Electrostatic Printing of Functional Materials, a Versatile, Novel Manufacturing Process

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Abstract

Functional materials like metals or glasses are formulated into liquid toners that are imaged on a fixed configuration electrostatic printing plate and then transferred across a finite, fluid filled mechanical gap to a variety of substrates. These substrates include glass and metal plates and non-flat surfaces like US coins. Details of this process, the toners formulated to date; and some suggested manufacturing applications are discussed.

Introduction

This paper describes work that applies the technology of electrophotography and electrostatography as a manufacturing tool for various industries. Electrox started this work in 1993 and our express goal was to print metals and glasses on glass substrates. We will report a little later that we have achieved that goal. Since then other functional materials have been formulated into liquid toners to satisfy other needs.

Electrox's Electrostatic Printing Process

There are three key elements to the electrostatic printing process:

1. the Electrox electrostatic plate (1,2)
2. functional materials configured as liquid toners
3. non-contact or gap transfer in which toner particles are transferred by an electric field across a gap of the order of 50 to 150μ to the receiving surface (3)

The process is best illustrated in the following figures. Figure 1 shows the plate making step. A photopolymer layer is coated on an electrically grounded substrate. The substrate can be metal, metallized polyester or polyimide film, or even glass made conductive with an indium tin oxide coating (ITO). The photopolymers typically vary in thickness from 12 to 50μ. The photopolymer is exposed to UV radiation in the 300 to 400nm region which causes exposed areas to undergo a chemical change. This raises the electrical resistivity of these regions significantly so that they can store charge for a useful period of time. The plate making step is now complete.

In Figure 2 the plate is sensitized by corona charging it with a standard corona unit from a copy machine. The resulting surface potential for a typical 37μ thick plate is from 500 to 1000 volts. After a short period of time the unexposed regions of the plate self discharge due to their relatively low electrical resistivity. We now have a traditional latent electrostatic image as in a standard copier or duplicator.

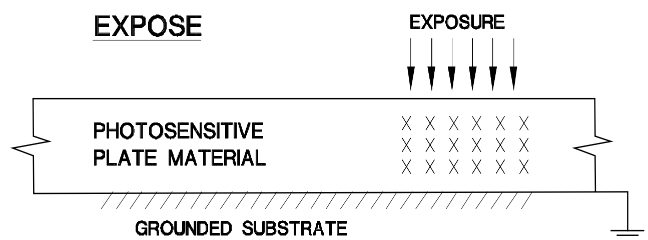

Figure 1. Plate Making

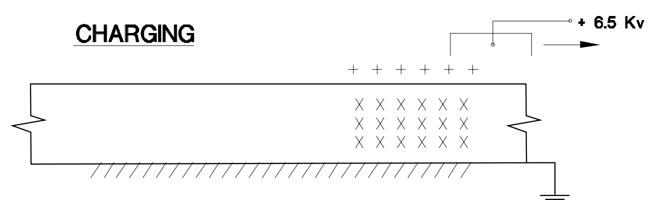

Figure 2. Plate Sensitizing

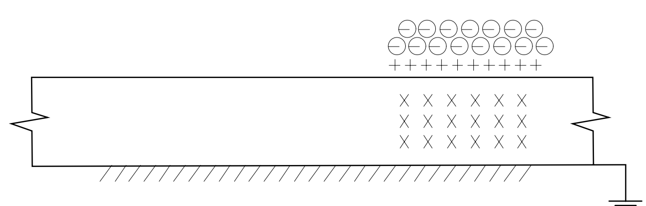

Figure 3. Liquid Toner Development

The latent image is processed by development with a liquid toner as shown in Figure 3. The small negative circles represent toner particles with a negative electrical charge attracted to the imaged areas of the plate by the electrostatic fields of the latent image on the plate.

Figure 4 shows the transfer step wherein the toner is transferred across a finite mechanical gap to a receiving glass plate by an electrical field created by the electric field plate on the other side of the glass driven to a suitable potential. An alternate scheme not shown in Figure 4 is to corona charge the other side of the glass with a charge of polarity opposite that of the toner (negative in Figure 3). Figure 4 shows a highly irregular surface. This is a particular advantage of electrostatic printing over other printing or deposition techniques. The toner travels the gap following the parallel electric field lines and it does not disperse as a function of distance between glass and plate. Therefore high resolution images, true to their design, can be deposited on the glass substrate, even if it has imperfections or a relief structure already on it.

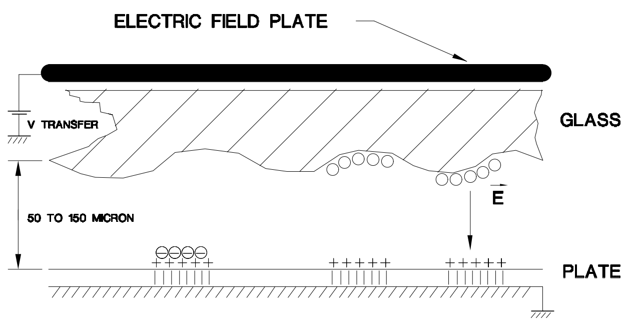

Figure 4. Toner Transfer Across a Gap

The Plate

While a photo addressable drum or plate could be used, Electrox chose an electrostatic printing plate for these reasons:

1. it offers a superior latent image over that of the photo receptor plate.

2. small features like 10µ or even smaller are possible

3. it offers reasonable process speeds of 250 mm/sec for high through put

Note: a 10µ feature implies a 2µ spot and a data rate of 37.5 X 10^{+9} pixels/sec for a 500 mm wide plate at 250 mm/sec process speed.

The Toner

In this area our work is far removed from traditional liquid electrographic toners. The following table shows these differences.

Comparison of Traditional Toners to Electrox's Toners

	Traditional Toner	*Electrox Toner*
Particle Size	0.1µ to 8µ	0.05µ to 90µ
Binder to pigment weight	9:1	1:9
Toner particle density	1.0 to 1.5	2.8 to 10
Transferability	some yes some no	yes,a requirement

Since the density of the Isopar diluents is of the order of 0.8 and the density of a typical glass frit is 5.0, Electrox started with the assumption that our toners would settle out. The question is could they be re-dispersed. Furthermore, we would prefer to make toners without any binder as they will eventually be burned off in many applications like the firing of glass frit particles or the bake out of phosphor toners before sealing in a vacuum.

Electrox has found that a minimum level of binder is needed to assure the re-dispersability of toners after settling though with some small particle metal systems no binder was used.

Non-contact or Gap Transfer

One of the principle advantages of liquid toner systems is their ability to be transferred across a significant mechanical gap between image plate and receiving plate (3). This is very important in some manufacturing applications where the receiving surface is either metal or irregular (like glass); or where high overlay accuracy is needed thereby eliminating elastomeric roller transfer. We will show samples of US coins printed with toners where the edge of the coins were spaced 125µ above the printing plate. The image show fine features with good edge acuity.

Results to Date

The following toners have been formulated and imaged successfully.

Toners- Formulated and Imaged

	Material	*Particle size*
Metals	Al	30µ
	Ag	0.2µ
Glasses, ceramics	Glass frit	0.5 to 7µ
	Phosphors	0.6 to 80µ
Catalysts	Pd	0.33µ
	Sn	0.8µ

Post Image Processing (Fusing)

Necessarily electrographic imaging puts particulate matter in an ordered manner on a receiving surface. This mass must be fused into a solid mass as in a typical copy machine. In our work some toners do not need heating to reflow them. The catalysts act as "sites" for electroless copper or other metals to grow from solution. This growth "joins" the image together in a solid mass.

The glass frits usually melt below the annealing temperature of the substrate glass, so simple heating does the job. Aluminum melts at 659°C and soda lime glass can be processed to 600°C, so a rapid thermal processing step is possible here.

The phosphors do not need heating since they are baked to boil off organics then aluminized to bind them together and to the face plate of their display panel.

There is a lot of interest to print metals on polymeric substrates like PET or polyimide. PET can be processed to 150°C, polyimide to 400°C while epoxies can go to the 260°C range. We are working with another firm to produce a silver toner that can "sinter" in the 230°C range. This has been a success and samples will be shown.

Some Manufacturing Applications

We have assembled the elements of a generic manufacturing technology. Virtually any material not swelled or dissolved by the Isopar diluent can be formulated into a liquid toner. They can be imaged by a suitable plate or drum then transferred in a non-contact mode to a wide range of substrates. In this program we have primarily printed on glass plates, usually soda lime glass 2.25mm thick. But printing on copper, brass, aluminum, stainless steel and US coins (both silver and Cu/Ni) are easily done. Possible manufacturing applications include:

1. Printing of phosphors in glass trenches for plasma display panels.
2. Printing of glass separator ribs for these displays.
3. Printing of metal conductors for them (Al or Ag).
4. Multi layer electronic wiring structures (printed wiring board).
5. Printing resistors and capacitors.
6. Printing phosphors for field emitting displays and CRT's.
7. Printing color filters for LCD, etch resists for traditional printed wiring boards.

Conclusion

Functional materials of high mass density have been successfully formulated into liquid toners. These have been imaged on a electrostatic printing plate and transferred in a non-contact mode to metal and glass substrates of useful thickness' like 2.25mm.

This is a generic manufacturing technology applicable to many products in various industries.

References

1. Reisenfeld, U.S. #4,732,831.
2. Detig, U.S. #4,859,557 and 5,011,758.
3. Bujese, U.S. #4,786,576 and 4,879,184.

Biography

Robert Detig has 30+ years of experience in the field of electrophotography, beginning with Xerox in 1965. He has extensive experience in every aspect of the electrographic imaging process including toner experience, having worked for Olin Hunt. He has been a key team member on several major machine programs using both liquid and dry toners.

He was awarded a Ph.D. in Electrical Engineering from Carnegie Mellon University, Pittsburgh, Pennsylvania.