

Effects of Coating Designs on the Imaging Qualities of Color Laser Printing Media

J. C. Song, B. A. Lyon, K. N. Sundberg and E. C. Tien
Arkwright Inc., Research and Development
538 Main Street, Fiskeville, Rhode Island

Abstract

The performance of a color laser printing medium is affected by various factors such as media design, printer design, toner characteristics, fuser temperature and dwell time. This paper discusses the effects of coating designs on the imaging qualities of both transparent and opaque film media for color laser printing applications. The interactions between toners and image receptive coatings are explored. Results of spectrophotometric characterization of various media will be presented in relations to their surface physical properties. Coating formulations and processing conditions for the imaging media are carefully optimized and controlled to obtain high imaging quality as well as reliable feeding performance.

Introduction

Color electrophotography, an important non-impact printing technology, has found increasing applications in today's reprographic industries. An electrophotographic printing process involves the following basic steps[1]:

(1) Charging: the photoconductor is pre-charged in the dark;
(2) Writing: a latent image is optically formed by converting the image information in the form of electronic signals to an electrostatic field stored on the photoconductor;
(3) Developing: a toner composed of charged colorant particles is deposited on the field pattern to create a visible image;
(4) Transferring: the visible image is then transferred to the media to be printed such as a sheet of paper or film;
(5) Fusing: the toners are fixed onto the media by heat and pressure;
(6) Cleaning: get ready for another cycle.

Among these, the transferring and fusing of toners are the two most critical steps from a media designer's point of view. For color laser printers, four toners including yellow, cyan, magenta and black are used and therefore media requirements for color laser printing applications are more stringent than the monochrome counterparts.

A typical structure of a color laser printing media is show in Figure 1. The PET substrate is usually surface treated for coating adhesion enhancement. The film can be symmetrically or asymmetrically coated with the same or different toner receptive coating on the two sides.

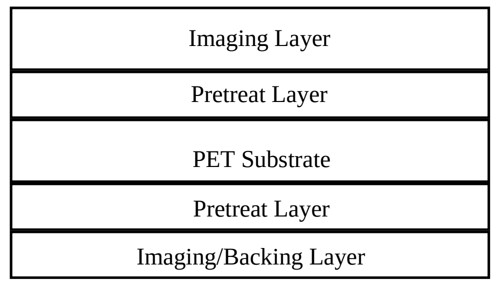

Figure 1: Schematic diagram of a color laser printing medium.

The color fidelity of an electrophotographic medium depends to a large extent on how well the toners are fused in the toner receptive coating. To obtain bright color images with high color fidelity, the toner resins must be compatible with the image receiving layer and properly fused to minimize loss of light transmission due to scattering. Thermoplastic transparent resins with low melting points and sharp melting peaks are often used as binder resins for color electrophotographic transparency coatings. As reported in our previous paper,[2] low molecular weight thermoplastic resins with low softening/ melting points were found to give higher color fidelity properties because they can be readily melted during the fusing process. However, low molecular weight resins are generally too soft to be used alone as binder resins for the toner receptive coatings due to their poor scratch resistance and susceptibility to toner off-set problem. To improve the coating hardness, we employed a hard/soft polymer matrix containing high and low molecular weight resins to achieve both high color fidelity and good scratch/toner off-set resistance properties.

The surface electrical properties of the toner receptive coatings can also have significant effects on the toner transfer processes. Incomplete toner transfer can occur when the toner receptive coating is too resistive, resulting non-uniform color images. Image receiving coatings with very low surface resistivities can also result in image deletions, especially under high humidity environments.

The feedability is the most important design parameter for any media. For if the media does not feed through the printer, none of the other qualities is relevant. The feedability is quite often printer-dependent. To achieve a reliable feeding performance, the surface electrical and frictional properties of the media must be carefully controlled. First of all, an adequate anti-static property is required to prevent static electric charge building-up that can leads to multifeeds or paper jams. Generally, there are two types of feeding jams: entry jam and timing error. Entry jams are usually caused by problems in paper separations which can be enhanced by reducing the surface resistivity and the coefficient of friction. Organic or inorganic pigment particles or waxes are often used to reduce the surface frictional properties. The coefficients of frictions data generally contain two parts of information: coefficients of static friction and kinetic friction. The coefficient of static friction is related to the start of movement (pick-up) of medium in the paper feed tray (cassette), and the coefficient of kinetic friction is related to the transport characteristics of the medium. The coefficient of kinetic friction of a medium is usually kept lower than that of the static friction to facilitate proper sheet separation of the media to be printed.

Experimental

Toner receptive coatings of appropriate thickness were applied to PET base film by a rod coating technique and dried in an oven. Imaging tests were done on commercial color laser printers and color copiers. A four-color block (Yellow, Cyan, Magenta and Black) test pattern was reproduced on various experimental color transparency media. The imaging qualities are evaluated through a combination of visual evaluation on a overhead projector, color measurement (L*, a* b*) using a Macbeth ColorEye 2020+ spectrophotometer with Optiview Lite software and haze measurement using a Gardener haze meter. Particle size analysis was accomplished using a Malvern Master Sizer MS20 particle size analyzer. Differential Scanning Calorimetry (DSC) studies were accomplished using a TA Instruments DSC 2910 with a TA 2100 data station.

Results and Discussion

In order to understand the fusing characteristics of various color toners in correlation with their physical properties, the particle sizes and particle size distributions and the softening points of the four basic toners (yellow, cyan, magenta and black) from three different commercial printers were analyzed (Table 1).

We can see that the average particle sizes of toners are quite different among the three color laser printers, ranging from 8 microns to about 18 microns. Generally speaking, the smaller the toner particle sizes, the more readily the fusing process and the brighter the color images. As expected, toners used in printer (A) which have average particle sizes of about 8 micron gave slightly brighter color images than the ones from the other two printers. Figures 2 and 3 gave the transmission spectra of the four color images made from toners of printers (A) and (B), respectively. The % trans-mission of the color images decreases as the toner particle size increases. The C.I.E. L*, a* and b* values of the two yellow toners of different particle sizes in a toner receptive coating were compared in Table 2. The smaller sized toner particles generate higher L* values and a brighter color image.

Table 1. Physical properties of toners (Y, C, M, K) from three commercial color laser printers.

Toner	Average Particle size (micron)	Softening Point (C)
Yellow (A)	8.1	59.4; 82.8
Yellow (B)	10.6	67.4
Yellow (C)	17.7	64.4
Cyan (A)	9.0	59.7; 82.4
Cyan (B)	11.8	66.8
Cyan (C)	17.7	64.1
Magenta (A)	8.0	59.5; 82.2
Magenta (B)	10.4	65.6
Magenta (C)	17.2	65.9
Black (A)	9	61.3; 82.4
Black (B)	10.9	67.5
Black (C)	13.1	64.1

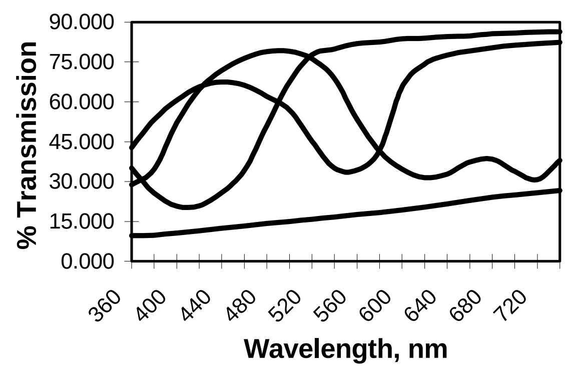

Figure 2: Transmission spectra of the yellow, cyan, magenta, and black toners from printer (A) dispersed and fused in a toner receptive coating.

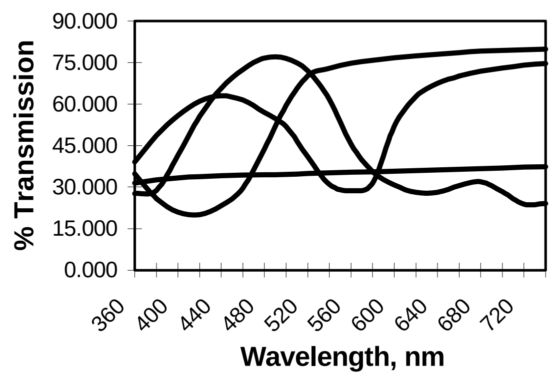

Figure 3: Transmission spectra of the yellow, cyan, magenta, and black toners from printer (B) dispersed and fused in a toner receptive coating.

Table 2. L*, a*, b* values of two yellow toners with different particle sizes in a toner receptive coating.

Toner	Average particle size (micron)	L*	a*	b*
Yellow (A)	8.1	90.9	-13.2	43.5
Yellow (B)	10.6	87.6	-12.1	43.6

The compatibility of the toner receptive coating with the toner resins is a key factor in determining the color imaging qualities of the media. Toners must be uniformly fused into the toner receptive coating to minimize the loss of light transmission due to scattering. Table 3 compares the color imaging qualities of a yellow toner in two different coatings: (A) a low molecular weight thermoplastic coating and (B) a thermosetting resin. The former has a higher degree of compatibility with the toner resin than the latter and thus a brighter color image was obtained from Sample A with a higher L* value and a lower haze value. Figure 4 shows the transmission spectra of the yellow color images made from the two samples. Sample A gives higher values of %transmission, indicating a brighter and cleaner image.

Table 3. L*, a*, b* values of yellow color images of two different toner receptive coatings imaged on a color laser printer.

Color Parameter	Sample A	Sample B
L*	77.1	69.9
a*	-13.9	-12.4
b*	46.6	43.6
Haze	27	40

(A) A low molecular weight thermoplastic coating;
(B) A thermosetting coating.

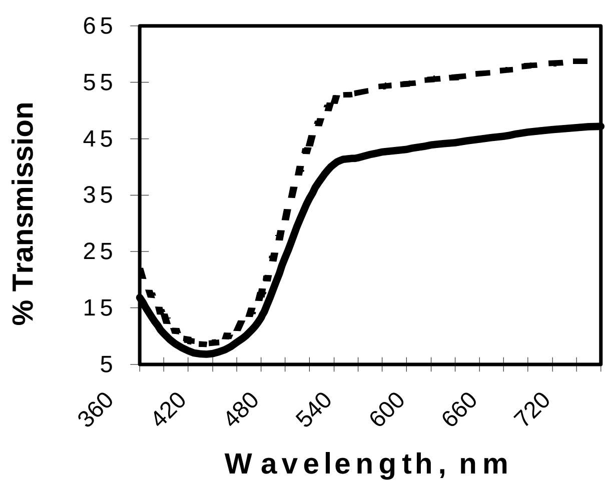

Figure 4. Transmission spectra of yellow color images made from a low molecular weight thermoplastic coating (Sample A, dash lines) and a thermosetting coating (Sample B, full lines).

The thickness of the substrate can also affect the imaging qualities of the media. Table 4 shows changes in the values of the C.I.E. L*, a* and b* of two different image coatings as a function of substrate thickness. We can see that as the substrate thickness increases, the lightness value decreases due to a reduced fusing efficiency. However, it must be pointed out that although a thinner film facilitates fusing, its thermal stability must be considered as thinner films are more susceptible to curl after the fusing process.

Table 4. L*, a*, and b* values of two different image coatings as a function of substrate thickness imaged on a color laser printer.

Substrate Thickness	L* value		a* value		b* value	
	Image Coat #1	Image Coat #2	Image Coat #1	Image Coat #2	Image Coat #1	Image Coat #2
4 mil	76.2	71.4	-12.1	-11.3	39.6	38.3
5 mil	65.3	60.4	-10.1	-10.1	35.0	30.9
7 mil	43.3	43.2	-5.7	-4.5	19.5	14.4

The anti-static properties of the color laser printing media are essential for feeding reliability and handability. Because of the high fusing temperatures used in commercial color laser printers ranging from 150-200 C, film media usually exhibit considerable amounts of static charge after imaging which make it difficult to jog the imaged sheets. Table 5 compares the changes in surface physical properties of two color laser transparency media before and after imaging on a color laser printer.

Table 5. Surface frictional and electrical properties of two color laser transparency samples before and after imaging in a color laser printer.

Property	Sample A		Sample B	
	Un-imaged	Imaged	Un-imaged	Imaged
COSF	0.32	0.51	0.33	0.50
COKF	0.25	0.38	0.27	0.38
Log SR (Image side)	11.0	14	10.8	12.1
Log SR (Back side)	10.8	10.9	10.7	10.9

We can see that the values of the coefficients of static friction (COSF) and the coefficients of kinetic friction (COKF) all exhibited over 50% increases due to the toner layer. The values of Log surface resistivity (SR) generally will also go up after imaging. By modifying the coating surface properties, we were able to reduce the Surface Resistivity values by 2 decades (Sample B). However, the coefficients of friction data of the two samples were about the same.

Toner adhesion is another important design parameter for color and monochrome electrophotographic media. Generally speaking, toner adhesion is affected by various factors including fusing temperature, dwell time, resin type and its glass transition temperature (T_g), pigment load, properties of coating additives, and coating processing conditions. Higher fusing temperature and longer dwell time enhance the toner adhesion. Low T_g toner receptive coatings usually give better toner adhesion properties than the high T_g ones. The disadvantages of low T_g polymeric coatings include problems of poor blocking resistance, high values of coefficients of frictions(C.O.F) and poor thermal stability. One way to overcome these advantages is by using organic or inorganic pigment fillers to impart anti-blocking and slip properties. The load level of inorganic/organic pigments in the coating formulation should be optimized for anti-blocking, slip and toner adhesion properties. Another way is to blend low and high T_g polymers to form a hard/soft polymer matrix. The use of other coating additives should also be at the minimum requirement level to achieve the specific performance requirements without sacrificing of the toner adhesion properties. Design of Experiment (DOE) is a very useful tool for the optimization of coating formulations and processing conditions.

Summary

The imaging qualities of color laser printing media are strongly affected by the physical and chemical properties of toners, coatings and their interactions. The compatibility of the toner receptive coating with the toner resins is a key in achieving high imaging qualities. Smaller toner particle size and thinner substrate are found to facilitate the fusing process. Finally, the optimization and control of the anti-static property of the toner receptive coatings are important for making high performance color laser printing/coping media.

Acknowledgments

Helpful discussions with Dr. Steve Sargeant and Dr. Bob Conforti are greatly appreciated. The author also wish to thank the sponsorship of Arkwright, Incorporated to this work.

References

1. P. Gregory, *Rev. Prog. Coloration* 24, 1, (1994)
2. J. C. Song, B. A. Lyon, R. A. Beneven to, E. C. Tien, *Proceeding of the IS&T's NIP-13: 1997 International Conference on Digital Printing,* Seattle, Washington, pp. 403-405, (1997).

Biography

J. C. Song received his B.S. in Chemistry in 1982 and his M.S. in Material Science and 1985, both from Shandong University, Jinan, China. He received his Ph.D. in Polymer Chemistry from the University of Connecticut at Storrs in 1993 and was subsequently a Postdoctoral Fellow at the Bowling Green State University. He joined Arkwright Inc. in 1994 and currently he is a Senior Chemist/Project Manager, working on product research and development of coatings for digital imaging applications.

E-mail: jc_song/arkwright@arkwright-ri.com