Development with Image-wise Charged Toner Layer

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Abstract

Traditionally, xerographic processes utilize toner charged to a single polarity (either positive or negative) in combination with an image-wise electrostatic field to develop a toner image. We present Reverse Charge Printing (RCP), a novel image development method and apparatus, whereby an image-wise charged toner layer along with a DC electrostatic field is used to produce a high quality toner image. The high resolution image-wise toner charging is accomplished by a wide beam ion source such that free mobile ions are introduced in the vicinity of an electrostatic latent image coated with a layer of developing material. The latent image causes the free mobile ions to flow in an image-wise stream corresponding to the latent image, which, in turn, leads to image-wise charging of the toner layer through ion bombardment, such that the toner layer itself becomes the latent image carrier. The latent image carrying toner layer is subsequently developed and transferred to a copy substrate to produce an output document. A liquid toner system embodiment of this process, Electro-Offset, is presented. This new electrostatic printing system can potentially enable an offset-like electrostatic printing system with characteristics such as very high resolution, high process speed as well as excellent extensibility to greater document width.

Electro-Offset, an Offset-like Electrostatic Printing System

Lithographic offset printing has been the most dominating printing technology for decades due to its excellent quality, high speed, great document width, broad substrate range and low cost. On the other hand, electrostatic printing has enjoyed the short term printing advantage. A printing technology with the combined advantages has been the goal of many research activities in the past decade.

In this presentation, we are going to demonstrate Electro-Offset, an electrostatic based printing technology, that can potentially achieve offset-like print characteristics while maintain the advantage of electrostatic printing with page to page content variation.

Figure 1 illustrates the commonality between the architectures of an offset printing press and our new Electro-Offset. The main components in terms of offset printing are the inking system, the plate and the blanket. The corresponding components in our new electrostatic system are the cake formation system, the imaging unit (photoreceptor, P/R) and the image bearing member (IBM). Similar to the inking system of a lithographic press, the cake formation system will put down a thin layer of liquid toner on the imaging unit (P/R). After going through the electrostatic process known as Reverse Charge Printing (RCP), which we will describe in detail in the next section, this toner layer will split into image portions and background portions at the contact between the P/R and the image bearing member. The toner image formed on the image bearing member will be subsequently transferred/transfused onto a substrate.

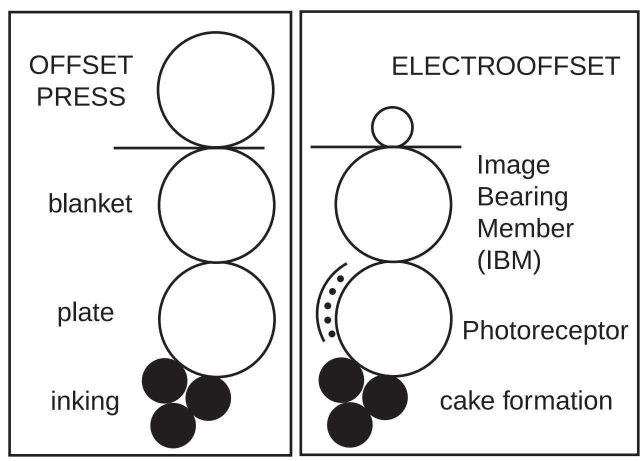

Figure 1. Offset Press and Electro-Offset

The Electro-Offset printing system as illustrated in Figure 1 has many subsystem and system options and associated issues and challenges. The focus of this paper is on the basic Reverse Charge Printing processes that enable and control the image formation at the contact nip between the photoreceptor and the image bearing member.

Basic Process of Reverse Charge Printing

The basic process of the Reverse Charge Printing starts after the cake formation and ends after the development at the photoreceptor-IBM contact nip. In general, a uniform toner layer charged to a single polarity is initially situated on an electrostatic latent image. A recharging device will deliver ions with charge polarity that is opposite to that of the toner charge to selected areas according to the latent image. These oppositely charged ions will be captured by the toner and consequently reverse the toner charge in these areas. This recharge process effectively converts the latent image on the P/R into an image-wise charge pattern in the toner layer. Once the image-wise charged toner layer has been formed, a development system consisting of a single bias between two electrodes can separate image from background according to the toner charge polarity.

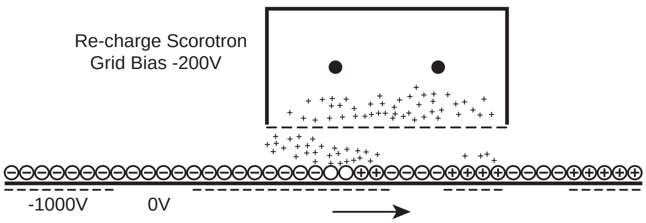

Figure 2. Re-charge Process of Reverse Charge Printing (RCP)

The Input: Uniform Layer of Toner on a Latent Image

One required input is the latent image. As it is commonly achieved through exposure of a photoconductive material. Other methods can also be used. The latent image is the driving force for the next re-charge step.

Another important input is the toner layer. RCP development requires a semi-rigid paste-like toner layer (a "cake" layer) in order to prevent toner migration under the influence of the fringe fields of the latent image and enable clean separation of the image areas from non-image areas in the development step. The desired input is a high solid content (20~40%) thin (~5μm) layer of toner cake on the photoreceptor drum with an electrostatic latent image formed thereon. As we will discuss in later steps, the RCP development as currently practiced is essentially a binary system. Ideally the cake on the photoreceptor in the development nip is either completely transferred (developed) to the image-bearing member in the image areas or left behind on the photoreceptor in the background areas. Ultimately the toner mass on the paper is controlled by the cake formation and the desired toner mass per unit area should be around $0.1 mg/cm^2$.

In addition, the uniformity of the cake is directly linked to image quality metrics such as macro-uniformity and the visual acceptability of the images on paper. Non-uniformities created in the cake will propagate through the rest of the marking process and eventually into the print.

The system implementation for generating a latent image and a uniform toner cake has basically two options. One option is to create a uniform cake on the photoreceptor and expose the photoreceptor in a subsequent step. Either exposure through the toner layer or exposure from the backside of the photoreceptor is acceptable. The second option is to create a latent image on a clean photoreceptor and load a toner cake thereafter. One concern for this second embodiment is that the latent image on the photoreceptor will potentially prevent the uniform loading of the toner cake. Another concern is the potential damage to the latent image during the cake loading process. However, it has been demonstrated that a cake can be uniformly loaded onto a latent image electrostatically with little damage to the latent image.

Image-wise Toner Charge: Re-charge

Re-charge is the heart of the RCP printing process. The function of recharge is to image-wise reverse the charge of an originally uniformly charged toner cake according to the underlying latent electrostatic image.

The input to recharge is ideally a uniformly charged 5 μm thick cake of 20-25 percent toner solids overlying a latent electrostatic image on the photoreceptor. A re-charging device, as a well known scorotron device, is provided for introducing free mobile ions in the vicinity of the charged latent image, to facilitate the formation of an image-wise ion stream extending from the source to the latent image on the surface of the image bearing member. Since the re-charging device has to reverse the toner charge, it is necessary that it can provide ions with charge polarity opposite to the toner charge. In addition, the flow of the ions is important since we want the oppositely charged ions to go only to the desired areas.

For illustration purposes, photoreceptor potentials of 0V and –1000V are used for the charged and discharged areas of a photoreceptor in Figure 2. The flow of ions to the latent image is controlled by the scorotron screen bias or more precisely by the field between the screen and photoreceptor. Qualitatively, when the surface potential is more negative than the screen potential a field exists in the gap such positive corona ions are attracted to the surface. As a consequence ion charging of the cake occurs as the corona ions impinge on the cake layer. When the bias of the screen of the re-charge scorotron is set at -200V, positive ions are driven towards the area of the P/R with –1000V potential causing positive charging of the toner layer. On the contrary, positive ions are repelled from the areas with 0V surface potential and the toner in theses areas maintain their negative charge.

It has been illustrated in Figure 2 that the free flowing ions generated by the re-charge device are captured by toner layer in a manner corresponding to the latent image on the imaging member, causing image-wise charging of the toner layer, thereby creating a secondary latent image within the toner layer that is charged opposite in charge polarity to the charge of the original latent image. Under optimum conditions, the charge associated with the original latent image will be captured and converted into the secondary latent image in the toner layer such that the original electrostatic latent image is substantially or completely dissipated into the toner layer.

In addition to the direction of ion flow towards the toner layer, the amount of ions bombarding the toner to cause toner charge reversal is important for image quality. Greater contrast in terms of toner charge density difference between image and background areas is desired. In general, this contrast should be smaller than the original photoreceptor charge contrast. Thus, a high contrast photoreceptor latent image is desired. It has been experimentally demonstrated that a photoreceptor charge contrast of 100nC/cm^2 is desired for a toner layer of 0.1 mg/cm^2 with the toner material we tested.

Another factor in the re-charging process is the fidelity of image fine details. It has been demonstrated that very high resolution (better than 20μm dots) can be achieved with a simple scorotron.

Image-Background Separation: Development

Development is the subsystem that follows the recharge in the imaging sequence. It receives a uniform but image-wisely charged toner layer as its input and develops an image directly onto an image bearing member (IBM) while leaving the toner corresponding to the background area on the original photoreceptor.

RCP development subsystem involves the photoreceptor, the image bearing member and a layer of image-wisely charged toner cake. In addition, pressure and electrical bias are implemented to impose physical contact and electrical forces for toner separation. The image bearing member is pressed against the photoreceptor to form the contact nip where the image bearing member and the photoreceptor come into contact and then move away from each other.

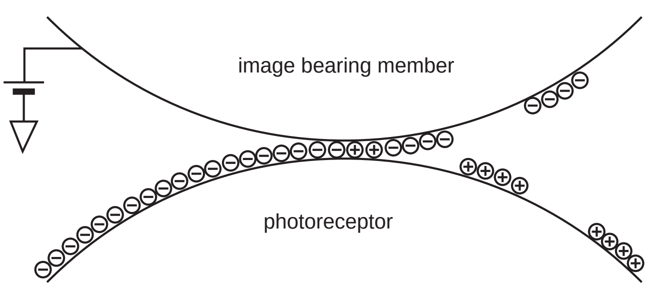

Figure 3. Development Process of Reverse Charge Printing (RCP)

The basic physics of the RCP development process is similar to that of a traditional electrostatic transfer. The development process can be generally divided into three phases (or zones), namely nip entrance, nip contact and nip exit. At the entrance, carrier fluid within the cake must wet both surfaces and seal the nip entrance to prevent air from entering. If the cake is too dry, trapped air will cause white spot in the solid area of the image. On the other hand, if the cake is too wet, the entrance meniscus and the field will disturb the cake structure substantially and the fluidized charged toner will move under hydrodynamic shear flow and produce a smeared image. In the nip, strong electric field forces the toner cake to migrate and compact and form a weak release layer on the back. At the exit, a strong electric field keeps the toner on one surface while the fluid release layer splits to accomplish the image development.

The primary functional requirement of the development subsystem is the application of a strong electrostatic field. Image-wisely charged toner layer is separated into image and background portions due to the image-wise force contrast created by the DC field and the toner charge contrast. To achieved strong field that is beyond the Pachen limit, field tailoring is typically used. Various field tailoring schemes known in traditional electrostatic transfer systems can be used. The field tailoring scheme with a single roll requires that the image bearing member have a well controlled resistivity. To accommodate a broad range of material conductivity, multiple electrodes and long nip contact can be implemented. Based on our preliminary study, field tailoring is not necessarily required to achieve the desired field strength. A conductive image bearing member and a photoreceptor with small dielectric thickness can produce strong field in the nip without entrance air breakdown.

The bias polarity on the image bearing member will determine which portion of the toner layer become the image. In principle, either positive or negative bias can be used and two complementary images will be obtained. However, the quality of the images obtained with opposite biases will be different. In general, it is preferred that the toner of the original charge polarity is used as the image. One reason for this choice is the better background. During the recharge, it is impractical to prevent any wrong sign ions from contaminating the original toner in the discharged area, which will cause background problem if the positive toner is chosen as the image. Another reason for this choice is the better binary development that can be achieved with positive bias on the image bearing member.

Another critical functional requirement on the development subsystem is the mechanical pressure at the nip. It is related the rheological strength of the cake and the solid content of the cake. In order to maintain the fluid meniscus at the entrance, higher nip pressure and lower solid content of the cake are desired. However, lower nip pressure and higher solid content of the cake will be favored for non-smeared images. When coupled with a certain nip pressure, the existence of a certain window of the solid content of the cake that satisfy both requirements is one of the keys to the system latitude. The current study has shown that the development system has the latitude space for proper pressure and solid content variations.

Clean background is one the most critical challenges for RCP development. Compared to traditional development systems, it is clear that a clean background must be very challenging because the background area is in good contact with a high solid content toner layer in the development nip. Preliminary studies suggest that the ink material is the most important factor to eliminate background. Wrong sign toner should be prevented. Charge injecting photoreceptor can be another cause of background because the strong field in the development nip will cause charge injection and produce wrong sign toners. Process variables also have some effect on the background control. Pre-wetted image bearing member, cohesive toner cake (high solid content) and short development nip, for example, have shown developments with better background.

Image resolution is generally believed to be one of the strong points of this development process. High resolution capability of the development process is one of the consequences of a thin cake layer. It has been demonstrated that 20μ dots (Figure 4) and 30μ shadow holes can be reproduced.

High speed capability is another advantage of this process. The belief is based on an analogy to liquid toner image transfer and the demonstration of some bench experiments (up to 40 in./s). Modeling work confirmed the speed capability for solid area and background.

Pressure contact of the development system is yet another advantage of the RCP system. It eliminates precision gap control of traditional electrostatic developments and improves system performance and reliability.

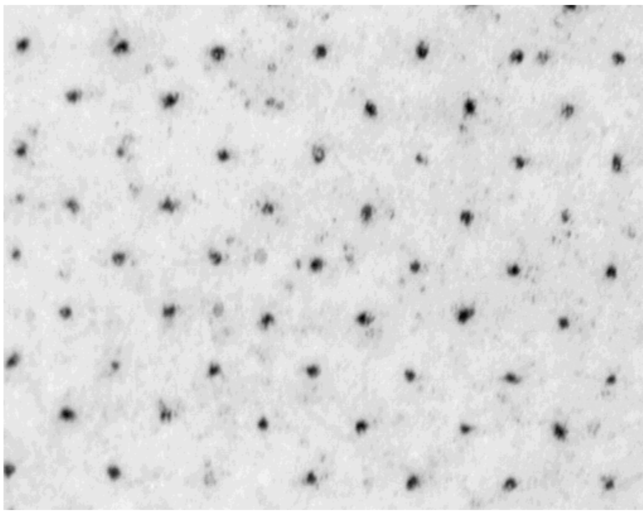

Figure 4. RCP reproduction of 20μm dots

Conclusion

We have shown the basic process of a novel electrostatic development process known as Reverse Charge Printing (RCP). It has demonstrated many good attributes such as high speed and high resolution, and it is also believed to possess more promises. In addition to the short term printing advantage of an electrostatic printing system and the advantages directly provided by RCP process, the Electro-Offset system can potentially achieve many other good characteristics currently enjoyed by offset printing press. Broad range of substrate can be achieved through the implementation of transfuse in the Electro-Offset system. Greater substrate width can be enabled by the pressure contact development nip. Custom color capability has been demonstrated by using the binary development option with selected ink materials. The carrier fluid used in the liquid toner is more environmental friendly than most of the offset inks. Low print cost can be achieved through the maturing of the technology, low cost materials, and improved reliability of the system and subsystems.

References

1. Chu-heng Liu & Weizhong Zhao, *US Patent* 5826147 (1998)

Biography

Chu-heng Liu received his Ph.D. degree in physics from the University of Chicago in 1993. After two-year postdoctoral work on polymer solutions at Exxon Corporate Research, joined Xerox in 1995 with background in granular materials and complex fluids. Research interests since joining Xerox cover a broad range of xerographic processes with special focus on development, transfer and liquid toner related processes. He is a member of the IS&T and the American Physical Society.

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