Ferroelectric Printing: Electrical Surface Conditions and Print Quality

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Abstract

The paper deals with ferroelectric printing. This digital print technology is based on imagewise poled ferroelectric PZT and liquid toner. Print quality depends strongly on the electrical conditions on the surface and mainly the difference in electric potential between printing and non-printing areas. On the other hand, the electric surface potential depends on parameters of the ceramic itself, conditions during the imaging process, conditions while printing, and time.

While basic ceramic properties like the dielectric constant, coercivity, and remanence are mainly defined by the material and the manufacturing process, imaging and the printing processes may change the surface conditions with regard to the electrical contrast between the printing and non-printing areas. That concerns the value of surface potential as well as the transition curve between the different regions.

Important print quality parameters are optical density and edge resolution. Thus, experimental work was carried out to investigate the relation between these features and surface potential on the ferroelectric printing cylinder during printing. The paper describes the main components used for ferroelectric printing and the experimental work. The results obtained are discussed to deduce first conclusions for further improvements of the process.

Introduction

Ferroelectric (FE) printing belongs to the electrographic printing technologies. The main element and carrier of the image is a ferroelectric ceramic, which can be polarized imagewise by an external electric field. The result of the imaging process is a defined local difference in the poling state in the bulk material with corresponding electrostatic surface potential of the ceramic. This electrostatic image can be transferred afterwards to paper using toner, as it is known from other electrographic or electrophotographic technologies.[1] The main difference - and what makes ferroelectric printing interesting for further research - is the charge image remaining after the toner transfer. The result is a permanent, but erasable printing form, what is the characteristic of a Computer-to-Cylinder-Technology.

Ferroelectric material suitable for printing application are ceramics like PZT, a mixed crystal structure of $PbZrO_3$ and $PbTiO_3$. In this material, the energy gap between the two stable polarization states is defined by the structure of the crystal and may be modified be additives. Several techniques including thick film as well as thin film technologies have been developed to produces layers of appropriate grain structure, thickness and homogeneity for different applications.[2,3] The use in a printing system requires PZT layers on a cylindrical surface, e.g. of steel or Al_2O_3.

The imaging by poling can be achieved by charge transfer to the surface until the region of coercive field is reached, i.e. contactless using an ionographic printhead (locally controlled discharges). Further charge transferred will not change the polarisation in the bulk material but will be bound as free charge on the surface.[4]

The main parameter with respect to printing using toner is the electrical field near the surface , which is caused by the remanent polarization locally distributed imagewise[5]. This electrical surface potential can be measured contactless by electrostatic voltmeters as it is known e.g. from investigations of photoconducters used for electrophotographic printing.

The toner currently used for the experimantal work is a liquid one based on isoparaffinic hydrocarbons as carrier fluid. These toners have several advantages and are promising for a lot of future applications.[6]

Experimental

For the investigations a special test machine was used, enabling a flexible configuration and control of all parts and components necessary for the process. It is basically a small web machine, designed for research and development. A scheme of the FE printing system is shown in Fig. 1.

The printing cylinder has a diameter of 220 mm and is coated with an approximately 100 micron thick PZT layer on a ground electrode of Pt. The typical grain size is about 3...5 microns. The dielectric constant is approximately 800, ranging from 650 to 980.

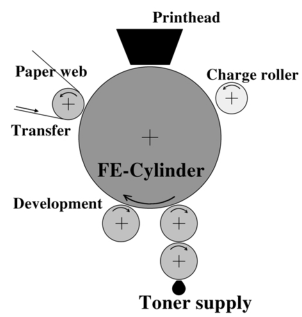

Figure 1. Scheme of the ferroelectric printing system

As the first step, the FE cylinder is polarized by a charge roller (conductive rubber) applying up to +480 V to the surface. Thus a uniform poling is reached. The remaining free charges at the surface are removed with ethanol. Afterwards the cylinder is imaged using an ionographic printhead with a resolution of 300 dpi. Negative charges, mainly electrons, are deposited on the surface and cause the electrical field for the local polarization leading to a defined surface potential. This is measured by an electrostatic voltmeter (noncontacting, by Monroe Electronics), and the data are recorded on-line during the imaging process as well as during printing.

For the printing liquid toner was used with a solid content of about 1 vol % in Isopar. The toner has positively charged particles, so that those areas are covered with toner where the printhead deposited negative charges on the surface of the FE cylinder. To improve the development of the image, a voltage of +200V is applied to the ground electrode underneath the ceramic layer, resulting to a surface potential in the non-image areas is in this range and toner repelling in these regions. The additional development roller is used to remove toner nevertheless occuring there due to adhesion effects.

To transfer the image from the FE cylinder to the paper an external electrical field is needed. Therefore a voltage of 2.3 kV is applied at the transfer roller which forms a nip with the FE cylinder. The transfer roller is made of conductive rubber with an insulating cover. The paper used was an uncoated paper with 80 g/m^2.

For the experiments discussed here, the printing speed was limited to 0.2 m/s, but it is in principle possible to achieve higher rates up to at least 2 m/s. It was mainly reduced by restrictions of the toner transfer system with respect to the homogeneous distribution of toner along the web width, not the development process itself in the gap between the toner system and the FE cylinder nor the transfer process from FE cylinder to paper.

The printed test form consists of several elements. Here solid areas were used for determination of optical density and edge resolution. The optical density was measured with a standard Techkon Densitometer R410. Since the used paper has a rough surface the toner did not cover completely, the measured densities are lower than expected from the properties of the toner itself. For the edge comparison a microscope with a digital camera system was used.

Results

The surface potential on the ferroelectric cylinder during the run is shown in Fig. 2. There are basically two main value areas to distinguish corresponding to the non-image areas (upper level, starting at about 200V) and the image areas (lower level, starting at about 400V). The dots between these bands result from the fact that the spot of the electrometer probes is in practice not infinitesimal small and mean values may occur. Moreover, the ceramic itself is not homogeneous with respect to the electrical properties, resulting in a certain variation of the measured values especially in the image areas.

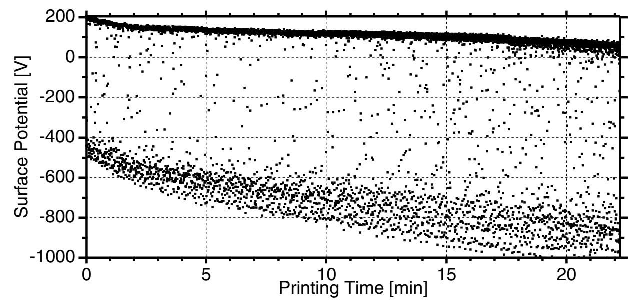

Figure 2. Surface Potential vs. time during printing

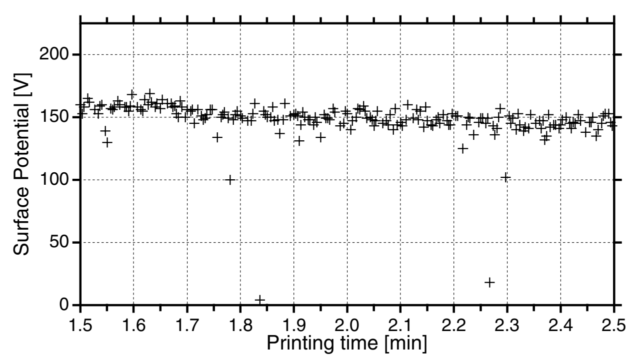

Figure 3. Surface potential in non-imaging areas at the beginning of the printing process

A deeper look into the electrical surface potential in non-image areas is shown in fig. 2 and 3, at the beginning of the print run (2min) and at the end after approx. 22 min, respectively. It can be seen that not only the overall level of potential is decreased, but that it is more alternating than at the beginning. It is expected that this downturn and fluctuation may cause differences in the development of the toner image concerning edge resolution as well as optical density.

The figures 5 and 7 show the edge of a solid area after 2 min and 22 min printing time. To illustrate the loss of resolution, the corresponding profiles in horizontal x direction are displayed in Fig. 6 and 8.

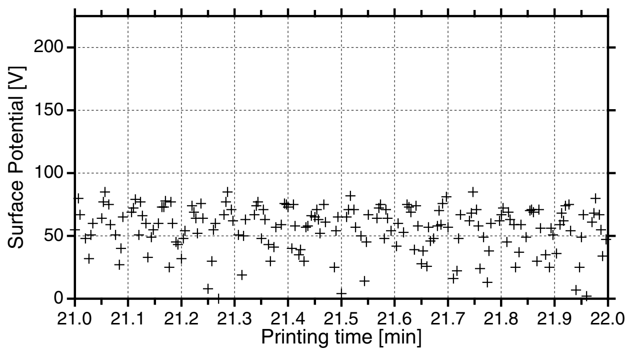

Figure 4. Surface potential in non-imaging areas after 21 min of printing

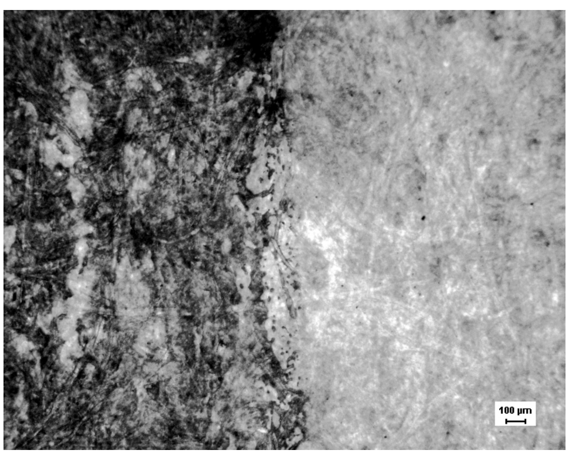

Figure 5. Edge of a solid area at the start of the run (2 min)

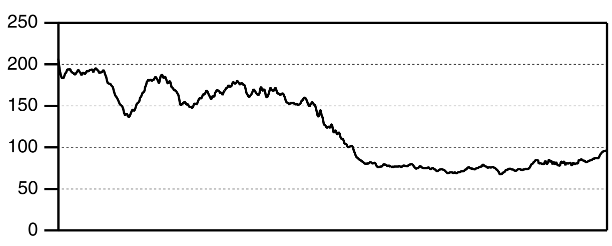

Figure 6. Horizontal Profile of the test sample in Fig. 5

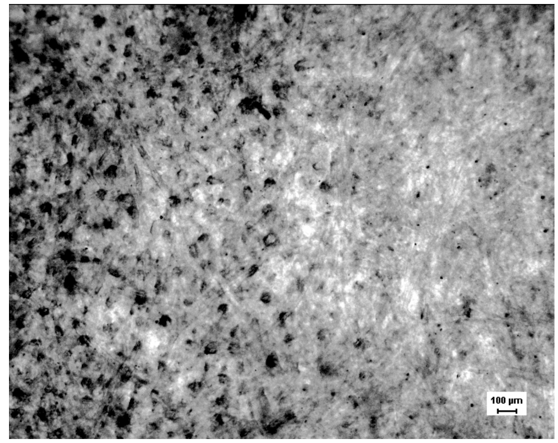

Figure 7. Edge of a solid area at the end of the run (22 min)

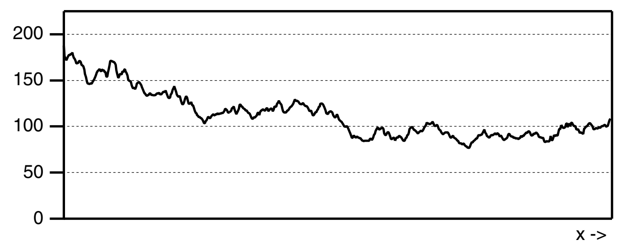

Figure 8. Horizontal Profile of the sample in Fig. 7

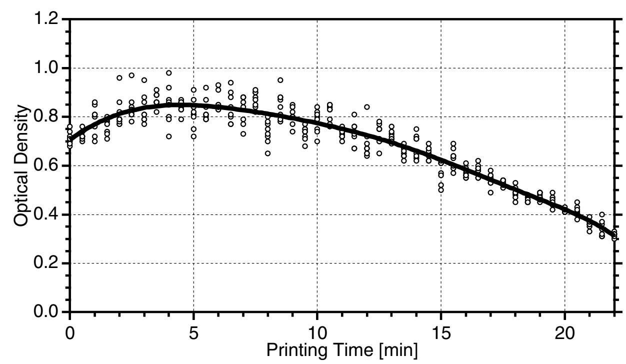

Figure 9. Optical density vs. time

The optical densities measured on samples after every 30 sec are shown in Fig. 9. Due to the inhomogeneities of the ceramic cylinder, several measurements in different were necessary. There is a maximum reached after 4 min, followed be a decline, although the potential in the image areas is further decreasing and should lead to better development. However, as can be seen by comparison of fig. 5 and 6, not only the edge resolution is lost during prining, but also the covering in solid areas. Thus, optical density measured by densitometer with a spot of about 3mm will drop down.

Conclusions

The electrical charges on the surface of the ceramic cylinder are changed by the development and printing processes. That has consequences for the print quality concerning optical density and edge resolution.

To obtain improved and stable print quality it is therefore necessary to control charge transfers. One possibility is to use improved transfer components, which avoid or at least minimize additional, unwanted charging of the imaged FE cylinder and suspected crosstalking and compensation effects. Another one is active control and specific "re-charge" when necessary.

Further investigations should be carried out to better understand the processes on the surface as well as in the bulk of the ceramic cylinder, including the contributions of the other components involved in the complex printing process, like toner and paper.

Acknowledgements

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Biography

Susann Reuter got her Diplom-Ingenieur in Electronic Devices from Chemnitz Technical University in 1989. From 1989 to 1994, she was co-worker at the Centre for Micro-technologies of this university. In the following 4 years she worked in a microelectronic engineering company. At the Institute for Print and Media Technology, where she worked since 1998, she was involved in several digital printing projects, and since 2000 she has been working in the Ferroelectric Printing project for MAN Roland.