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Digital printing

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1. Overview and distinctive features in comparison with conventional printing methods
2. Electrophotography
3. Inkjet printing
4. Marketing in digital printing, applications, future prospects of digital printing

For industrial print production, above all electrophotography (in everyday language: laser printing) and inkjet printing are of importance.
Electrophotography was invented by the American Chester F. Carlson, the patent application for it was filed in 1937. The first successful test resulting in the very first photocopy was already made in 1938.
The technical implementation of the patent was only carried out in 1947 by the Haloid Company which launched the first commercial photocopier in 1949. In 1961, the Haloid Company was renamed Xerox. In Germany, the licence was granted to the English Rank Group, whereupon Rank Xerox was established. Therefore, xerox machine and/or xerography are often used as terms for the process and the copying device. Another name under which this technology is known is "laser printing".
At the very heart of electrophotography is a dynamically rewritable printing forme (drum, plate, disk). This is a so-called photo semiconductor: a photo semiconductor drum with an aluminium core is partly also designed as a flexible band. These carriers are coated with a photo semiconductor layer.
The layer mostly consists of organic photoconductors (OPCs), in some cases, amorphous silicone or selenium-containing compounds are used. In such layers, free charge carriers are generated under incident light; the more incident light, the higher the conductivity – and this effect is used in electrophotography.
The electrophotographic printing process consists of the following steps, also see Figure 1:

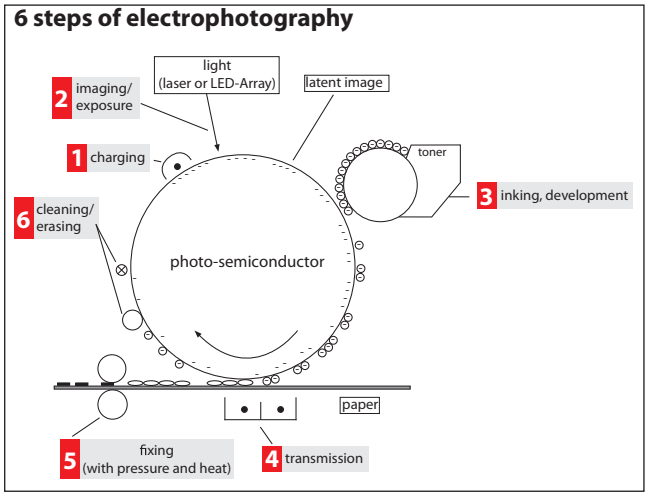


Figure 1: The electrophotographic printing process

1. Loading
The photo semiconductor layer is statically charged by means of a corona. The corona is a thin wire to which several thousand volts are applied. This ionisizes the air, and the loads move to the photoconductor surface.
2. Exposure
In the second step, the photo semiconductor surface is imaged. This is done with a laser beam or with LED arrays (LED = Light Emitting Diode) which are arranged as bars.
Due to the incident light, the load on the drum surface changes, a latent image is created. This image is not visible; it consists of load differences on the photo semiconductor surface.
3. Developing
Now, the latent image is made visible by colours. A toner powder which is charged oppositely to the image areas is applied via a developing unit so that the image becomes visible.
A precondition is that the toner is chargeable. The different types of toners will be dealt with below.
4. Transfer
Now, the printing image is on the photo semiconductor layer and must be transferred onto the substrate. Here again, coronas and, thus, electrostatic effects are used in order to get the toner onto the substrate.
For the transfer process, too, there are different technological variants.
5. Fixing
The toner is held on the substrate by electrostatic forces and could simply be wiped off mechanically. Therefore, it must be fixed by means of pressure and heat (ironing effect), i.e., it must be melted and bonded to the substrate.
6. Cleaning/discharging
During the transfer process, the toner is not transferred completely; it may well be that there are still toner particles and residual loads on the photo semiconductor surface. Since the drum is exposed with

every new rotation, it must be cleaned both mechanically and electrically. This means that any residual loads on the full surface are discharged by light and toner particles are removed by means of brushes.
Then, the surface is ready for the next exposure process.
This also shows the great advantage of digital printing – due to the dynamic printing forme, it is possible to create a new printed image with every printing cycle so that "single-copy run" production is possible and reasonable.
As far as the use of the electrophotographic printing method in practice is concerned, there are different technological variants.

Exposure:
As already mentioned, there are two variants, i.e. laser beam and LED array. Machines with laser technology are equipped with complex optical devices; most of these machines are expensive, but thanks to the laser beam they enable to achieve sharper and finer edges and higher resolutions (e.g., Xerox). Devices with LED technology are more robust, but the quality in fine details is sub-optimal (Minolta, Xeikon).

Types of toners:
Depending on the printing system, different types of toners are used. In general, we distinguish between dry and liquid toners. (Figure 2)
Dry toners are mostly two-component toners. They consist of the colour pigments and carrier particles. The carrier particles (approx. 50-150µm) can be charged (they mostly consist of ferric oxide) and transport the toner to the image area. These particles are transported back into the developer circulation. The toner particles (approx.5-20µm) consist of polymers, colour pigments and additives. One-component toners are rather rare. Since they must be chargeable, they are bigger and it is not possible to achieve clean colours due to the necessary iron content.
The ink film thicknesses which are achieved with the dry toners are approx. 3-8µm. A frequent problem is that the dry toner does not set properly, but lies on the paper. On the one hand, the impression produced in this way is not similar to that achieved in offset – which is expected for many print products. On the other hand, this causes also problems in print finishing, e.g. during folding when the toner surface cracks. The machinery manufacturers consistently endeavour to improve the toners, one example is the chemical EA (Emulsion Aggregation) toner with smaller and more uniform toner particles due to a special production process. (Figure 3)
In liquid toners, the colour pigments are suspended in a dielectric liquid so that smaller toner particles (approx. 1-3µm) are possible; during the drying process, the liquid evaporates; the particles partly set and enable to produce offset-like ink film thicknesses. The handling of the toner and the ink transfer process are, however, more complicated than with the dry toner.

Transfer variants:
In many devices, the toner is transferred from the drum direct to the substrate.
Some manufacturers use the offset principle in which the blanket has the function of an intermediate carrier. This enables, e.g., to print on materials with an uneven surface.

Kinds of toners

Powder toner	• polymers (80-90%), pigments (5-15%), additives (1-3%) • particle size: 6-20 µm • available as single component or two component toner (toner + carrier) • ink film thickness: 2-7 µm
Liquid toner	• pigments, additives, sometimes also polymers are solved in an electric carrier liquid, particle size smaller than 2 µm • most important example: ElectroInk from Indigo • ink film thickness: approx. 1-3 µm

Figure 2: The different kinds of toners

Conventional / chemical toner

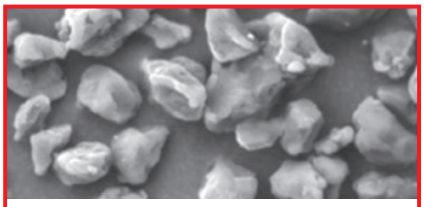
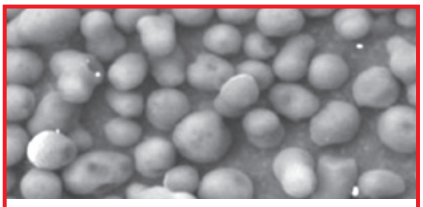
Conventional toner	Chemical toner
	
20 µm	20 µm
• produced in melting & grinding process • inkfilm thickness: 5-7µm	• produced by an aggregation of layers (emulsion aggregate toner) • ink film thickness: 2-3 µm

Figure 3: A comparison of the results achieved with a conventional toner and a chemical toner.

Often all four toner inks (CMYK) are first of all collected on a transport belt and then transferred from there onto the substrate in one single step. This ensures better colour register.

Multi-pass/Single-pass:
In multi-pass systems, all four process inks are exposed with one exposure unit one after the other, i.e. the photo semiconductor drum needs one rotation per colour.
Single-pass machines have one colour per exposure unit and, as a result, are significantly faster.

Fixing:
The toner is always pressed and fused to the paper by means of heated elastic fixing rollers. To prevent toner from staying on the rollers, silicone oil is used as a separating agent – which, however, often also produces a mostly undesired gloss. Modern devices have separators in the colour toner which mitigate this effect.
The electrophotographic systems presently offered on the market are available in different quality levels which, of course, is reflected in the price.
The lower priced segment, the so-called office systems, is fit for professional printing only to a limited extent. The colour cannot be controlled (no calibration/linearization possible, no profiles can be stored). Furthermore, paper guiding is not consistent; the paper is transported by means of rubber rollers without guidance so that register-true prints are not possible. (Colour register, register on the individual sheets, register for front and backside printing)
High-quality systems, on the other hand, have features that we know from the conventional printing machines: Side lays for the positioning of the sheets, double-sheet detection, the RIPS are prepared for colour management, inline colour measurement and control; there are redampening units after fixing and smoothing units.