New Thermal Offset Printing Employing Dye Transfer Technology (Tandem TOP-D)

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Abstract

In this paper, we describe the development of a tandem-type new thermal offset printing technology that enables reproduction of high speed and high quality full color images on a pulp-based paper (e.g. ppc, re-cycled ppc paper, RC paper, etc.), employing a newly developed thermal transfer engine, and print media including an acceptor layer sheet, ink sheet, and an intermediate belt.

The process consists of three steps:
(1) acceptor layer (AL) formation from the AL sheet onto an intermediate belt;
(2) dye transfer printing with dye sheets into the AL on the belt; and
(3) transfer from the dyed AL onto a sheet of paper.

The print head for the AL formation and three heads for dye transfer printing are separately located outside the belt along a large drum.

The head for the dyed AL transfer is installed inside the belt. The new acceptor layer (AL) of the AL sheet, which has a heat-resistant sliding layer on the back side of the sheet, is arranged on a releasing layer (RL) on the base sheet, separately from the ink sheets including sublimation dye layers and back coat layers.

This report describes studies of the basic print engine and print method on pulp-based papers for full color images, and the specially prepared AL sheet, ink sheets and the intermediate belt. More detailed results are given below of the relationship between the materials' properties and the AL formation and transfer mechanism, release strength between the AL and the other interfaces, print density characteristics, and color fastness properties.

Introduction

The digital printing world continues to evolve rapidly, with mega-pixel digital cameras (DSCs), becoming increasingly common.

Conventional mini-labs in the photofinishing market are increasingly being upgraded to digital mini-labs. Meanwhile, the image quality of thermal dye transfer and inkjet printers is about to overtake that of conventionally printed photographs, with the result that business competition between these printing methods is intensifying.

However, conventional dye transfer printing has up to now has had several drawbacks: it has been inapplicable to plain paper, was usable only by the inclusion of a specially prepared and expensive receiving sheet, and had to use a laminating method to counteract poor color fastness. To eliminate the drawbacks inherent to conventional dye transfer printing, we previously developed a TOP-D printing method[1,2] using a single print head and a heat-roller for dyed AL transfer. However, the method in ref.(2) has several disadvantages: low printing speed, undesirable effects on the intermediate belt caused by the heat roller, problems with regulating the release strength between the AL and the surface material of the belt, and the life of the belt on which AL formation closely depends.

Reported herein is an improved tandem TOP-D printing method for eliminating the above-mentioned disadvantages.

Principle and Constitution of Process

Figure 1 shows a schematic cross section of the tandem TOP-D printing system wherein three printing processes are carried out: (1) acceptor layer (AL) formation process onto the intermediate belt, (2) dye transfer printing process into the AL formed on the belt, and (3) the dyed AL transfer process onto the paper. Figure 2 shows a schematic cross-section of the media used. Fig. 2-a shows an AL sheet and Fig. 2-b illustrates a single-color ink sheet. In this print engine, three parts, consisting of the AL formation section, dye-transfer section, and dyed AL transfer section, are arranged along the intermediate belt along a large drum, where the key devices and materials listed below are used: five edge-type line heads with a resolution of 300 dpi, five sheet-rolls which comprise the AL sheet roll, three primary color (sublimation dye) sheet-rolls and a paper sheet roll, and the belt consisting of a 25 μm-thick polyimide film. The AL sheet consists of an AL overlaying the releasing layer (RL) coated on a PET film with a heat-resistant sliding layer on the reverse side. Moreover, it is possible to use an AL sheet with a top layer (TL) on the AL to protect the printed images.

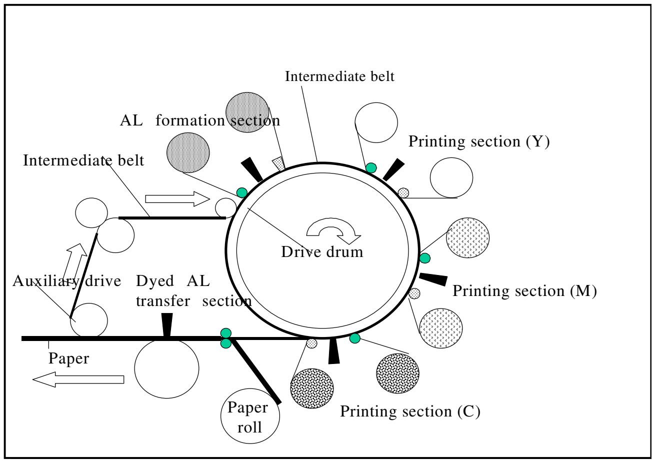

Figure 1. A schematic cross section of tandem TOP-D printing system.

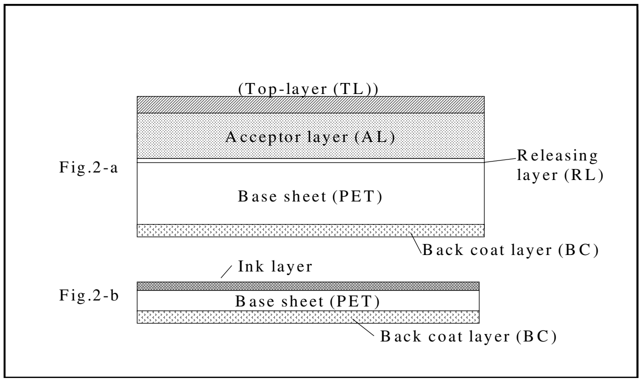

Figure 2. A schematic cross section of print media. (2-a): Acceptor layer (AL) sheet, (2-b): A single-color ink sheet

The first step in AL formation takes place using the AL sheet, the head for AL formation and the belt wherein only the AL is transferred from the RL onto the belt during the AL formation step. The second process, that of dye transfer printing, takes place by printing the ink sheet dyes onto the AL formed on the belt in three printing areas arranged in the order of yellow, magenta, and cyan dye. The final stage of the dyed AL transfer process is carried out using a head installed inside the belt and a receiving paper, where images of dyed AL are reproduced onto a sheet of paper which can be of any type. The degree of release strength by the AL onto the surfaces of the other materials governs the above-mentioned three processes.

The specifications of the print engine are shown in Table 1.

Table 1. Specification of the Print Engine.

Items	Contents
Print head	Edge-type line thermal head Number of head: 5 per engine Resolution: 300dpi
Print size	152mm(head-line direction) x 103mm
Printing conditions	Simultaneous print of AL formation, Primary colors, and dyed AL transfer. Period of print: 5ms/line. Gradation: Y,M,C 256 steps.
Print speed	Continuous: 7 sec. First print: 40sec.
Intermediate belt	25 µm thick Polyimide film
AL sheet	(Top layer: 2 µm thick) Acceptor layer: 6.5 µm thick Relesing layer: 0.1 µm thick Base:12 µm thick PET film Back coat layer: 1.5 µm thick
Ink sheet	Dye layer: specially prepared Base: 6 µm thick PET film Back coat layer: specially prepared
Paper	RC paper, Coated Paper

Experimental

The experiments concentrated on the following aspects: (1) the improvement of factors for achieving the above-mentioned three processes at higher speeds than that described in the previous paper,[2] (2) high print density, and (3) stable color fastness.

More specific improvements in (1) were achieved with respect to the following: (a) taking account of the surface energy of the components, (b) the relationship between the thermal properties of the AL and the stability of AL formation, (c) the release strength between AL and the other surfaces (the RL, the ink layer, the belt material and the paper), and (d) the stability of the release strength between RL and AL.

Concerning the AL, the use of soft thermoplastic resins suited for AL formation, with higher affinity for the dyes, and the dyed AL transfer process itself were explored. The thickness of the AL was designed to be 6-7 µm taking account of the depth of diffusion of printed dyes.

The resin for TL was examined to prevent unwanted effects caused by plasticizers.

As for the RL, a cross-linked resin was explored with the aim of maintaining a suitable release strength between RL and AL which did not generate problems with peeling of the AL from the RL during the coating of the AL, and which maintained a range of stable strengths suited to the TOP-D process.

The measurement method of release strength was based on the Japanese industrial standard (JIS Z 0237) wherein the releasing angle is 180 degrees, releasing speed is 10 mm/sec, and the width of the sample is 86 mm.

The back coat layer was designed to confer optimal properties of heat-resistance, sliding, and cleaning of the head surface under conditions of AL formation energy applied at a constant high level, taking account of little contamination onto the belt surface by the free silicone oil in the back coat layer.

The sublimation dye layers of primary colors are prepared using indoaniline and anthraquinone dyes (cyan), an azo dye (magenta), and stylyl and quinophthalone dyes (yellow).

Results and Discussion

Surface Energy of Components

Table 2 shows the surface energy of the AL and the other materials' surfaces relating to the process. The surface energy of the AL (and TL) is greater than that of RL, and smaller than that of the surface of the belt. This indicates the possibility of easy AL formation. However, it has a value close to that of the ink layer and the surfaces of some types of paper. This indicates the need for several devices, described below, to achieve the process.

Table 2. Surface Energy of AL and the Other Materials' Surfaces

	Surface energy (mN/m)	Contact angle (water)(Degree)
AL RL PET BC TL	36.6 27.8 56.5 34 44	95.6 102.5 57.1 100.8 83.5
Belt	53	51.4
ink layer	30-42	101
RC-paper coated paper	40 40	85.7 94.6

Thermal Properties of the AL and Stability of AL Formation

Table 3 shows the dependence of the composition of the AL on the Tg of the AL, and the stability of AL formation. The AL comprises an acrylic resin with hydroxyl groups plus other resins. Table 3 indicates that the Tg of the AL falls with increasing proportion of acrylic resin and UV absorber. The stability of AL formation increases with falling Tg. The release strength between RL and AL at 80 °C increases at higher ratios of acrylic resin. This is attributed to the interaction between AL and RL. Nevertheless, this unsuitable correlation can be reversed due to the plasticizing effect of the UV-absorber.

Table 3. Composition of AL vs. Tg of AL, and stability of AL formation.

Weight ratio of Acrylate resin	Weight ratio of the other resins	Weight ratio of UV absorber	Tg (°C)	Stability of AL formation	Release strength of RL/AL at 70/80 °C
0.5	3.98	0.2	83.5	Not acceptable	20/21
1	3.48	0.2	72.6	Less acceptable	19/20
1.2	3.28	0.2	68.7	Acceptable	19/65
1.2	3.28	0.4	66	Acceptable	18/15

Release Strength Between AL and the Other Surfaces

Figure 3 shows the temperature-dependence of the release strength between RL and AL (RL/AL), the ink layer and AL (ink/AL), and belt and AL (belt/AL) at temperatures from 25 to 70 °C. Herein, RL/AL, ink/AL, and belt/AL show the respective strength of peeling of the RL, the ink, and the belt from the AL fixed on a base. On the other hand, AL/belt (the release strength of the AL from the belt) is confirmed to be the largest compared to that for belt/AL, ink/AL and RL/AL. (Measurement samples were prepared using a static heating method). It is very important to the overall process that RL/AL and belt/AL show lower values for the strength and negative temperature coefficients. Nevertheless, ink/AL shows a higher value and a convex curve towards the bottom. This indicates that the peeling time of the ink-sheet from the AL after printing is important.

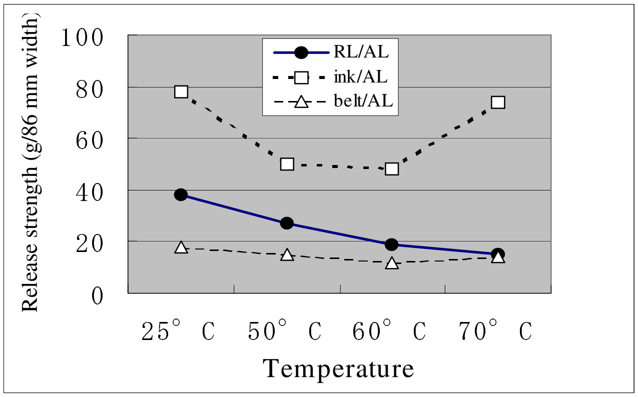

Figure 3. Release strength of RL/AL, ink/AL, belt/AL.

Stability of Release Strength Between RL and AL

Table 4 shows the interaction and stability of the release strength between RL and AL. The interaction and stability between the RL, made from a cross-linked resin, and two ALs containing acrylate resins with different hydroxyl contents, was examined. The AL(a) of the acrylate with higher hydroxyl value shows a markedly higher value at 70 °C, but the AL(b) with a lower hydroxyl content shows stable values at over 70 °C. Moreover, the

AL(b2) involving the UV absorber of 10 phr shows a stable value at 80 °C.

Table 5 shows changes in temperature dependence on the release strength of RL/AL (with a UV absorber of 5 phr) of AL sheet stored at 50 °C and 60%RH.

Table 4. Interaction and stability of release strength between RL and AL.

	25°C	50°C	60°C	70°C	80°C
AL(a)	32		40	200	
AL(b1)	31	28	22	19	65
AL(b2)	20	18		18	15

*Unit: g/86 mm width,

*AL(a): Acrylate with high hydroxyl value.

*AL(b): Acrylate with low hydroxyl value

*AL(b1): UVA = 5phr, AL(b2): UVA = 10phr

Table 5. Change of temperature dependence on release strength between RL and AL of the AL sheet stored at 50°C, 60%RH.

	25°C	50°C	60°C	70°C
Initial	33	30	28	15
1 week	31	29	26	22
2 week	30	17	16	15
3 week	30	25	24	16
4 week	20	23	23	10

*Unit: g/86 mm width, *Angle of peeling: 180 deg.,

*Vertical column: stored periods.

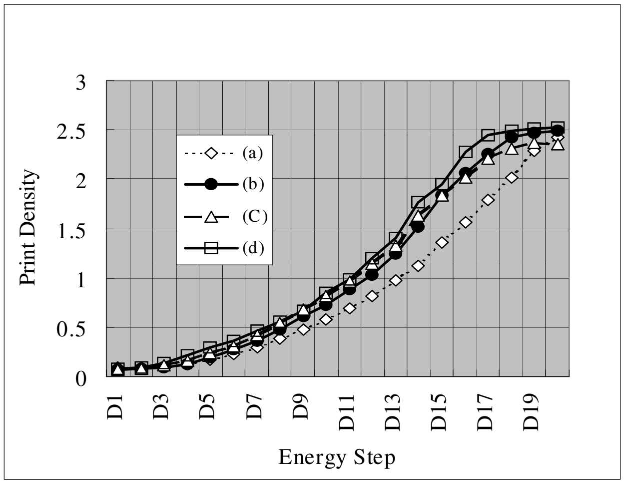

Figure 4. Structure of AL vs. print density. (a): Conventional, (b,c,d): TOP-D

Print Density

Figure 4 shows the print density characteristics of print samples (magenta) with various AL structures using the same materials, and the position of dyes in the AL shown in Figure 5. Structure (a) in Fig. 5 indicates the structure of an (over-layer)/(dye in the top of AL)/(paper) reproduced by conventional dye transfer. Structure (b) is for that of a (dye under AL)/(paper) by this method. Structure (c) is for a (dye under AL)/(AL)/(paper) (the structure in which dye is placed between two ALs). Structure (d) is for a (TL)/(dye under AL)/(paper). As shown in Fig. 4, the TOP-D process gives a higher print density than the conventional method. Moreover, (d) gives a slightly higher value than (b) or (c). This method delivers higher density, more glossy printed images.

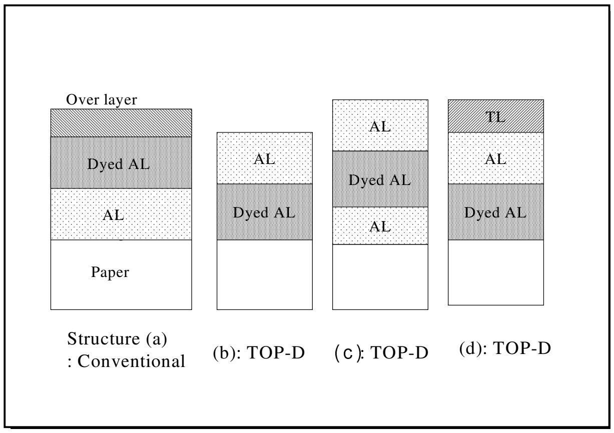

Figure 5. Structure of AL and position of printed dyes.

Color Fastness of Printed Images on an RC Paper

Using the structures shown in Fig. 5, color fastness properties were examined. Table 6 shows the color fastness of printed images with various structures above-mentioned by TOP-D process, compared with that made by conventional dye transfer. This comparison shows that the color fastness of images created using this method is markedly better than that of conventional prints. We attribute this to the shielding of the printed dyes from air and light.

Table 6. Color difference (delta E*ab) of printed samples using these methods and conventional dye-transfer method subjected to xenon light exposure of 9 x 10^7 J/m^2.

Structure	Y	M	C	BK
(a)	16.4 15.7	17 13.8	8.8 11	25.7 27.6
(b)	12 5.3	7.6 4.2	8.7 6.4	23.4 7.9
(c)	11.5 8.8	2 4.3	8.2 7.3	18.3 10.1
(d)	13.4 7.3	8.1 5.2	7.6 5.5	20.7 6.7

*Structure (a): Conventional, Structure (b, c, d): TOP-D method

*Contents of UV-absorber involved in the AL of structures (a-d) = 5phr.

*Measurement density: upper; 1-1.5, lower; 2-2.3

Conclusions

A new thermal offset printing employing dye transfer technology, called Tandem TOP-D, which enables reproduction of highly glossy images and good color fastness of images on RC paper at high print speeds has been developed. Printing can be accomplished by using 5 line-type thermal print heads, a newly developed dye-acceptor sheet, ink-sheets, and an intermediate belt.

References

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Biography

Nobuyoshi Taguchi received his B.Sc. and Doctorate in Applied Physics from Waseda University in 1968 and 1993 respectively. He joined Matsushita Electric Industrial Co., Ltd. in 1968, where he has since been developing semiconductor film devices, thermal print heads, organic film technology, and thermal transfer printing technology. He is a member of SPSTJ, ISJ, IIEEJ, and High Polymers Japan. e-mail: ntaguchi@rel.ctmo.mei.co.jp (ntag@m3.kcn.ne.jp)