

Fundamentals of Xerography

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February 22, 1994

Contents

1	Basis of the xerographic process	2
2	The Corona charging step	2
3	Exposure and properties of the photoconductor	3
4	Transfer of the image	6
5	Fusing the image	7
6	Cleaning and restoring	8
7	LASER Printing comes of age	8

List of Figures

1	Basic steps in the Xerographic process.	2
2	Corona discharge device of corotron.	3
3	Decay time for photoconductor.	5

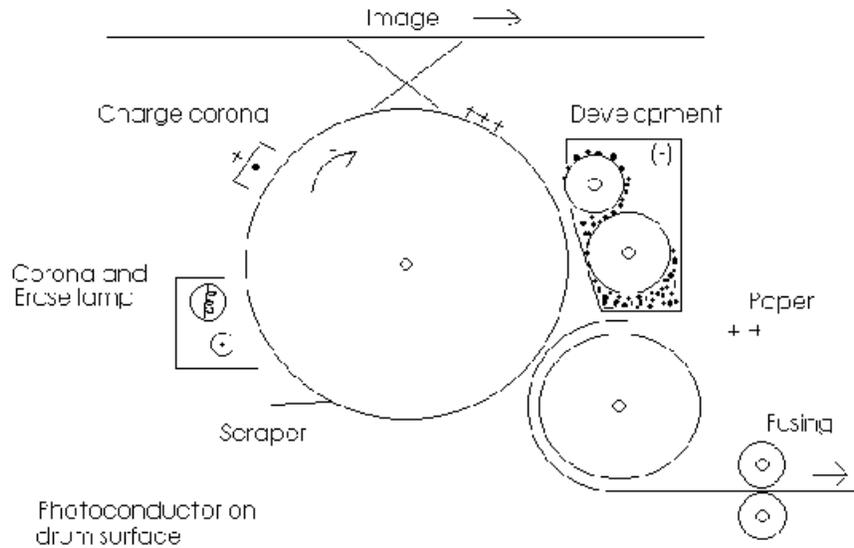


Figure 1: Basic steps in the Xerographic process.

1 Basis of the xerographic process

Xerography or *electrophotography* relies on six fundamental steps. The charging of a photoconductor, exposing the photoconductor or image exposure, the development of the latent image, transferring the newly formed image from the photoconductor to a sheet of paper or other medium, fusing or permanently fixing the image to the medium and finally cleaning and restoring the photoconductor for future use. These steps are outlined in Figure 1.

2 The Corona charging step

Earlier in the xerographic process the photoconductor surface is given an electrical charge or is said to have been sensitized. Prior to the image exposure, it is necessary to establish an electrical field within the photoconductor film. This charge distribution on the photoconductor surface is generated by absorbing ionized gas molecules that arise from an electrical corona device.

According to Websters dictionary one of the many definitions of corona is, "A faint glow adjacent to the surface of an electrical conductor at high voltage." This glow is due to electrical breakdown that ionizes the surround-

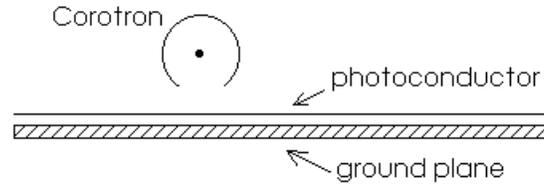


Figure 2: Corona discharge device of corotron.

ing air. A corona discharge device usually consists of a thin wire(s) that is strung within a metal enclosure which is open on one face (see Figure 2). These wires are then subjected to several thousand volts. The intense electric fields around the wires cause the air molecules to ionize and charged ions, whose polarity depends on that of the high voltage, are driven onto the photoconductor surface [5]. The wires employed in such devices are around $50\mu m$ in diameter and are usually made of tungsten. A typical corona device or corotron contains 3 to 8 individual corona wires that are set to potentials between 5 and 10 kV with a nominal voltage of 6 kV. These wires are placed about 0.5 cm from the photoconductor surface [4]. The polarity is dependent on a number of factors including the choice of photoconductor material, its dielectric strength at positive or negative voltages, and the polarity of the charged toner particles used to develop the electrostatic image [6].

The uniformity of the charge distribution on the surface of the photoconductor is important in avoiding non uniformity's in the developed image. The emission uniformity is good for positive corona wires but very poor for negative wires. The scorotron was invented to solve the problem of charging a photoconductor with uniform negative potential. The scorotron consists of a series of corona wires with a screen of larger diameter ($250\mu m$) wires at a much lower potential (500 - 1000 V) placed between the corona and the photoconductor surface. The screen wires are biased to a potential close to that desired at the photoconductor [4]. If the potential of the photoconductor surface tries to rise above the screen potential, charging ceases and control of the ion current is achieved. This charging procedure takes place in the absence of light hence the name dark voltage.

3 Exposure and properties of the photoconductor

One of the key components in the xerographic process is the photoconductor. Photoconductors have a special property in that they become conductive

when exposed to light and are insulative when in the dark. It is these properties that make the photoconductor essential to the process

At this point the photoconductor has a uniform surface potential associated with it. The next step is to expose the image of a document onto the surface of the photoconductor. The imaged areas of the photoconductor remain unexposed and charged, while the areas that receive light become neutralized. The neutralized areas are due to the fact that the charge is drained away from the surface of the photoconductor to the metalized ground. What remains is the electrostatic latent image. This electrostatic image can then be developed.

A typical photoconductor layer is usually around 10 - 50 μm and is coated onto a ground plane [6]. Earlier photoreceptors consisted of selenium coated on a metalized drum. Today they are coated on aluminized Mylar and be made into webs or seamless belts.

Photoconductors in xerography should exhibit some basic properties. The electrical conductivity of a photoconductor in the dark must be that of a good insulator. Good insulating qualities are important so that charge patterns can be retained for a period of time long enough to complete the development process. The material must also become electrically conducting during exposure to light. In this way an electrostatic image pattern can be formed on its surface by either optical or LASER means. The photoconductor should be fairly strong and be able to with stand continuous charging, discharging by light energy, cleaning, and recharging in the dark. One type of material that has been used because of its robustness is amorphous selenium [1]. Photoconductors also have dark current associated with them. That is, even when a photoconductor has been charged and is shielded from any source of light, there is still leakage current that flows (see Figure 3). The dark current that flows is a result of thermal activity in the photogenerating medium. This decay rate must be accounted for and is kept within certain constraints. If the decay rate is too high, the surface potential will decrease causing a decrease in contrast in the image and excess toner in the background.

By using lenses and mirrors, office copiers and duplicating machines are able to expose and form a latent image on the charged photoconductor. Some copiers scan the document in synchronization with the photoconductor. Other types of copiers use flash lamps and optics that focus the image onto the photoconductor. While still others use LASER's for image formation. These radiant energy sources can vary. Copiers may contain tungsten and tungsten-halogen incandescent lamps as well as xenon flash tubes. Developing the image

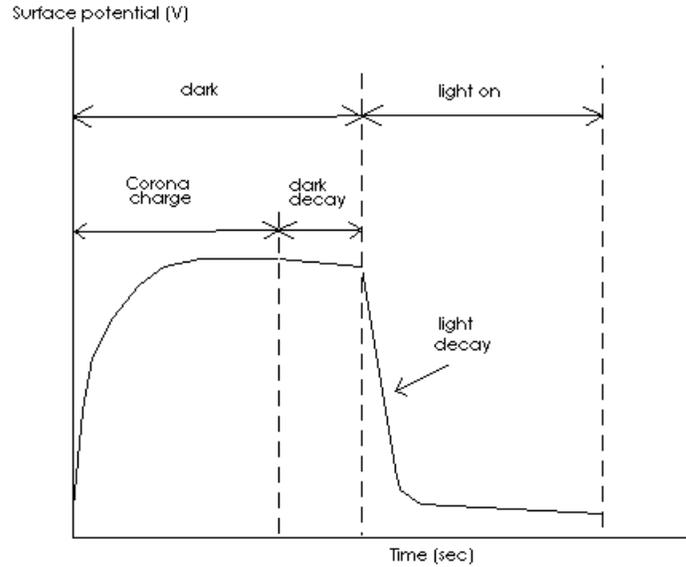


Figure 3: Decay time for photoconductor.

Once an electrostatic latent image is formed on the photoconductor, it is ready for development. The image is converted into a visible one by depositing charged toner particles on the photoconductor. There are two techniques used to develop electrostatic images. These are liquid ink development (LID) and dry development with the later being the most common. Of the dry developers there are single-component and dual-component development systems. The single-component system refers to toner only while the dual-component system refers to carrier and toner in the same housing. Early systems incorporated dual-component developers in order to reduce the dust problems encountered in single-component systems. These dual-component developers are also used for high speed printing and copying.

Many xerographic toners are made from copolymers of styrene and acrylic, with a small amount of carbon black pigment added. The material is milled down to small fragments ranging in size between 5 and 30 μm [6]. These toner particles are charged by triboelectrification. In the dual-component developers, the charged insulative toner particle is attracted to the larger magnetic carrier particle (70 - 300 μm) and is thus able to be transported.

The magnetic carrier has a thin dielectric skin on it so as to discourage permanent adhesion of the toner particle. When the toner particles

do stick permanently, either by chemical or mechanical means, the contact electrification properties are altered thus resulting in a degradation of the image. In these dual-component systems the developer is rubbed over the electrostatic image on the photoconductor. The regions that have a positive electric field attract negatively charged toner and, conversely, negative fields repel negative toner. If toner is attached to the carrier, it is important that the toner-carrier adhesive bond be broken. In this way the toner particles are free to move under the influence of the photoconductor image field. When there are sufficient forces available to break the bond, the toner will migrate to the photoconductor surface where there is opposite polarity [3]. The carrier in such systems is reused while the toner is depleted. Because of this depletion, fresh toner is added to maintain a consistent concentration of toner. It is the continued reuse of the carrier beads which damages them.

A problem that was encountered in developer units that used gravity to cascade the developer mix over the latent image was reduced carrier flow and the inability to retain carriers. This problem was eliminated by making the carrier out of magnetic material and by pulling them away from the photoconductor with magnets. This was the making of the magnetic brush. It is this magnetic brush that allows for high speed development.

Liquid development uses charged particles in a liquid dielectric medium. This process is much slower than dry development techniques and is usually found in small office copiers. The toner particles that are found in liquid developers are much smaller than in dry developers and are therefore able to attain greater resolution. Liquid ink development is plagued with other problems though, such as environmental effects from the dielectric medium (NORPAR).

4 Transfer of the image

The developed latent image is, at this point, ready to be transferred to a sheet of paper or other medium. In brief, the medium comes in intimate contact with the photoconductor and with the aid of a transfer corona unit is successfully transferred. The transfer corona unit provides an attractive electric field. If a machine is using positive toner then it must use a negative transfer corona unit. Without the attractive electric field toner will remain on the photoconductor. Toner has a tendency to transfer directly to metal sheets, insulating films, and paper. Since paper is usually the main medium of transfer, it advantageous to understand its physical properties to electrical charge and flow of ionized gases through the paper fibers. Image transfer to

plain paper is usually 80 - 90% efficient [6]. Dry paper can hold charge in the fiber matrix for many seconds. Because of this there are problems in paper handling. One technique that corrects this problem is to employ a discharge corona device that neutralizes the paper. Other aspects to consider are the moisture content in the paper and paper thickness. It has been shown that heavier papers tend to yield improvement in transfer efficiency [6].

5 Fusing the image

After the image has been transferred to the paper it needs to be made permanent. Prior to this step the toner-image formed is somewhat loosely bound to the paper surface and can easily be disturbed or rubbed off. One method in making the image permanent is to fuse the thermoplastic toner into the paper fibers using heat and pressure. Other techniques include pressure only fixing and solvent fixing. With solvent fixing, equipment is required to trap and condense the solvent vapors for reuse. Unlike heat and pressure fixing, pressure only fixing is simple and requires no warm up period. This method often calenders the paper and more importantly, it does not work well with all types of papers. The technique employs hardened steel rollers that are loaded against one another by compression springs. The paper is then passed between the two rollers and is fixed. Most high speed fusing is done with hot roll pressure fusers. There is usually a long warm up time associated with this method, 5 - 10 min. These rollers are heated from within usually by a tungsten quartz lamp. Typical fusing temperatures are around 130 deg C [5].

Thermal fixing without pressure rolls has been done with radiant energy. The possible advantage here is that it is a noncontact method. Unfortunately, due to the fact that most paper reflects 70 - 80% of the incident radiant energy, thermal fixing without pressure rolls has proven to be very inefficient.

In the fusing process there are three things to take into consideration. One of the first things is that the toner must be able to coalesce. The coalesced toner must then be able to spread and finally it must penetrate into the paper fibers. Melting temperatures where the toner begins to soften and flow are between 60 and 70 deg C for a pressure-temperature fuser. One noticeable property of amorphous materials is their ability to change from elastic solid to viscoelastic to rubber and then to fluid [6].

6 Cleaning and restoring

The toner is not always successfully transferred to the paper. Some of the toner particles are left on the photoconductor surface. The particles left behind are usually smaller in size than the particles that transferred. This is because the larger particles tend to shield the smaller ones upon transfer. In other words, the paper will make contact with the larger particles and transfer them over leaving the smaller ones behind never to have been touched. These particles must be removed from the photoconductor for they will interfere with the corona charging and the image exposure. A method for removing such particles makes use of scraper blades or rotating brushes. The cleaning process also involves the use of an erase lamp and a corona unit (see Figure 1). The corona unit here has a polarity that is opposite to the main charging corona device. The erase lamp removes the latent electrostatic image and the corona device neutralizes the surface charges. Under normal usage a photoconductor might be expected to produce over 1 million images in a given region before the image quality degrades below acceptable standards [6].

7 LASER Printing comes of age

It is possible to create a document by directly writing on the photoreceptor with a LASER or light pen. The use of a LASER can eliminate the necessity to create an intermediate optical image. There are three fundamental components in a system that utilizes LASER writing. These components are a computer to provide digital electrical signals containing the image information, a LASER whose output intensity is controlled either directly or indirectly by the computer and xerography to convert optical information into prints on plain paper [5]. Gas LASERs such as Helium-neon and solid-state LASERs are often used in these systems. Because of the small focused diameter of the LASER spot, high resolution can be achieved. In a LASER printer a LASER beam is scanned across and writes directly, but discontinuously in a series of light pulses, on the surface of the photoreceptor. The result is a grid of exposed or unexposed areas or pixels that will later be developed. After this writing has been completed, the remaining steps in the xerographic process are unchanged.

The modulated LASER beam represents a series of pulses that will image the photoreceptor. These pulses are the actual data of the image to be formed. The data is sent to the printer in a bit stream. The bit stream is

made up of 1's and 0's (binary data). The 1 represents the on state or pulse and the 0 represents the off state or absence of a pulse. To accommodate a font together with numbers and other symbols such as the comma, question mark and so on a 7 or 8 bit code, is used [5]. A widely used code is known as ASCII (American Standard Code for Information Interchange). This code is interpreted by the controller in the printer unit. The controller is an independent computer within the LASER printer which deciphers the code and creates a video signal of the data. It is this signal that ultimately modulates the LASER and exposes the photoreceptor.

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