PAPER SURFACES IN ELECTROPHOTOGRAPHY

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OUTLINE

• Electrophotography:
  • Principles
  • Toner
  • Toner transfer and fusing
  • Technology and applications
• Paper for electrophotography
  • Paper making
  • Uncoated paper
  • Coated paper
Electrophotography: Charged toner particles are pulled from the photoconductor towards the paper surface by an electric field. The toner particles contain colorants (CMYK).

Electrophotography

The photoconductor drum is cleaned and recharged before every new printout: allows for changing of the print from copy to copy.
DIGITAL PRINTING TECHNOLOGIES

- Digital Printing
  - Electro-photography (laser printing)
  - Inkjet
  - Other digital printing technologies
    - Dry toner
    - Liquid toner

ELECTROPHOTOGRAPHY

- Chester Carlson patented Electrophotography in 1938. A single-colour photocopy was made by charging of a drum, by shining light upon selected parts of the drum, and transferring of ink to drum and then to paper.
- First automatic copy machine, Xerox 914, was introduced in 1959.
- 70s and 80s: IBM introduced laser printer (1970), Ricoh and Canon introduced new electrophotographic machines in the 80s. 1938
1. IMAGING: CHARGING

By sufficient charging of a tip or a wire, air can be ionized (air breaks down). This creates a plasma, and can act as a source of charged particles.

1. IMAGING: LASER/LED

The photoconductor drum contains photoconductors. A laser or a LED shines light on a part of the photoconductor. The photoconductive molecule picks up sufficient energy to transfer charge to the photoconductor surface. A pattern is printed (by laser or LED) onto the drum.

The active part of the photoconductive drum is typically made of Selenium compounds, organic photoconductors, or amorphous silicon.

1. IMAGING: CHARGING AND PATTERNING BY LASER/LED

First charging, and then the laser/LED light creates the pattern on the photoconductor drum.

2. INKING (DEVELOPMENT)

The toner is transferred to the drum by electrostatic forces. Here: two-component toner system consisting of carrier and toner. Mixing of carrier and toner is done by magnetic brushes.
3. TONER TRANSFER

The negatively (in our example) charged toner particles are situated on the photoconductor drum (below the paper in the figure). Corona poling is done above the paper. Toner transfer to the paper by electrostatic forces.


4. FUSING/FIXING

1. Imaging
2. Inking (Development)
3. Toner Transfer
4. Fusing/fixeding
5. Cleaning
5. CLEANING

1. Imaging
2. Inking (Development)
3. Toner Transfer
4. Fusing/fixing
5. Cleaning

DRY TONER

Two-component systems consist of carrier particles and toner particles. The carrier particles are magnetic and stay in the development unit. Toner is transferred to the drum and then to the paper.

The toner contains pigment (~10%), wax, charge control agents, and a viscous fluid (resin: ~80-90%) which cures upon heating (e.g. styrene-acrylate, polyester) and acts as a binder.
DRY TONER

Magnetic one-component toner systems consist of iron oxide and pigments, binding agents and additives.

Advantage: no mixing system needed.
Disadvantage: high content of iron oxide needed.

MECHANICAL TONER

Mechanical toner: traditionally toner is made small enough by mechanical milling (or jet milling) (schematic drawing).

Problems: Uneven shapes and size distribution. The concentration of pigments, charge carrier, etc. in the toner particles can vary.
CHEMICAL TONER

Chemical toner: toner is made by polymerisation (in suspension or emulsion) (schematic drawing)

Size of particles can be determined by polymerisation time (and conditions). Even shapes and even size distributions.

DRY TONER

Mechanical toner  Chemical toner
LIQUID TONER

Liquid toner: Indigo using liquid toner was launched in 1993. The liquid toner particles are transferred to the paper by electrostatic forces, just las for dry toner. The liquid toner particles can be made smaller for improved print quality. The liquid toner particles are dissolved in an oil-based solution.

Print quality close to offset print quality.

LIQUID TONER

The toner particles (~10 %) are dissolved in a hydrocarbon solution. The solution also contains small amounts of binder and additives. The solvent must be removed from the paper in order to get a good printout, and is typically recycled.
TONER TRANSFER

Paper

15µm
5µm
10µm
3µm
2µm
1µm

Photo conductor

Dry toner (mechanical)
Dry toner (chemical)
Liquid toner

TONER TRANSFER

Paper

F = q*E
F_{cohesion}
F_{adhesion}

Photo conductor

F = q*E
F_{cohesion}
F_{adhesion}
TONER TRANSFER

... ink splitting occurs ("toner splitting"), meaning that cohesive forces (van der Waals forces) and electrostatic forces are determinant ...

**Toner**, improved print quality with improved:
- Spherical shape
- Smaller particles
- Even size distribution
- Even charge distribution

**Paper**, print quality influenced by:
- Grammage. Thicker paper can hold E-field better.
- A smooth surface improves interfacial contact and toner transfer.
- Reduced porosity improves toner transfer.

FUSING / FIXING

Sintering of toner particles at elevated temperatures (above $T_g$)

$T_g =$ glass transition temperature

Thereafter: spreading on surface and penetration into paper.

The penetration into the paper is small or very small compared to other printing technologies.

The driving force is a lowering of the total surface energy (which is lowered if the surface area is lowered)
DRY TONER & LIQUID TONER

Dry toner
- DocuColor, DocuTech, Xerox
- DCP, Xeikon
- CLC, Canon
- NexPress, Kodak
- Digimaster, Heidelberg
- Demandstream, Oce
- etc...

Liquid toner
- Indigo, HP
- MD Mitsubishi
- Ricoh
- Myikoshi

TONERS
TECHNOLOGY
(Electrophotography)

Docucolor 40, Xerox (1995)

Single pass printer: the paper passes by only once
TECHNOLOGY

(Electrophotography)

Multi pass printer: the same photo conductor drum is used for all colours. The paper passes by one time per colour.

One example: Xerox DocuColor 8002, colour printer. Speed: 80 pages/min. Resolution: 2400 x 2400 dpi
Paper: 60-300 gsm, 320 mm x 480 mm.
Finishing: Booklet Making, Hole Punch, Lay Flats, Perfect Bound, Stitched Sets, Tape Bound, etc.
APPLICATIONS (EP)
For printing of
• Transactional data
• Transpromo
• Direct marketing
• Labels
• Brochures
• Books
• Cards
• …

EP=Electrophotography

PAPER FOR ELECTROPHOTOGRAPHY
PAPER MAKING
- a short reminder

... forming of a wet web of fibers ...

Figures from Husum mill Paper school, courtesy of Husum mill, Örnsköldsvik.
Formation

Paper formation is a measure of how uniform the paper is. If the formation is poor, the whiteness of the paper varies spatially. Poor formation can be due to an uneven distribution of fillers and fibers (e.g. flocculation of fibers).

Poor formation may also cause mottling when printing, i.e. the print density on the paper is non-uniform.

The uniformity of the paper can be adjusted by machine settings, by changing amount of retention agent, amount of dry mass, length-to-width ratio of fibers, etc.
COCKLING AND CURL

Cellulose fibers swell mainly in the cross direction (schematic drawing):

Fiber before water uptake  Fiber after water uptake

Swelling of the fiber mesh leads to cockling and curl.

The fibers become aligned in the machine direction in the paper making process.

MOTTLING

Upon printing, spatial variations in moisture content in the paper may also cause mottling (uneven print density).
MOTTLING

Possible reasons for mottling:

• Electrical conductivity variations in the paper due to poor formation.
• Electrical conductivity variations in the paper due to unevenly distributed moisture content in paper.
• Varying distance between paper and photoconductor drum.
PAPER FOR ELECTROPHOTOGRAPHY

... so we would like a paper with a smooth and even surface, with low or medium porosity, and preferably with a high surface energy for improved toner adhesion.

Since colour is transferred by electrostatic forces, runnability requires controlled moisture content and an optimization of the resistivity and the conductivity of the paper. The paper must also withstand temperatures of ~200°C for short periods of time.

SURFACE SMOOTHNESS

Surface roughness, or rather surface smoothness, is improved by coating.

Figures from Husum mill Paper school, courtesy of Husum mill, Örnsköldsvik.
COATED PAPER

Coated paper can be divided into

• Matte paper. Low gloss, does not produce disturbing reflections. Good for reading.
• Silk: been matte and glossy.
• Glossy paper: vibrant colours, disturbing reflections. Popular for printing of photos.

The coating consists of pigment (clay or Calcium Carbonate or Titanium dioxide), and casein, starch or latex, etc. as binder. The binder binds the pigments together and the pigments to the paper surface.

Clay:
• High gloss
• Smooth surface
• Low brightness

Ground Calcium Carbonate (CaCO₃)
• High brightness
• Low gloss

PCC (Precipitated CaCO₃)
• High light scattering

Figures from Husum mill Paper school, courtesy of Husum mill, Örnsköldsvik.
A comparison between different printing technologies

<table>
<thead>
<tr>
<th>Print technology</th>
<th>Viscosity Ink (Pa s)</th>
<th>Thickness (microns)</th>
<th>Resolution (µm)</th>
<th>Printing speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offset</td>
<td>40-100</td>
<td>1 µm</td>
<td>15 µm</td>
<td>10-15</td>
</tr>
<tr>
<td>Flexography</td>
<td>50-500</td>
<td>1 µm</td>
<td>40 µm</td>
<td>5-10</td>
</tr>
<tr>
<td>Gravure</td>
<td>50-200</td>
<td>1 µm</td>
<td>15 µm</td>
<td>5-15</td>
</tr>
<tr>
<td>Pad</td>
<td></td>
<td>5 µm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Screen</td>
<td>0.05-5</td>
<td>12 µm</td>
<td>50-100 µm</td>
<td>4500 copies/hr</td>
</tr>
<tr>
<td>Electrophotography</td>
<td>powder toner</td>
<td>5-10 µm</td>
<td>30 µm</td>
<td>2</td>
</tr>
<tr>
<td>Inkjet</td>
<td>1-15</td>
<td>0.5 µm</td>
<td>20-50 µm</td>
<td>2 (increasing)</td>
</tr>
<tr>
<td>Micro Contact</td>
<td></td>
<td>2 nm</td>
<td>30 nm</td>
<td>Slow</td>
</tr>
<tr>
<td>Micro-molding</td>
<td></td>
<td>100 nm</td>
<td></td>
<td>Very slow</td>
</tr>
</tbody>
</table>

DIGITAL PRINTING TECHNOLOGIES

- Digital Printing
  - Electro-photography (laser printing)
  - Inkjet
  - Other digital printing technologies
    - Ionography
    - Magnetography
    - Electrography
    - Thermography
    - ... and more

IONOGRAPHY

Ions are accelerated onto the imaging drum, giving a pattern of charges on the imaging drum. Toner is then transferred in a similar way as done for dry toner electrophotography. Printing of tickets, tags letters.
MAGNETOGRAPHY

The drum is being magnetized by sending a current through the coil of the imaging head. A magnetic field pattern is created on the drum. The toner contains iron oxide.

The toner does not give pure colours and is typically used for printing one colour (K).

ELECTROGRAPHY

Printing on paper coated with a dielectric. The imaging system creates a pattern of charges in the coating. The liquid toner is transferred to the charged parts of the coating.

Large format printing, but limited applications
THERMOGRAPHY

Direct thermography

Transfer Thermography

Thermal Transfer

Thermal Sublimation

SUGGESTED FURTHER READING


THANK YOU FOR YOUR ATTENTION!