Effects of Paper Properties on Liquid Toner Transfer

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Abstract

Printing on a wide range of papers (and other substrates) remains a challenge for liquid toner electrophotography. The two main print quality defects produced during transfer are smear and/or microvoids. In this paper we provide causal trees for the origins of these two defects. We focus on the interactions of paper properties with image wetness in causing or eliminating these defects. And we describe the effects of paper coating in eliminating print quality defects by changing paper roughness and porosity.

Background

As non-impact printing spreads from the office to home use and to commercial printing, substrate range becomes more important. Especially at the high end, customers demand printing on essentially all substrates. Liquid toner electrophotography provides some advantages over other non-impact printing methods: high speed, high resolution, and thin image layers. But complex paper-carrier interactions during transfer typically cause smear and/or microvoids. It may be possible to avoid fluid effects by using intermediate transfer and completely drying the image before final transfer. This would be more complex and expensive than direct transfer from photoreceptor to substrate. In this paper we analyze the interactions of paper porosity and roughness with process speed and image wetness.

Simms et al.[1] analyzed transfer in the high speed ELECTROPRESS®. They defined microvoids as "small areas of the transferred image where there is no toner present," and found that microvoids increased as image mass/area decreased, or as image % toner solids increased, or as paper Sheffield roughness increased. They explained microvoids by the inability of the qE transfer force to overcome surface tension at the interface between the image and a small air bubble trapped in the transfer zone. A related patent[2] shows that transfer to a porous substrate can be improved by treating with a fluorinated hydrocarbon to reduce penetration of the carrier into the substrate. In an earlier patent[3] Saito and Kubu found that transfer efficiency decreased as paper oil absorbency increased. They coated absorbent papers with aqueous dispersions of fillers, then calendered the paper. This decreased oil absorbency and increased transfer efficiency.

Reference 1 also attributed a backward smearing of the transferred image to hydrodynamic shear of weakly held particles at the top of the toner image layer. They found no correlation of this smear (which they called transfer drag) to paper properties.

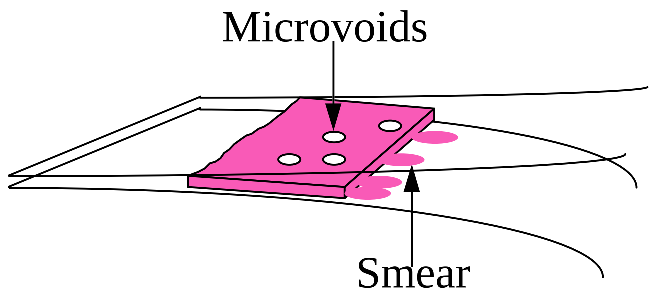

Figure 1. Microvoids and smear introduced in transfer.

Experimental Method

We developed liquid toner images onto a permanent electrostatic master[4] and transferred the images to a range of papers at 10 inches/second. Our toner was an experimental lab preparation with approximately 2 micron diameter particles suspended in Exxon Isopar® M carrier. Our development method applied the liquid toner to the electrostatic master with slot coater, used a biased forward-turning development roll to control the development field between roll and master, then removed some of the excess carrier liquid with a reverse-turning metering roll. We were able to control DMA (developed mass per unit area) between about 0.1 mg/cm^2 and 0.4 mg/cm^2. Carryout was measured by scraping a known background area into a preweighed pan and, then reweighing. Isopar® M facilitates this process because it evaporates very slowly. We were able to increase carryout by decreasing the metering roll speed to values below that which produced the minimum carryout.[5] We were able to decrease the carryout entering transfer by conditioning the image between development and transfer.[6] Image conditioning removes some Isopar® from the image, increases the weight fraction of toner solids in the image layer to about 15%, and also compacts the image. This compaction helps stabilize the image against smear. We were able to control carryout in the range of 0-5 mg/cm^2.

Figure 2 shows the average surface roughness (in microns) and the Gurley porosity (in seconds, with smaller values at higher porosities) for the range of substrates to which we transferred. The two properties are strongly correlated since paper surface smoothness is often achieved by adding surface fillers that also reduce porosity. Xerox 4024 is the standard "plain paper" for xerographic copiers and printers. Xerox Image Series LX is a smoother paper often selected for higher quality color printing. Kromekote and Lustrogloss are heavy, filled papers which are very smooth and nonabsorbent. Xerocover is filled and less porous than 4024, but not less rough. Hammermill and Springhill are similar to 4024. Nekoosa Bond is the roughest paper in the set and showed the most microvoids.

After transfer we rated the severity of microvoids and smear from 0 (no detectable defect) to 10 (very severe).

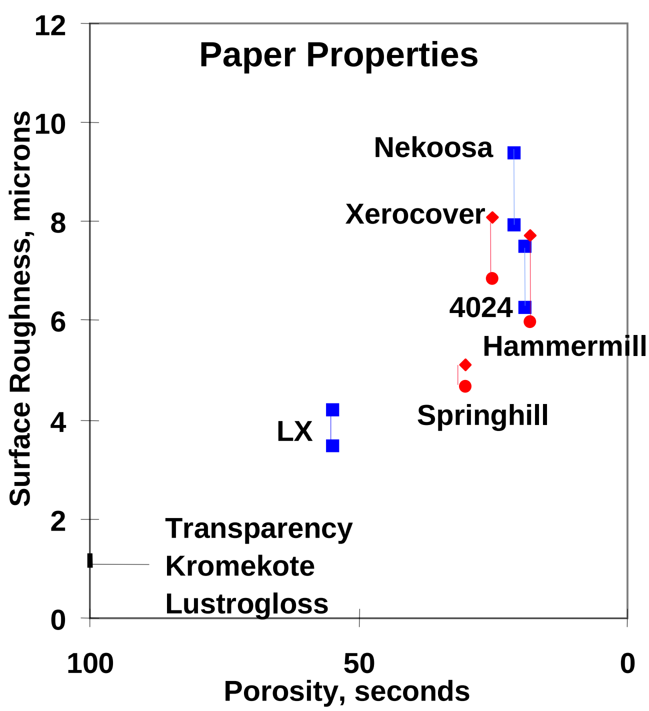

Figure 2. Surface roughness and porosity of 9 substrates.

Experimental Results

An initial survey confirmed that microvoids are not normally a problem for images transferred to smooth substrates and that image conditioning can eliminate smear, even on smooth substrates. We next investigated the effect of DMA and found that increasing DMA did little to decrease microvoids but that blotting increased microvoids.

Table I. Transfer of blotted images to smooth substrates.

Substrate	Smear	Microvoids
Transparency	0	0
Lustrogloss	0	0
Image Series LX	0	0

Table II. Effects of DMA and blotting on microvoids.

Paper	DMA (mg/cm2	Blotted?	Microvoid Level
LX	0.133	Yes	3
LX	0.133	No	1
LX	0.190	No	1
4024	0.122	Yes	5
4024	0.124	No	2
4024	0.190	No	1
4024	0.210	Yes	2
4024	0.310	No	1
4024	0.310	Yes	6

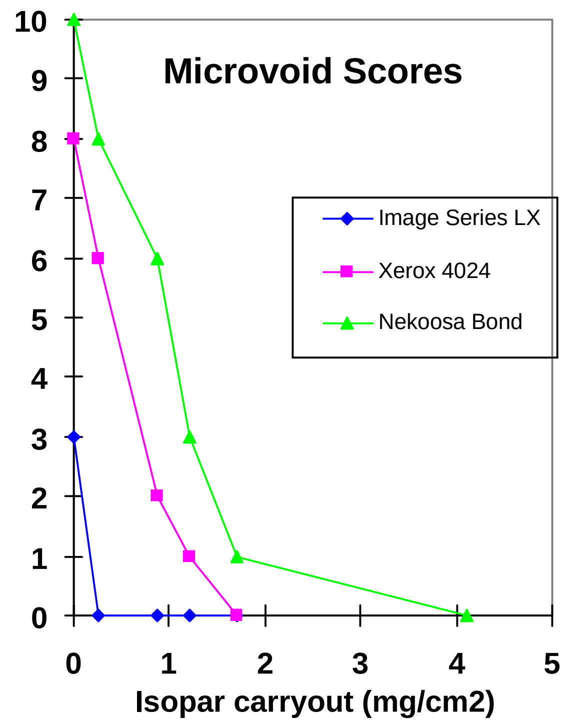

Figure 3. Effects of paper and carryout on microvoids.

Figures 3 and 4 show the effects of Isopar carryout on microvoids and smear for three papers. Image conditioning to below 1 mg/cm^2 carryout can always reduce image wetness and eliminate smear. The smoother the paper, the lower the carryout must be to avoid smear. Unfortunately, rougher and more porous papers still have to have fairly low levels of carryout to avoid smear. And, as paper roughness and porosity increase, image wetness must increase to avoid microvoids. Taken together, Figures 3 and 4 show that controlling carryout to 0.3-0.9 mg/cm^2 can produce defect-free transfer to LX paper. But the two figures show no level of carryout that eliminates both smear and microvoids in transfer to 4024 and Nekoosa papers.

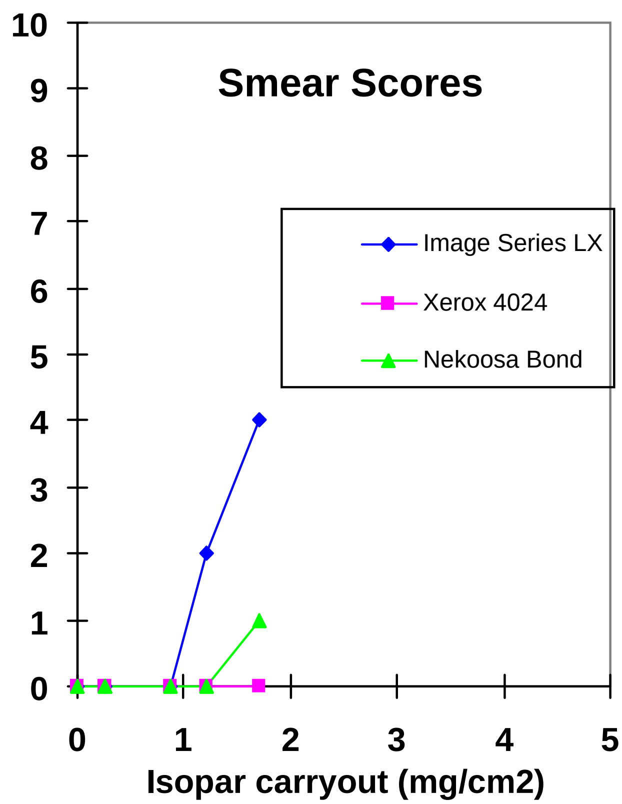

Figure 4. Effects of paper and carryout on smear.

Effects of Paper Coatings

A possible solution to the problem of rough papers is to coat the papers, as in [3], with a material that reduces carrier penetration into the paper, or that fills surface irregularities and increases smoothness. We were especially looking for a material that would reduce porosity without the "look and feel" of the paper. Such a coating would allow us to separate the effects of porosity from the effects of surface roughness. Such a coating might even be built into a marking engine.

We first tried a 10% solution of Nylon (Elvanude 8063) in 90/10 MeOH/1-propanol coated on Xerox 4024 paper with mild pressure. The paper was air dried for one hour before being used. The transferred image in the uncoated area showed microvoid level 6. The image in the coated area showed microvoid level 2. While it was possible to dry this material without causing paper cockle, it is generally difficult to add and then remove water from paper without causing distortion of the paper fibers.

We next tried a variety of commercial products with high solids and a generally creamy texture. These were coated onto Xerox 4024 paper by light hand rubbing. No heating or evaporation was performed prior to use. Images were developed and conditioned as before, then transferred to the coated papers. Table III shows two cases, Carnuba Wax and Chapstick, which eliminated microvoids without changing the appearance or texture of the paper.

Table III. Effects of coatings on 4024 paper.

Coating Material	Microvoids	Effects on Paper
None (baseline)	6	
Glue Stick	3	Coating turns brown in fuser
Rain X	3	Yellows the paper
Armorall Pro	4	Feels like rag paper
Parafin & Naptha	0	Makes paper translucent
Carnuba Furniture Wax	0	No change in look or feel
Chapstick	0	No change in look or feel

Conclusions

Figures 5 and 6 summarize our findings in the form of causal trees.

Air bubbles in the transfer zone cause microvoids. Carrier absorption into the substrate produces air bubbles. Both paper porosity and roughness contribute to these air bubbles. Insufficient carrier in the developed image increases air bubbles. In addition to these factors, longer contact time in the transfer zone will also increase carrier absorption into the substrate. Slower process speeds will increase transfer time. This is one reason the ELECTROPRESS®, transferring at 50-60 inches/second, is able to print on rougher stocks than slower speed copiers like the Savin 870.

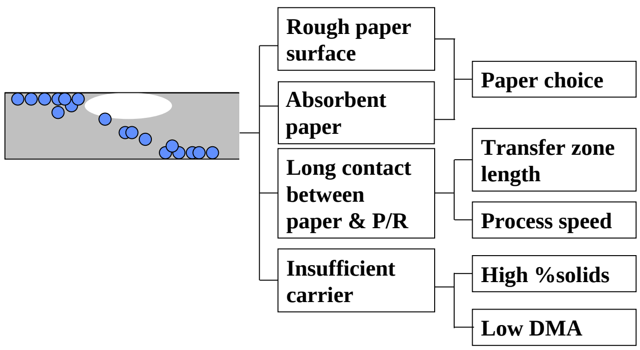

Figure 5. Causes leading to microvoids.

When high speed couples with high image wetness and smooth, non-absorbent paper, the image is sheared in transfer, producing smear. Toner formulation[7] as well as DMA and image solids content can contribute to image softness or hardness. The transfer geometry can influence the shear forces through pressure on the back of the paper and the paper entrance angle.

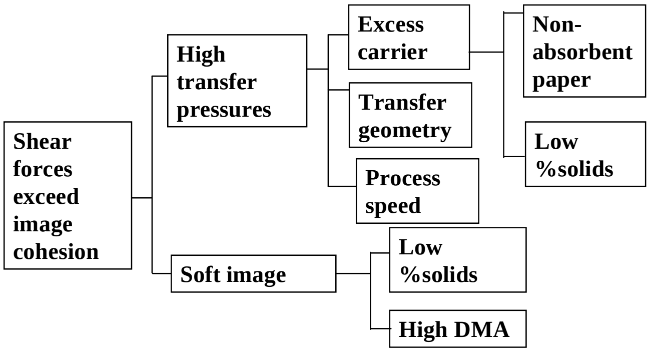

Figure 6. Causes leading to smear.

References

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Biographies

Ed Caruthers has a Ph.D. in theoretical Solid State Physics from the University of Texas at Austin, 1973. He has worked in liquid electrophotography at DuPont (1985-1987), DX Imaging (1987-1991), AM Graphics (1991-1992) and Xerox (1993-present). Previous papers at IS&T's 8th, 10th, and 14th NIP meetings concerned liquid toner formulation, toner charging mechanisms, toner replenishment, electrophoretic development, metering, transfer and image quality.

Weizhong Zhao received her Ph. D. in Materials Science and Engineering from SUNY at Stony Brook in 1994. She did postdoctoral work on a polymer-colloid system at Exxon Research and Engineering Company. She has worked on liquid electrophotography since joining Xerox in 1995. Her research interests include liquid-xerographic development and transfer, liquid toner ion charging mechanisms and liquid toner design.