocity of a fluid (mass transport)
k	Thermal conductivity
Q	Generation of heat

We evaluated the time history temperature data of Print Head heat element and media generated with this analytical model.

Thermal diffusivity and effectiveness to power saving as print head was calculated. Calculation result and experimental result are shown in Figure 2. Specimens are Quartz Glass, ASF1761 (Asahi Glass) and Phosphate Glass. Phosphate Glass was made by ALPS.

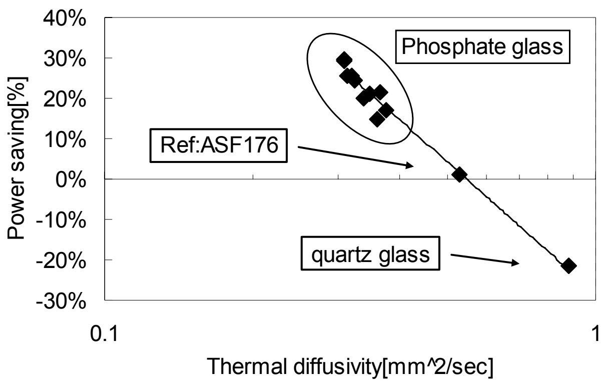


Figure 2. *Thermal diffusivity and Power Saving (thickness 0.2mm)*

From this result, we have made 30% Power saving = Thermal diffusivity 0.3 mm2/sec as a target.

Addictive factors were adopted to study composition.

It is widely known that additively can be used on glass since it is amorphous. Therefore, we used around 30 kind oxides and used rapid cooling method to make few 10s of glass.

We took thermal diffusivity from which we could visually recognize vitrification only. Addictive factors were calculated by multiple regression analysis. Figure 3 shows calculation result corresponds to actual measurement well.

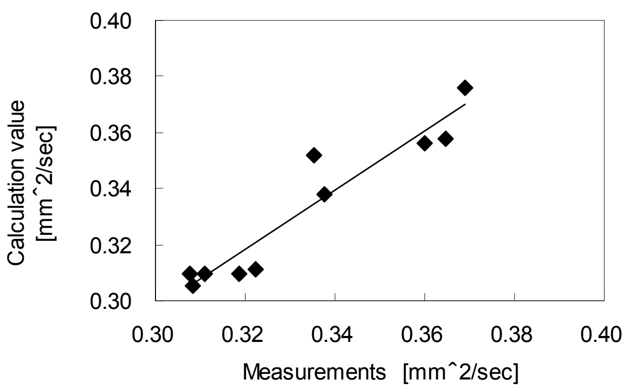


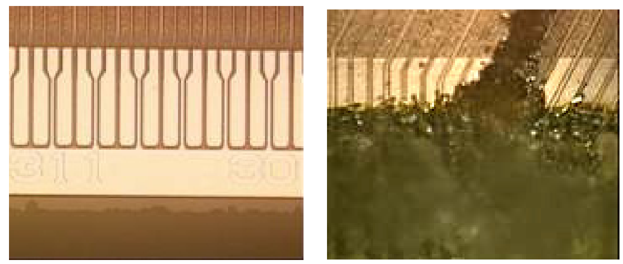
Figure 3. *Thermal diffusivity (Calculation and Measurement)*

While addictive factors are usually positive, large negative factor which is unique was shown with Pr_6O_{11} within a range it could be glass. It is considered that it was not effect of Pr_6O_{11} only but formed cluster with other oxide and disturbed thermal conduction. In addition, alkaline oxide should be noticed because negative factor was also shown. It should be treated with care when adding because while it helps to obtain more oxide with larger molecular weight into glass, it will make climate resistance worse.

Since additively also applies to Tg, composition design was done by addictive factors. Designed composition was melted and evaluated with TMA.

In regards to climate resistance, power glass specimen was used for water resistance test. The concentration level of P in eluate was measured by absorption-meter. We determined criteria that concentration level of P to be 0.25mg/l or less as appropriate to make device. (Figure 4)

The oxides which improve climate resistance are CeO_2, Al_2O_3, Cr_2O_3 and Ta_2O_5.



[P elution: 0.2ug / ml] [P elution :0.5ug / ml]

Figure4. *Climate resistance test result showing corroded device*

The stability of glass including molten condition was evaluated with TG-DTA, composition analysis and XRD by checking crystal existence and so on.

Based on the study, we confirmed that climate resistance could be secured under Tg >= 650 Dec C condition. We also could achieve the Thermal diffusivity to be 0.33mm2/sec having the material stably vitrescible under molten condition.

Thermal Characterization

We made a Thermal Head with low thermal diffusivity glass substrate and evaluated thermal characteristics. We compared the result against glazed Alumina substrate (Glass thickness 0.2mm, Alumina thickness 0.9mm)

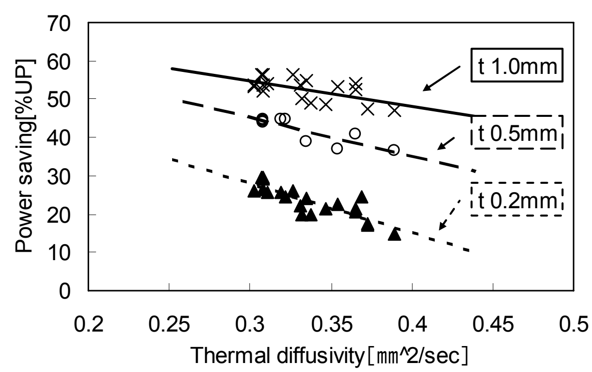


Figure 5. *Relation between thermal diffusivity rate and thermal efficiency (New HD)*

Figure 5 shows the relation between thermal diffusivity and thermal efficiency related to substrate thickness. The lower thermal diffusivity goes and the more substrate thickness increases, the thermal efficiency increases. Figure 6 shows the relation between thermal diffusivity and “Obiki” related to substrate thickness.

Thermal efficiency and “Obiki” are opposed. “Obiki” is more effected by substrate thickness than thermal diffusivity. “Obiki” can be controlled by substrate thickness.

In order to adjust substrate thickness, the back grinder created internal ALPS was used (Figure 7). Figure 8 shows the process variation of substrate thickness adjusted by this equipment. We could achieve the variation less than 0.026 mm in range while target substrate size was 4*4 inches and 0.2mm thickness.

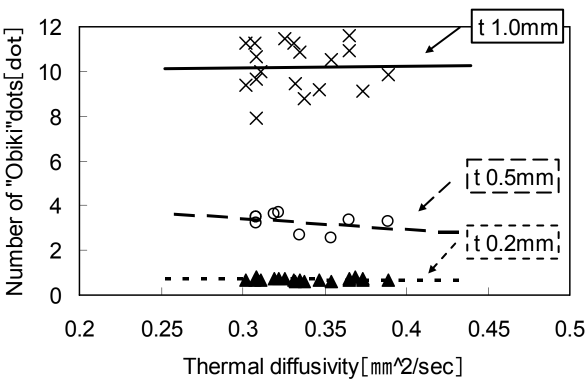


Figure 6. Relation between thermal diffusivity rate and “Obiki” (New HD

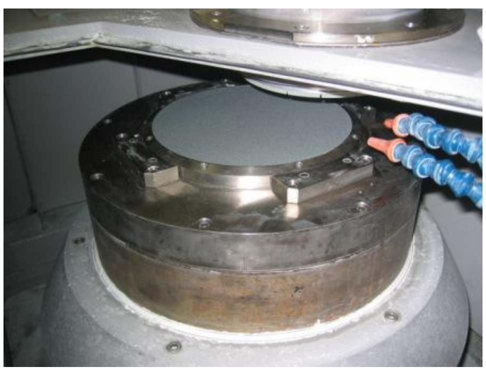


Figure 7. Back Grinder (ALPS)

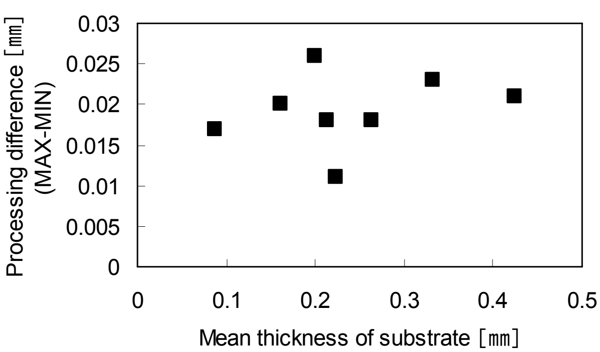


Figure 8. Relation between thickness mean value of substrate and processing difference

Power saving characterization by printing

We confirmed the power saving effectiveness while printing with sample print head. Result shown on Figure 9. Although the power saving effectiveness is different depending on substrate thickness, it shows power saving improvement over conventional head. The result is re-organized in Figure 10 to show the efficiency based on substrate thickness. As shown, power saving efficiency is higher when substrate is thicker. From relation between power saving and “Obiki”, we chose 0.25mm thickness. The power saving efficiency is 25% with this setting.

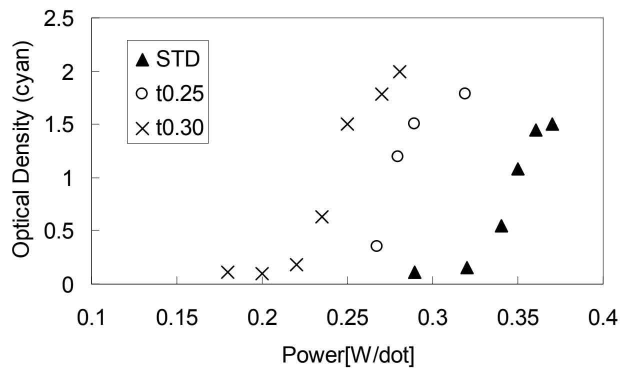


Figure 9. Relation between Power and OD on sample head

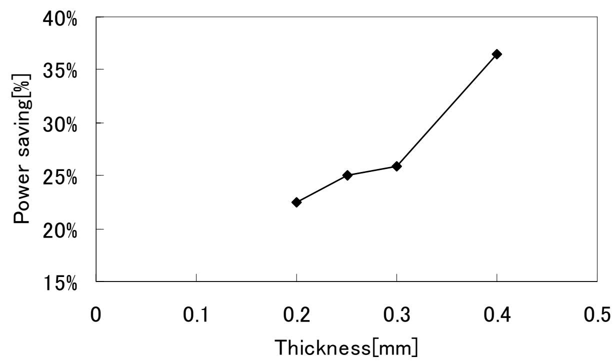


Figure 10. Relation between power saving efficiency and substrate thickness

Conclusion

We developed "Power saving thermal head" and "Low thermal diffusivity glass material" this time. As a result, mobility and further down sizing of thermal printer became possible. Following findings were obtained during the development.

1. We found thermal diffusivity of substrate have to be 0.3mm2/sec to achieve 30% power saving by simulation.

2. Phosphate glass shows very low thermal diffusivity and therefore we adopted the material for power saving thermal head.

3. Climate resistance was secured under Tg 650Deg C or higher and confirmed that thermal diffusivity 0.33mm2/sec is achievable.

4. The actual thermal head was made and evaluated. 25% power saving was achieved by 0.25mm thick substrate.

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Author Biography

Hirotoshi Terao received his BS degree in materials engineering from Mining College at Akita University in1991 and .he received his Dr degree from Niigata University in 2006. He has worked at Alps Electric Co., Ltd. since 1991 and is currently a senior research scientist chief engineer 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 Electro photography of Japan in 1996 & 2010.