Liquid Toner Transfix Print Process

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Abstract

An intermediate belt architecture and a transfix process are in use for liquid toner electrophotography systems. Here we describe the impact of transfix temperature and carrier content in the toned image layer on transfer efficiency and fix level. Temperature has to be high enough to melt the toner. Increasing carrier concentration lowers the toner melting point and increases image fix to paper. But high carrier concentration decreases the cohesive strength of the toner layer and causes incomplete transfer and toner penetration into uncoated paper.

Introduction

Liquid toner electrophotograpy (LTE) has many potential advantages over dry toner electrophotography, primarily deriving from the smaller particle size that a liquid carrier enables.[1] There are other advantages of the liquid nature of LTE, e.g., blending of toners to form custom colors.[2] LTE technology has gravitated to a printing process that initially develops an image on a photoreceptor, transfers the image to an intermediate member, and then transfers and fixes the image to the final substrate in a single step (transfix). While this adds complexity to the system it has several advantages, for example:

1) Minimizes liquid carrier in final substrate
2) Reduces impact of substrate on electrostatic transfer
3) Transfers image as a film

It is interesting to note that the advantages of intermediate transfer for xerographic systems were patented by Chester Carlson over 40 years ago.[3]

Example LTE Transfix Systems

Examples of LTE transfix systems are shown in Figures 1 and 2. In Figure 1 the HP/Indigo system,[4] which has been commercialized and is serving the color digital production market, is displayed. This printing engine performs the following operations sequentially: 1) Electrostatic charging of the photoreceptor (designated PIP in Figure 1); 2) Exposure to form a latent image on the photoreceptor; 3) Inking the photoreceptor using a development roller in a process called BID (Binary Ink Development); 4) Electrostatic transfer of the image to the offset blanket; 5) Heating the image on the blanket which serves to reduce the hydrocarbon carrier level in the image and to partially melt the toner particles; 6) Transfixing of the heated ink image to the substrate. This process is repeated for each color, i.e., it is a multi-pass print process. In Figure 2 the Samsung system,[5] which has been the subject of numerous patents since 1999, is displayed. In contrast to the HP/Indigo system the Samsung print process is single pass with the four color image developed on the photoreceptor and transferred in one step to a transfer roll and then transfixed to the final substrate. Another difference between the HP/Indigo and Samsung processes is that in the latter the transfer to the transfer roll is not electrostatic but is driven by the higher surface energy of the transfer roll relative to the surface energy of the photoreceptor.

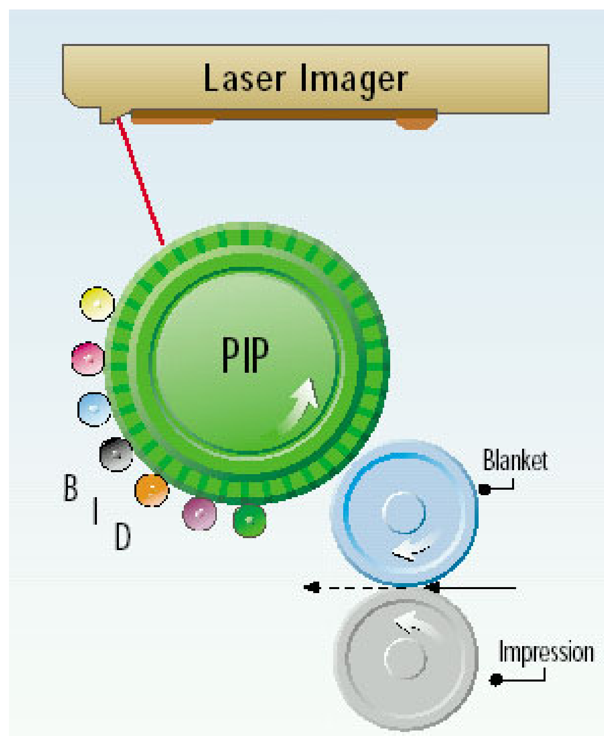

Figure 1. HP/Indigo LTE transfix system

LTE Transfix Experiments

We report the results of transfix latitude experiments carried out using a simple model system. (1) We prepared LTE dispersions[6] in mixtures of Norpar 15 (low vapor pressure) and Isopar L (high vapor pressure). (2) We coated this mixture onto an intermediate transfer belt (ITB) at thicknesses equivalent to 0.2 mg/cm^2 of toner solids. We then evaporated the Isopar at 70-80°C, leaving toner particles in Norpar carrier. (By varying the Isopar/Norpar ratio we could achieve different final ratios of carrier to toner while always having enough carrier for good initial dispersion of the toner particles.) (3) We heated the toner-carrier layer on the ITB in an oven. (4) We transfixed the heated toner-carrier layer to the final (unheated) substrate using two unheated pressure rolls. The control variables are (a) the weight% Norpar after the Isopar is evaporated, (b) the transfix temperature. The output variables are completeness of transfer from the ITB to paper and the permanence or fix of the image to paper.

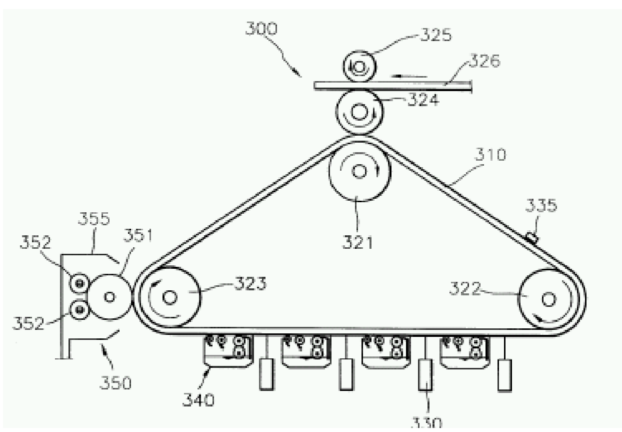

Figure 2. Samsung LTE transfix system

Preliminary tests showed that pressures of 100-500 psi provided good ITB-paper conformance for a range of papers and a range of ITBs from 2-4 mils thick and from 40-70 ShoreA durometer. In the rest of this section we will describe transfix at 10 in/sec and 250 psi. The nip width between the rolls is 9.5 mm and the dwell time in the nip is 37 msec. The ITB is 0.003" thick Viton®, a fluoroelastomer with a low surface energy that is often used as a surface coating for fuser rolls, to reduce toner adhesion to the fuser roll. Xerox Image Series LX paper is the final substrate.

Experimental Results – The Latitude Space for Viton ITB

There are many parallels between the requirements for good dry toner electrophotographic fusing and those for good LTE transfix. The LTE ITB, like the surface of the fuser roll, should be an elastomer and the transfix pressure, like the fusing pressure, should be high enough so that the elastomer conforms to the paper surface irregularities and all parts of the toned image layer contact the paper surface. The basic latitude space for transfix from Viton is shown in Figure 3. The operating window is from about 35-60 weight % carrier and temperatures greater than about 90°C. In the rest of this section we describe the basic processes occurring in transfix and the reasons for the process space boundaries.

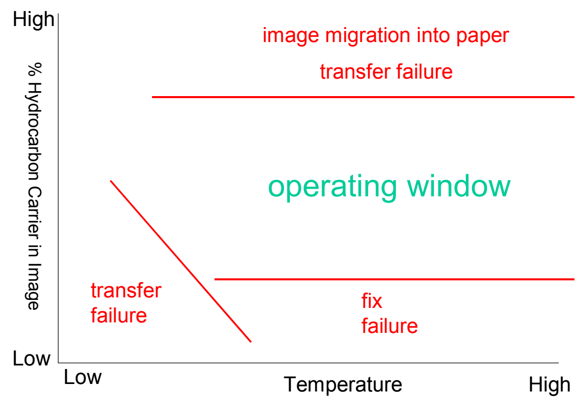

Figure 3. Transfix latitude window

Transfer Efficiency

Transfer efficiency is controlled by the force balance at transfix nip exit. If the toner layer's adhesion to the ITB is lower than the toner layer's internal cohesion and is also lower than the toner layer's adhesion to the paper, then transfer will be 100%. Otherwise, transfer will be incomplete. The incomplete transfer of images with more than about 60 wt% Norpar is caused by image layer splitting. High carrier content reduces image cohesion to a value less than toner adhesion to the ITB. As the paper separates from the ITB at the transfix nip exit, the liquid toner layer splits somewhere in the middle and a fraction of the layer remains adhered to the ITB. For example, for images containing 70% Norpar 15 we have observed 85% transfer for temperatures of 80-120°C. That is, 15% of the toner layer remains on the ITB. Figure 4 shows photomicrographs of toner images after transfix to paper. The increasing layer thickness from 7-40% Norpar is consistent with our picture of toner and carrier melting together to form a layer whose thickness increases as the carrier content increases. Melting of this layer is necessary for the layer to conform and adhere to the paper. But 60% Norpar causes the image layer viscosity to become so low that toner has migrated into the paper.

Image Fix

We measured fix by the change in reflective optical density after abrasion with an eraser. The definition is,

$$Fix = OD(abraded) / OD(original) \qquad (1)$$

By measurements on offset lithographic images in a number of national publications, we have established a requirement that fix be greater than 0.5 to be acceptable. Figure 5 shows that fix increases approximately linearly as Norpar in the image increases, even beyond the point where image transfer is incomplete (~60%). For temperature above about 90^{o}C, there is little effect on fix.

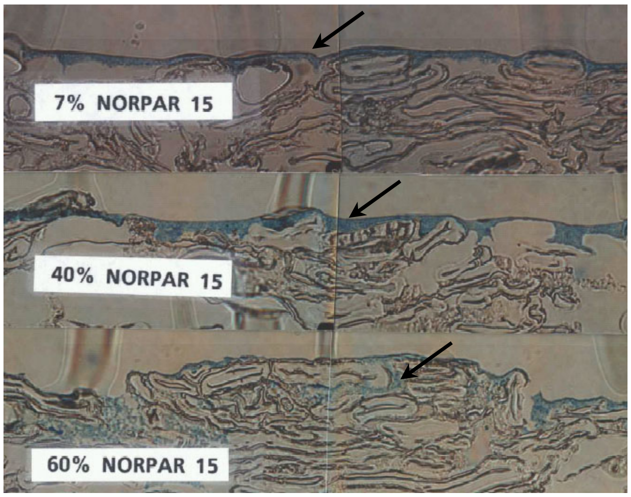

Figure 4. Micrographs of Toner After Transfix to Paper

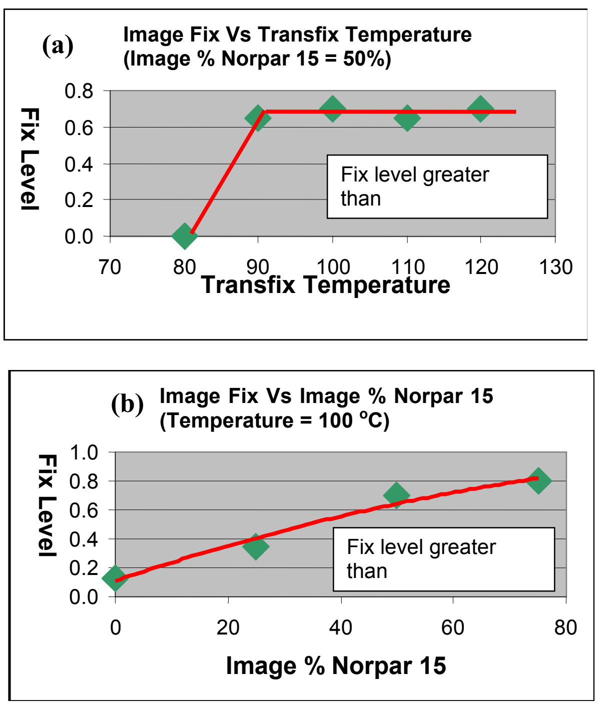

Figure 5. (a) Fix vs. transfix temperature at 50% Norpar 15. (b) Fix vs. Wt% Norpar 15 at temperature =100^{o}C.

Conclusions

For the model system that we have studied, we have found the following.

Toner particles must melt in order to transfer completely to paper.

Carrier suppresses the toner's melting point and enables lower temperature fusing. When toner melts it takes up carrier, increasing the ultimate image layer thickness. More than about 60% carrier in the image layer reduces the layer's viscosity to a point where image splitting occurs and results in incomplete transfer. Less than about 35% carrier weakens toner layer adhesion to paper and produces unacceptably low fix. Our system is only a model for transfix. In other systems the kinetics of heating, melting and carrier evaporation may be very different. This could lead to significantly different boundaries for the control variables.

References

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Biographies

Ed Caruthers has a Ph.D. in theoretical solid state physics from the University of Texas, Austin, 1973. He has worked in liquid toner electrophotography at DuPont, DX Imaging, AM Graphics and Xerox Corporation. Previous papers at IS&T's NIP meetings concerned liquid toner formulation, charging mechanisms, replenishment and custom color; the development, metering and transfer subsystems; and image quality. He has also worked in catalysis, medical imaging and xerographic components.

Jim Larson is a Manager in the Joseph C. Wilson Center of the Xerox Innovation Group. He received a Ph.D. in Chemistry from the University of Washington in 1980. Two years later, after a postdoctoral appointment at the University of Chicago, he joined the DuPont Company. In 1984 he became part of a small DuPont team working on liquid electrostatic toner technology. By 1987 this effort grew into DX Imaging, a partnership company parented by DuPont and Xerox, of which Dr. Larson was a founding member. He joined Xerox in 1991 and continued work on liquid toner technology. He holds 60 issued U.S. patents and has authored 33 technical publications.

John Berkes recieved a PhD in Solid State Science from Penn State in 1968. From 1968 until 2003 he was involved in Xerographic materials and process R&D at the Xerox Corp. in Webster NY. He has 15 journal publications and 40 US Patents. He is currently retired.