Development of Digital Photo Prints for Thermal Dye Transfer Method

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Abstract

Recently with rapid spread of digital cameras, we find growing needs for digital photo printing. Out of many digital print methods, thermal dye transfer method excellent in print speed, photo quality, and preservation, is recognized as a method which can print high quality image matching that of silver-halide and that instantly. This method, because of its fast output and ease of use, is widely utilized as an effective means for kiosk terminals and on-demand printing at retailers. We, at DNP, in search for further performance improvement, have shed light on and researched improvement of high sensitivity and preservation of this thermal dye transfer image.

Improvement of image's high sensitivity has been achieved by adopting a new adhesive/barrier layer in order to transfer the dye in the transfer film (ink ribbon) more effectively to the receiver. As for preservability improvement, we have successfully developed a new dye structure excellent in inter-dissolution stability with resin (binder) that comprises dye and durable against external factors such as light, heat, humidity, etc.

With these new technologies, we will be able to obtain images with high speed output instantly on the spot, a beautiful photo print with high contrast and wide tone range, a beautiful photo print with negligible deterioration of photo quality by light and heat, etc.

Introduction

Thermal dye transfer method is a thermal transfer recording system whose image is formed by the dye in the transfer film transferred to the receiver according to heat energy from thermal head. This method makes it possible to continuously change dye transfer volume by controlling the electricity flow time to the thermal head and to obtain clear and crisp image with wide tone reproduction range. This enables thermal dye transfer method to be used in various fields such as digital photofinishing, amusement such as print club, ID photo such as ID card, passport and for medical usage. Among others, demand for digital photo print is very positive, therefore, following functions are deemed particularly important.

- High speed output adaptability
  (→Improve media's high sensitivity)
- Electricity saving
  (→Improve media's high sensitivity)
- Image high permanence
  (→Improve light- , heat- , humidity-resistance)
- Image high quality
  (→High glossiness, high resolution)
- Reproducibility of output image
  (→Media's preservation stability)

This report introduces improved new thermal dye transfer media concerning "ink ribbon's high sensitivity" and "image's high permanence (preservability)".

Ink Ribbon's Improved High Sensitivity

As print speed gets faster, necessary energy consumption per unit time only increases to achieve the same print density as before. While on the other hand, print energy increase puts huge load to device media and certainly there is a limit. If developing even higher sensitive media is possible, we can clear away those limitations.

Thermal dye transfer media has following ink ribbon and receiver sheet configuration shown in Figure 1.

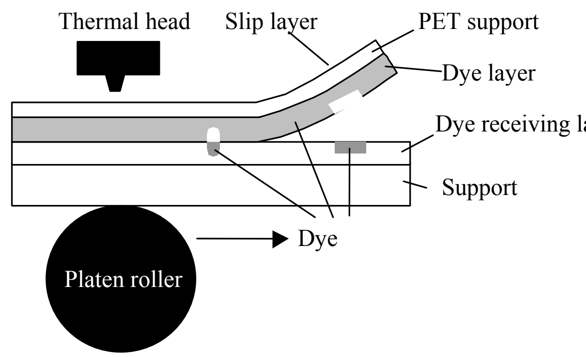

Figure 1. The principle of thermal dye transfer system

Some of the methods usually taken for improving high sensitivity are:

1. Increase dye volume in the dye layer
2. Increase coating volume of the dye layer
3. Increase dye's molar extinction coefficient ε
4. Lower dye's molecule volume
   (Increase dye transfer volume to receiver)
5. Use thin ink ribbon PET support
6. Increase heat energy application
7. Select receiver with better dyeing ability

Above approaches are often taken, however, they have their disadvantages too. It is inevitable, for instance, to face up to deterioration of image permanence, ink ribbon's preservation stability, print performance and cost increase of the product. Traditional methods cause above inconveniences, therefore, we have thought of and tested a new "adhesive/barrier layer" to be installed between PET support and dye layer whose affinity to dye is low but heat resistance high which resulted in effective transfer of the dye in the dye layer to the dye receiving layer. Our concept concerning improvement of adhesive layer to achieve media's high sensitivity is shown in Figure 2.

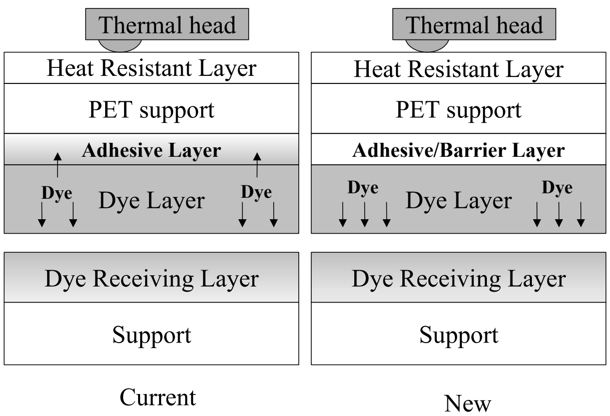

Figure 2. Schematic view of dye diffusion

In the traditional method, the dye responded to heat from thermal head diffused not only to dye receiving layer but also to adhesive layer direction. By this phenomenon it is believed that the adhesive layer is partially dyed and therefore loses print density. It is also believed it happens primarily for one reason that the affinity between adhesive layer and dye is high, still for another reason that the heat-resistance of adhesive layer is not sufficient enough to suppress dye diffusion in adhesive layer resin segments. Consequently, we have concluded that it is important to install the new adhesive layer acting also as a barrier layer with low affinity to dye and with high heat resistance, not to mention adhesiveness to PET support and dye layer and thus carried out our new development.

Adhesive layer of the ink ribbon only has been changed to the newly developed product for printing evaluation. As a result, this new product has increased the dye transfer rate by 26% (dye's effective transfer) in the highest density area compared to the current product. (See Figure 3, Reference 2, Fig. 4 data as "Current layer")

Dye transfer rate = Pre-printing ribbon absorbance / Post-printing ribbon absorbance

Furthermore, by improved effect of dye transfer rate in utilizing the new adhesive layer, the new media has achieved 10% sensitivity improvement compared to the current product. (See Figure 4)

With this method, we will be able to increase sensitivity by keeping the dye layer, dye receiving layer, PET support and printing conditions the same as before. It turned out to be extremely effective with no deterioration of preservation stability and printing performance.

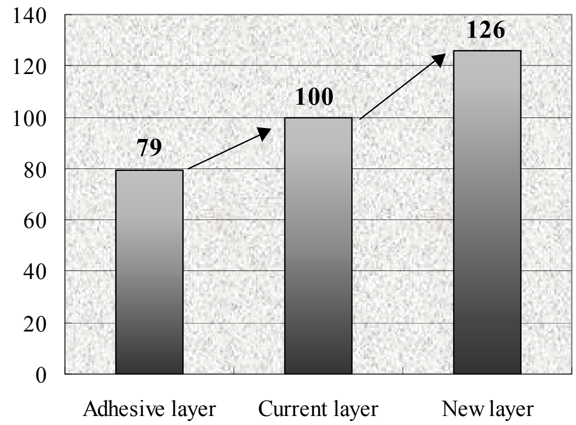

Figure 3. Comparison of the dye transfer ratio (as compared with the current adhesive layer : 100)

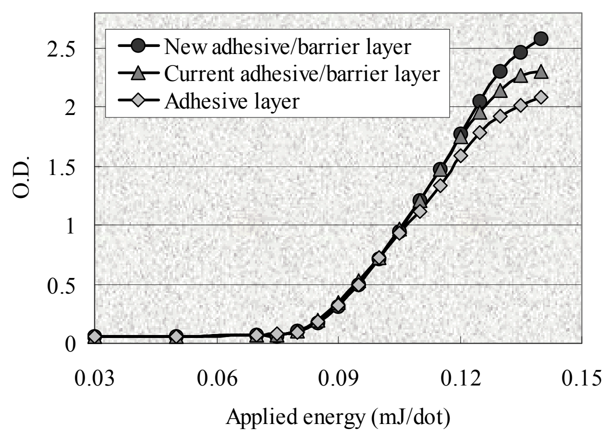

Figure 4. Effect of enhanced sensitivity of media (Print:1.0msec/line, Paper:Currently available)

By above sensitivity increase technology, it enables the method to save energy to be consumed at high speed printing, though energy consumption increase is inevitable for density maintenance for yet faster print speed. Figure 5 shows relation between print speed and print density when the new adhesive layer is utilized.

It is already confirmed that further faster print speed will result in having matte finish in high energy print area lowering the highest density. In order to comply with future high print speed, we continue our study trying to improve dye receiving layer and overcoat layer in order not to lose density even when higher energy will be given.

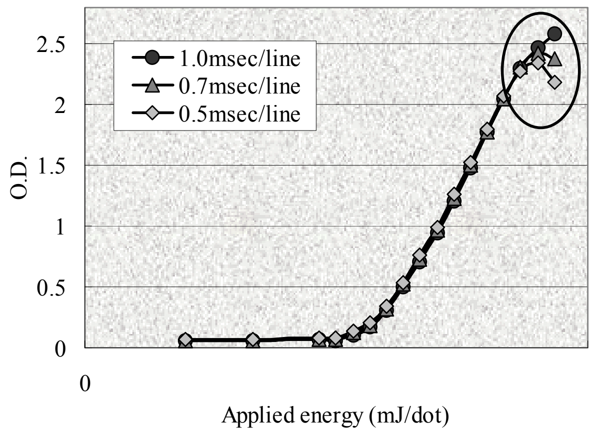

Figure 5. Print speed and density relation

Improvement of Image Permanence

After an image is printed by a user, the image is laid out bare to external environmental factors, such as light, heat and gas. In order to preserve image quality the same as long as possible like when it was printed, an important theme is to improve light-, heat-, and gas-resistant stability. For improving image permanence of the thermal dye transfer media, introduction of new dye structure, overcoat layer improvement and changing the receiver layer are the approaches usually taken. In this report we introduce the result of the trial of image permanence improvement by changing the dye structure.

When dye materials fade or experience hue variation in the receiving layer, not only each color dye material itself deteriorate, but phenomenon is also detected they further deteriorate by being influenced by other dyes. For instance, green is a mixed color of yellow and cyan. Compare density deterioration rate of yellow itself and density deterioration rate of yellow in the green and in general find the latter clearly showing much worsening. We have looked into this inter-catalytic fading between dyes in our development and studied the combination that do not give bad influence to other dyes when fading and color variation, and tried to improve image high permanence.

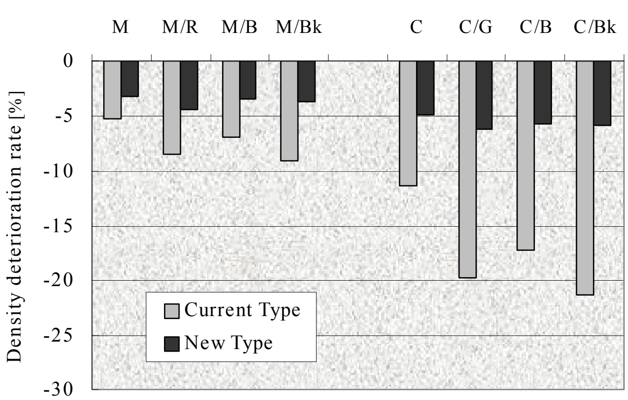

Figure 6. Each color O.D. ≒ 1 density deterioration rate

Figure 6 shows density deterioration rate of each color when Xenon is shed upon.

In the traditional products, Ye dye combined with Mg (M/Red) and Cy (C/Green) light resistance, compared to that of Mg or Cy alone, shows distinct worsening, however, in the newly developed products any dye combination shows smaller density deterioration rate.

See Figure 7 for Xenon radiation hue variation (ΔE*ab).

$$\Delta E^*ab = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$$

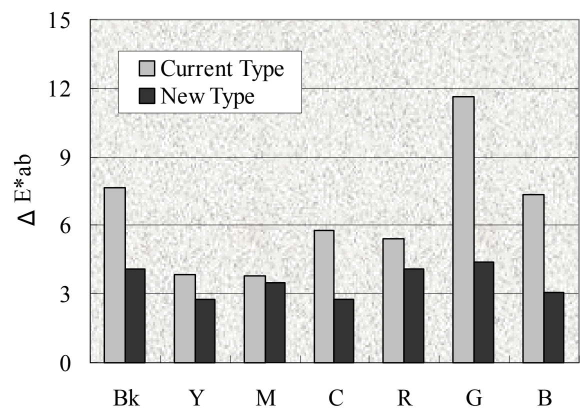

Figure 7. Each color hue variation (O.D. ≒ 1)

In the new product, because interaction between each color dye has been suppressed, not only density deterioration but also hue variation has been remarkably improved as a result.

Figure 8 below shows hue variation (ΔE*ab) data of a photo printed with above dye material with improved light-resistance performance and preserved for 3months at 60°C, 70% humidity.

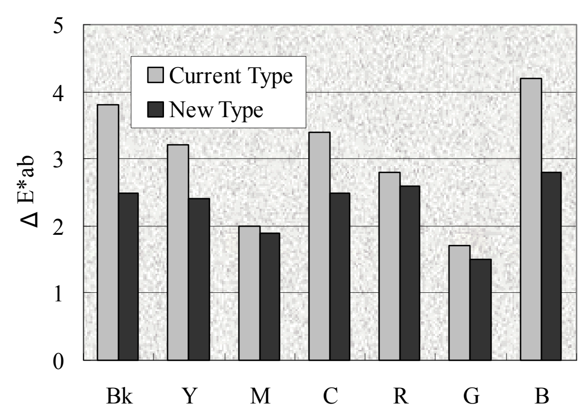

Figure 8. Hue variation of a photo preserved 3 months, at 60°C, 70% humidity (O.D.≒1)

Also in a longer period preservation test under high temperature and high humidity environment, hue variation in the newly developed product is very well suppressed. It is important to select excellent dyes with stability against heat and humidity, with little interaction between dyes and with inter-dissolution stability with binder resin.

Conclusion

We have been working on improvement of ink ribbon's high sensitivity and image's high permanence in order to improve further thermal dye transfer method performance. For ink ribbon's high sensitivity, we have introduced our new adhesive/barrier layer to achieve our goal by enhancing dye transfer ratio.

As for image's high permanence, we have introduced new dye materials with little interaction between dyes and excellent in inter-dissolution stability, thus confirmed distinct improvement in light-, heat-, and humidity-resistance performance.

It is our desire that the newly improved thermal dye transfer method introduced in this report will give much wider possibilities in photo printing for the photo-loving people as well as contribute to the photofinishing industry.

References

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2. D. Fukui, International Conference on Digital Printing Technologies, 980-983(2004).

Author Biography

Munenori Ieshige received his master's degree in engineering from Meiji University in Japan in 1999. Since then, he has been working at Dai Nippon Printing Co., Ltd. Information Media Laboratory (research & development of thermal dye transfer media.)