Contact Electrography – A New Electrographic Printing Technology

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Abstract

In order to improve the quality of text and graphic printers in electrophotographic powder marking technologies, the resolution of the imaging subsystem has been increased and the diameter of toner particles has been decreased. We present a new electrographic printing technology called contact electrography, which has the potential for a high image quality without the need for further improvements in toner particle size or image resolution.

Contact electrography works for example with square metal pads on 50 µm centers (500 dpi) fabricated on an insulating layer of a metal cylinder (image cylinder). A write head with a row of electrodes (metal fingers) is in contact with a row of the metal pads of the image cylinder. Voltages are applied to the metal fingers so that the metal pads are charged and an electrostatic latent image is formed during the rotation of the image cylinder. The following steps (development, transfer, fusing, and cleaning) are very similar to conventional electrophotography.

Laboratory systems using this technology have been built and tested. These systems have demonstrated the ability to print for the first time, to our knowledge, in any powder marking system based on electrophotography, both black and white single pixels at 500 dpi, using conventional 9 µm diameter toner. The reasons for this improved image quality have been investigated and an explanation for this result is presented.

Introduction

Besides ink-jet, electrophotography is a well-known and widely used technology for printing. The most commonly used implementation of electrophotographic printers uses a laser or a LED bar as an illumination source and develops the latent image with dry toner. Despite the wide usage of this technology, there are, however, some drawbacks with respect to image quality. For example, output quality of electrophotographic printers has not reached the standard set by offset lithography or gravure printing. One of the important contributors to the lack of output quality in electrophotographic printers is the low or inferior quality of the single pixels. To the knowledge of the authors, it is not possible to print single white pixels and single black pixels in one image in electrophotography with dry toners. A single pixel is the smallest dot that the printer can address. In first order, the pixel size is defined by the spot size of the laser or the spot of a single LED of the LED bar.

Images created with electrophotographic printers typically use bilevel halftoning to create different gray scales [1]. Full color images are produced by superimposing for example 4 colors (black, cyan, magenta, and yellow) on paper. Obviously, a more consistent gray scale for a single color will result in an improved total output quality. In bilevel halftoning typically squares of several pixels, for example a 4×4 array, are organized to form a screening dot of 16 pixels. Within this screening dot a number between zero and all pixels can be either white or black, resulting 16 gray levels for the 4×4 array. Electrophotographic systems use bilevel halftoning because this method produces more consistent gray scales than multilevel halftoning, where the gray level of single pixels is controlled by exposure level. The electrophotographic process is most stable for printing "white" (= zero density) and "black" (= full density), while intermediate states (for example half density) are less stable.[1] Bilevel halftoning avoids intermediate levels and therefore increases gray scale consistency.

In this paper we present a new printing technology called contact electrography, which offers improved quality while still using conventional dry toner. Experimental results on pixel level demonstrate improved image quality and they will be discussed. The theoretical reasons for the improved image quality are outlined.

Contact Electrography - A New Imaging Process

Technology

The well known electrophotographic process works in 6 steps[1]: charging of a photoconductor, imagewise exposure of the photoconductor, development of the latent image with a dry toner, transfer of the toner from the photoconductor to paper, fusing of the toner image to paper, and finally cleaning of the photoconductor.

The new imaging process called contact electrography works very similar, only step 1 and 2 are summarized in one

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step. An image cylinder with micro-capacitors and solid sliding contacts is used instead of a photoconductor, a corona and an optical imaging device.

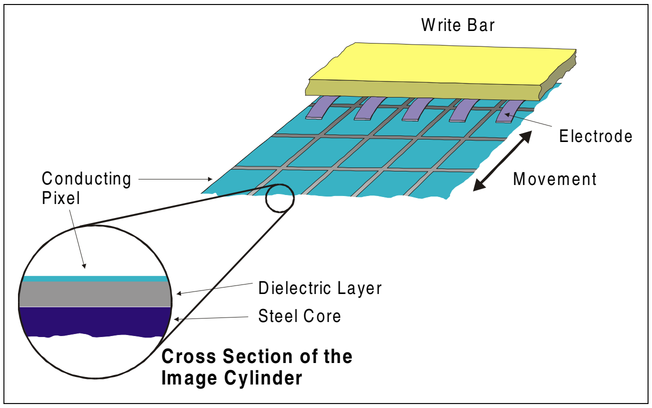

Figure 1. Principle scheme of contact electrography

The simplified schematic drawing in Fig. 1 shows a write bar carrying an array of microscopically small contact springs on an insulating substrate that are physically contacting the image cylinder surface. The surface of the image cylinder is patterned with conductive pads electrically isolated from each other. In the cross section portion of Fig. 1 the composition of the image cylinder surface layers is indicated. The conductive core of the image cylinder is coated with a dielectric layer of 8 µm thickness, which is again covered with a wear-resistant and conductive coating that is structured into square pads. The pads together with the dielectric and the conductive core of the image cylinder create the above-mentioned micro-capacitors. By rotating the image cylinder underneath the sliding contacts and applying definite voltages to the finger electrodes, every single pad will be charged with high precision to a definite potential. The time needed for the charging of the pads can be as low as in the range of 10 nanoseconds. The latent image created on the image cylinder then goes through identical steps as in electrophotography, namely development, transfer, fusing, and finally cleaning of the image cylinder.

Potential Advantages and Challenges

In summary, contact electrography offers the potential for an improved image quality, as well as more reliability and higher speed. However, as with every printing technology, there are also challenges. Here we present a brief discussion of these three key features

Image Quality

The mechanism of contact charging allows nearly perfect control over the pad potential, which is related via the electric field to the optical density of the corresponding pixel after development. Due to the conductive nature of the pads (thereby acting as equipotential planes) an inherent feature of contact electrography is the perfectly constant spatial distribution of the potential at the pad surface within the dimensions of the pad.

These are basic differences in comparison to other electrographic or electrophotographic imaging processes using a dielectric surface or a photoconducting surface. With those technologies it is rather difficult to achieve and control precisely and reproducibly:

- the desired surface potentials for the different pixels,
- an even potential distribution within the pixel,
- a good confinement of the pixel.

These difficulties result from the facts that in conventional electrography electrons and/or ions have to be deposited on an insulator and for electrophotography a radiation source with a non-square intensity distribution is used to discharge the photoconductor. Altogether, these features of contact electrography offer a potential for an improved image quality, which will be demonstrated on a pixel level later in this paper.

Reliability

Comparing contact electrography and electrophotography with respect to reliability shows two advantages and two disadvantages for contact electrography:

Pros:

- Very robust image cylinder compared to OPC. The core is made of steel and the coating is highly wear resistant.
- Needs only one step for the creation of the latent image (pixel dependent charging) whereas electrophotography needs three (uniform charging, pixel exposure, uniform discharging). Reliability typically increases with a reduced number of process steps.

Cons:

- Needs mechanical contact to charge the pixels, which is difficult to maintain over time, especially in the presence of "dirt" as toner, paper dust and perhaps silicone oil.
- Mechanical alignment: The 50 µm pitch of the write bar has to match the 50 µm pitch of the image cylinder.

Speed

The principle of solid contact charging has been demonstrated at 90 cm/s and there seem to be no fundamental limitations for higher speed while at the same time maintaining a high image quality. Commercialy available are b&w and spot color Electrophotographic printers which work at speeds around 1 m/s but only with office quality.

Experimental Setup

The experiments were done with a pitch of 50 µm for the electrode array on the write bar and the same dimensions for the corresponding pad structure on the image cylinder. The image cylinder is covered with full square shaped pads of

40 µm × 40 µm area size and 10 µm space, building columns and rows (a planar pattern with 4-fold symmetry, see Fig. 1).

The image developed on the image cylinder was either analyzed under the microscope or transferred to paper by using electrostatic transfer. After transfer the image cylinder surface was preconditioned for the next revolution by means of a cleaning device and charging/discharging devices.

The following set of experiments for testing the image quality of contact electrography on pixel level was developed with a commercially available nonmagnetic monocomponent gap development system. The distance between development roller surface and image cylinder surface was 250 µm with +125 V DC bias applied to the development roller. Additionally, an AC sine wave of 1500 V_{pp} at 1000 Hz was applied. The average size of the ground toner particles used was around 9 µm. These tests were run at an image cylinder surface speed of 4 cm/s, although the process is inherently capable of much higher speed. A schematic diagram of the experimental set-up is given in Fig. 2.

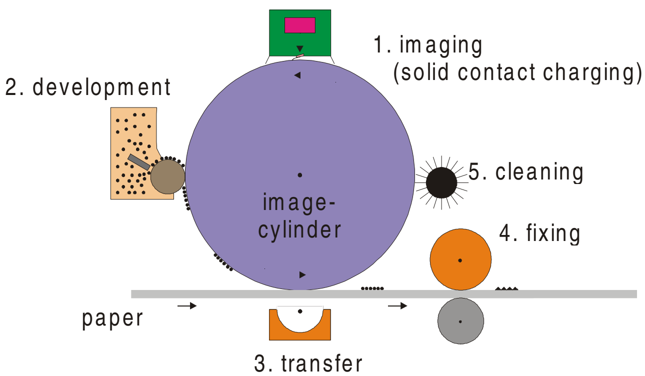

Figure 2. Schematic diagram of the experimental set-up for contact electrography.

Results and Discussion

In this section we will present the results from experiments with contact electrography. These results are discussed especially with respect to the impact on image quality.

Single Pixels

Single dark pixels are created when all of the writing elements are driven by a pattern consisting of continuous 0 V with a short pulse to 250 V sent to one element while the image cylinder passes. Single white pixels use continuous 250 V with a short pulse to 0 V sent to one element.

Fig. 3 shows a single dark pixel on the image cylinder. Dark pixels appear as 65 to 70 µm squares, with toner sitting not only on the conducting area of the charged pixel, but also covering most of the gap to adjacent pixels. As shown in Fig. 4, single white pixels appear as 40 µm untoned squares in a full density field on the image cylinder. Most of the image cylinder pixel edges are still visible, with the toned field covering the dielectric gap around the pixel Note that the single black pixels and the single white pixels were obtained in the same experiment without optimizing the development system parameters separately for each image.

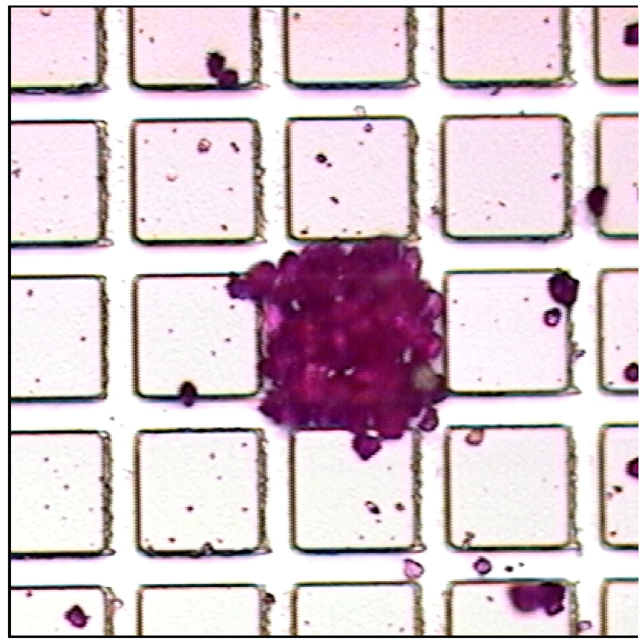

Figure 3. Single black pixel at 500 dpi on the surface of the image cylinder. Some toner extends over the area of the conducting pixel so that it has a size of about 65 to 70 µm.

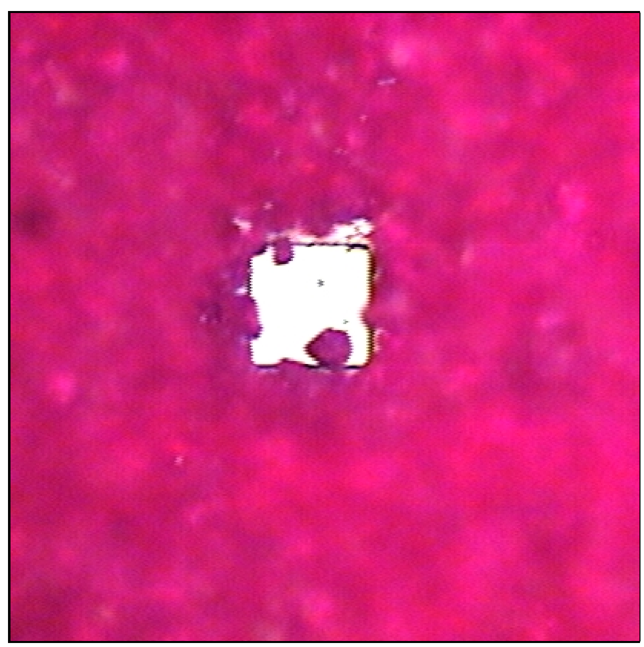

Figure 4. Single white pixel at 500 dpi. The white area has a size of about 40µm.

The difference in size between white and black pixels can be explained by a finite conductivity of the surface of the dielectric between pixels. Some of the charge leaks from the highly conducting pixel to the dielectric and thus increases the size of the developed area. An additional contribution is given by toner particles, which are hang over the edges of the pads and cover the gap.

What has been demonstrated here with contact electrography, namely single white pixels in a black area as well as single black pixels in a white area under identical conditions, is something that, to our knowledge, has not been possible with electrophotography. On a high level the rational for this result is that contact electrography has a much better latent image due to the metal pixels on the surface of the image cylinders. This is confirmed by calculations of the electric fields for both technologies under similar configurations. More details are discussed in different papers[2,3] and in the next section "Electric Fields".

The ability to print single white and black pixels has two important benefits for image quality:

- Output quality: The fact that contact electrography can print single black and single white pixels under standard conditions and that this is not possible with electrophotography shows, that basically dots can be printed with a higher stability when using contact electrography. "Stable" means that shape and even more important size are more consistent than in electrophotography. As discussed in the introduction, this is an important factor for consistent quality of gray scale and color reproduction.
- High density areas: In images that are made by bilevel halftoning the high density areas are printed by laying down full density and just leaving a very low number of pixels within a given area white. Obviously, the smallest element that can be left white, is one pixel in contact electrography. For electrophotography, more than one pixel has to be kept white, so that a dark area contains bigger white spots, which can be captured by the eye and thus negatively affect image quality.

Some clarity of the images on the image cylinder is lost during transfer and fusing. However, enough of the difference compared to electrophotography is maintained on the receiver substrate to result in image quality advantages for contact electrography.

Adjacent Pixels

In electrophotography intermediate gray levels are made by partially exposing pixels (by controlling the on-time of the laser or LED) next to fully developed pixels. The question of how contact electrography behaves in this respect is the subject of the following discussion.

Several print runs were made while printing two directly neighboring pixels at different voltage levels. In one configuration, the first of the two adjacent pixels was a 120 V pixel while the second pixel was at lower voltage, 30 V. Fig. 5 shows a typical result: the full voltage (120 V) pixel has a full density toner stack, while the lower voltage pixel (30 V) has a partial toner layer. The toner on the high voltage pixel creates a toned square covering the pixel and the dielectric around the pixel. This is typical of the single pixels printed in earlier experiments (as described above). The toner on the lower voltage pixel remains mostly on the conducting pixel of the image cylinder, with much of the pixel material remaining visible. This pixel has a low density, and has been seen to have toner scattered across the entire conducting pixel area, with no clear preference to be at the side near the high voltage pixel.

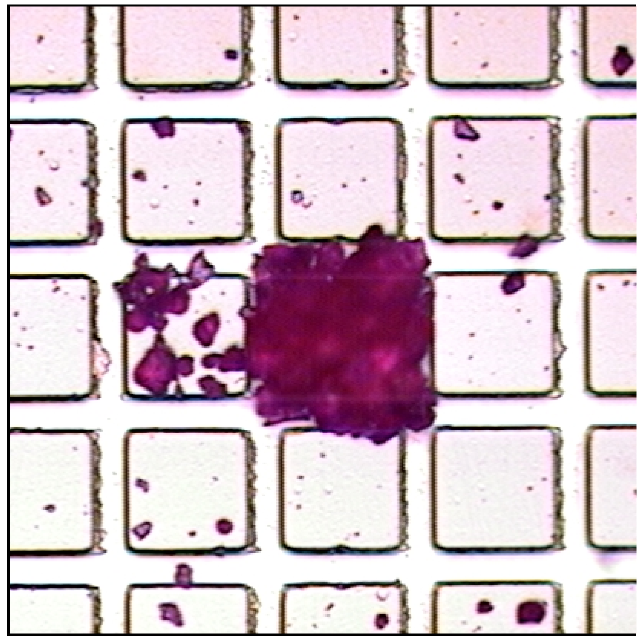

Figure 5. A black pixel (right, 120 V) directly beside a gray pixel (left, 30 V) on the surface of the image cylinder.

Tests at higher voltage levels (for example 250 V for the black and 125 V for the gray pixel) showed at first sight two black pixels on the image cylinder. A closer investigation showed much more toner on the black pixel, where the stack height was about 20 µm, where by contrast it was only about 10 µm on the gray pixel.

Clearly in contrast to electrophotography, contact electrography does not show a change in pixel width as a function of the gray level of adjacent pixels. Though contact electrography does not offer the opportunity to vary line width, this is compensated by the possibility to print individual gray pixels. For more details see also Ref. 2.

Electric Fields

As shown and discussed above, contact electrography can print single white and single black pixels under identical conditions. By a theoretical analysis we found that the reason for the differences between the two technologies is a result of the different electric fields. This analysis is presented in a different paper.[3]

In summary, the Gaussian beam profile of an exposure device in electrophotography causes within a single pixel a fairly "broad" region with a low electric field. This leads to a spatially "broad" region, where neither a strong attracting nor a strong repulsing force for a toner particle is present. In contrast, the electric field in contact electrography shows the transition between strongly attracting and strongly repelling in a spatially very narrow region, which leads to the better defined pixels.

Summary and Conclusions

The potential of higher image quality of contact electrography compared to electrophotography has been experimentally demonstrated on a pixel level. At the present resolution of 500 dpi single white pixels in a black area as well as single black pixels in a white area have been printed under identical conditions. This is something that, to our knowledge, has not been possible with electrophotography with dry toner. The reason for the improved performance with contact electrography is the better defined electric field due to the confinement of the surface charges to the area of the conducting pixels. In electrophotography the Gaussian beam profile does not allow for such a well-defined spatial surface charge distribution.

An improvement of the quality of single pixels leads to an improvement of image quality, especially with respect to output quality.

References

1. L. B. Schein, *Electrophotography and Development Physics,* Laplacian Press, San Jose, 1992
2. To be published: G. Bartscher, S. O. Cormier, G. Hauptmann, D. Kostyk, B. Lyness, F. Morgenweck, K.-U. Preißig, D. Rohde, L. B. Schein, "Print Quality in High Resolution Electrographic Printing", *J. Imaging Sci. Technol.*
3. To be published: G. Bartscher, S. Cormier, B. Lyness, L. B. Schein, "Comparison of the Electric Fields of Electrophotography and Contact Electrography", *J. Electrostatics*

Biographies

Gerhard Bartscher studied Physics at the Aachen University of Technology and received his Ph. D. in electrical engineering in 1995. He has been working in R&D for non-impact printing technologies since 1987. After being with Heidelberg Printing Machines and NexPress he is now working for the Felix Böttcher GmbH & Co. KG in Cologne, Germany.

Domingo Rohde received his diploma in physics in 1994 and joined Heidelberg Printing Machines in 1997 and later NexPress in Kiel, Germany. Since this time he worked for the Advanced Technology department dealing with non-impact printing technologies. Currently he is the team leader of the Advanced Technology department of NexPress in Kiel.