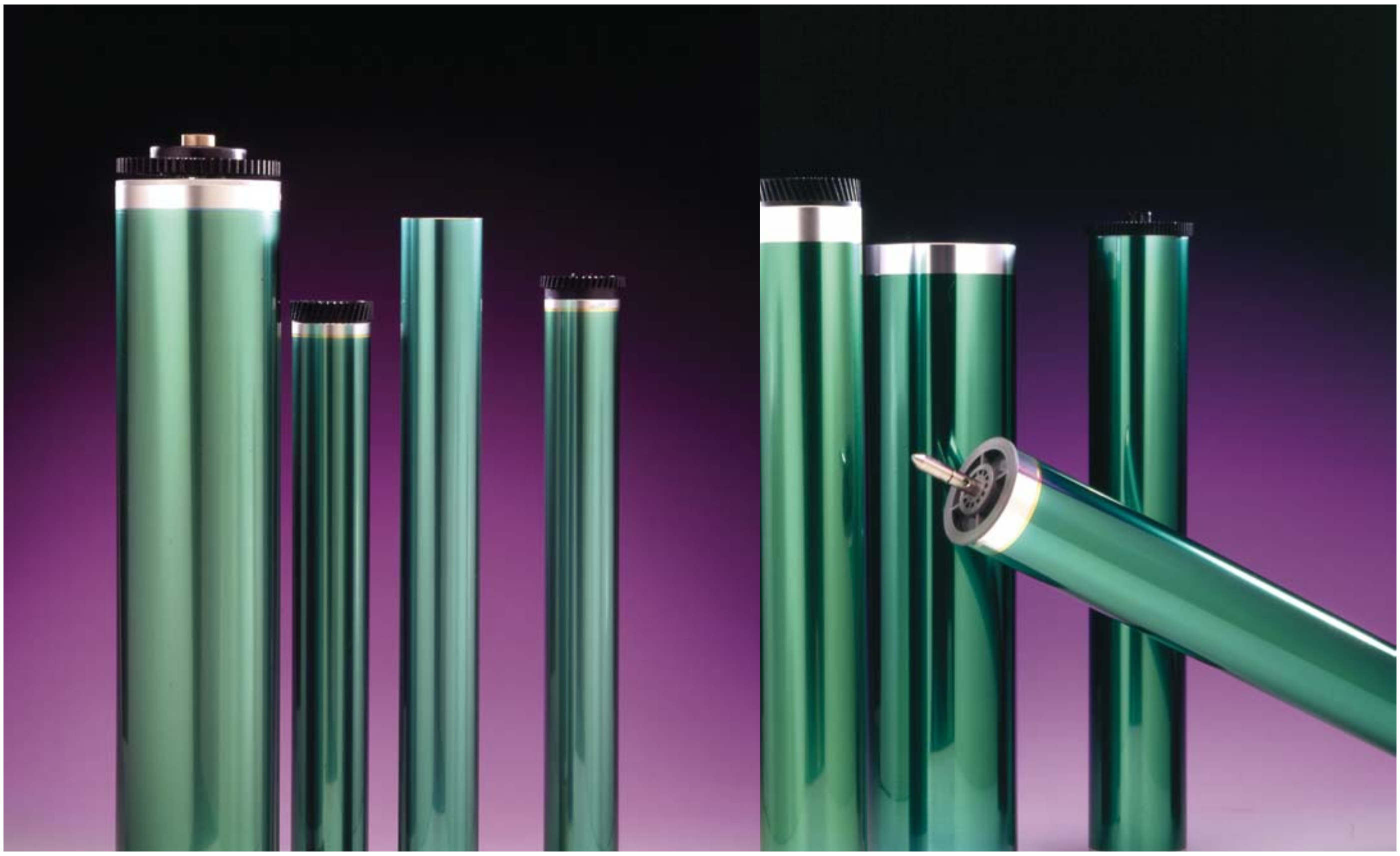
Photoreceptors

Static Control Components, Inc.
USA



Construction

The photoreceptor most commonly used in electrophotographic printer and copier cartridges consist of an aluminum tube coated with organic chemicals. The terms OPC (Organic Photo Conductor), drum and photoreceptor are used interchangeably in the remanufacturing business. The aluminum tube is about 10" long for portrait oriented printers and about 13" long for landscape oriented printers. The diameter of the tube ranges from less than 1" to over 1.5". The smaller the diameter, the more difficult it is for the printer designer to fit all components around the OPC drum. The drum is usually fitted with a helical drive gear on one end and a spur gear with electrical contact on the other end. For most Canon-based printer engines the electric input/output is on the left side, while the mechanical and drive gears are on the right side. The photoreceptor coating has several layers. The blocking or adhesion layer on the aluminum substrate provides a defect free and high adhesion surface. It also provides the proper electrical contact between the photoreceptor layer and the grounded substrate. The active portion of the OPC is formed by the charge generating layer (CGL) and the charge transport layer (CTL). On the top of the CTL there may also be a wear resistant layer.

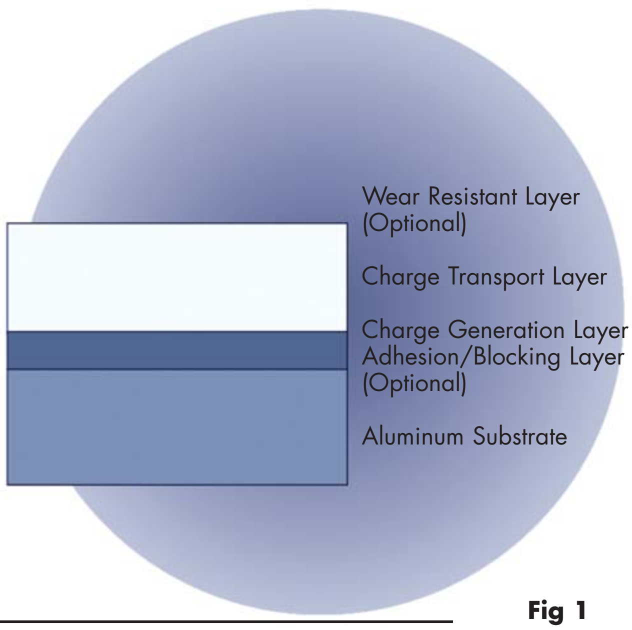


Fig 1

The commonly used materials require a 15-30 µm (Micron) thickness of the CTL to store 600-800 volts.

The CTL receives the charge from a corotron (corona wire) or primary charge roller (PCR) and stores it on the surface like a capacitor plate. The amount of surface charge stored is determined by the thickness and dielectric properties of this layer. The commonly used materials require a 15-30 µm (Micron) thickness of the CTL to store 600-800 volts. The CGL is a very thin layer which provides electrical insulation in the dark. However, when exposed to the laser beam the molecules in the layer become "activated". The activated molecules create electrical conduction through this layer which will then discharge the CTL. The charge image is created on the photoreceptor surface by selectively exposing the CGL with the laser beam.

Principles of Operation

An even surface charge is placed on the OPC during the charging step by a corona or primary charge roller (PCR). The surface charge will remain on the CTL surface as long as the CGL is not activated by the laser beam. Some charge decay in the dark can occur between charging and development. However, in most laser beam printers the latent charge image is developed within a few hundred milliseconds after charging and there is no significant decrease in surface charge.

At the exposure step a focused laser beam activates the CGL. The CTL must be transparent to the laser beam so that the CGL is exposed. A low cost semiconductor laser with radiation in the infrared (800 nm) is commonly used in desktop printers. The CGL molecules are selected to be most sensitive to this energy. The laser beam is scanned across the drum one line at a time using a rotating mirror and focusing lens. The actual exposure time at each pixel is very brief, usually well less than a microsecond. The number of charge carriers generated is dependent on the photogeneration efficiency of the molecules, the intensity of the laser beam and the length of exposure time. The photogeneration efficiency is the number of carriers generated for each unit of light. Once the charge carriers are generated in the CGL, they will cause the surface charge to move through the CTL under the influence of the electric field between the OPC surface and the aluminum substrate. It is the combination of their ability to move (mobility) and the number of carriers than determines the discharge of the OPC surface. The terms "hot" or "cool" drum are often used by remanufacturers to describe the combination of photogeneration efficiency and mobility of the photoreceptor. A "cool" drum has lower sensitivity to the laser beam. During the laser exposure time fewer charge carriers are activated in the CGL. The few charge carriers activated will cause only a minimal amount of charge to be removed from the OPC surface. Only the area immediately surrounding the laser beam spot will be discharged. (See FIG 4) For a "hot" drum many charge carriers are activated in the CGL for the same amount of laser energy. In this case additional charges will be removed from the CTL surface. However, since the charge is evenly placed by the corona or PCR on the surface, the additional charge must come from a wider area surrounding the laser spot. (See FIG 5) The wider area of discharge will increase the size of the development area and cause dots or thin lines to be visibly wider. As the characters are thickened, a text page will appear darker, although the print density is the same. The result, of course, is higher toner usage.

If the mobility of the CTL is low and charge is unable to move from the surface through the CTL during the time allowed, some charge will remain "trapped" in the layer. This is referred to as residual voltage. Some residual voltage is normal and will not

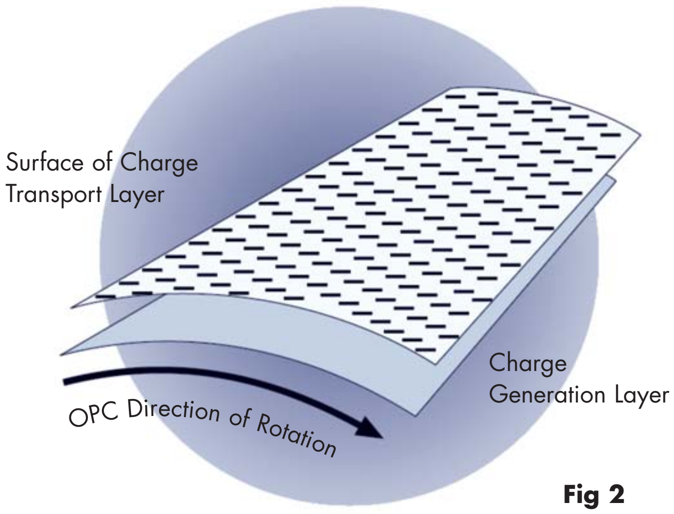


Fig 2

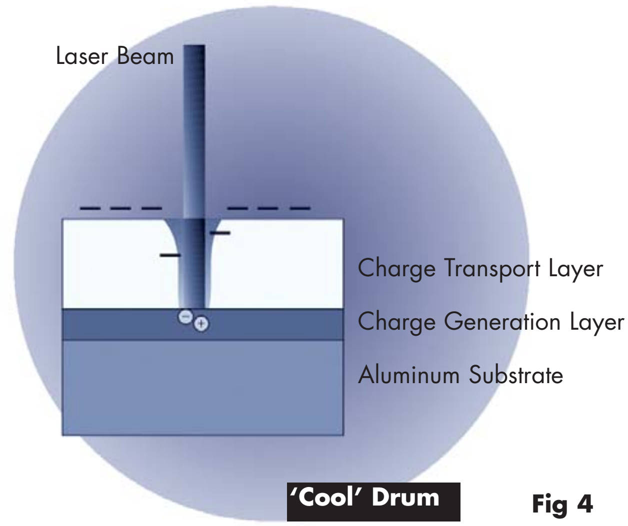


Fig 4

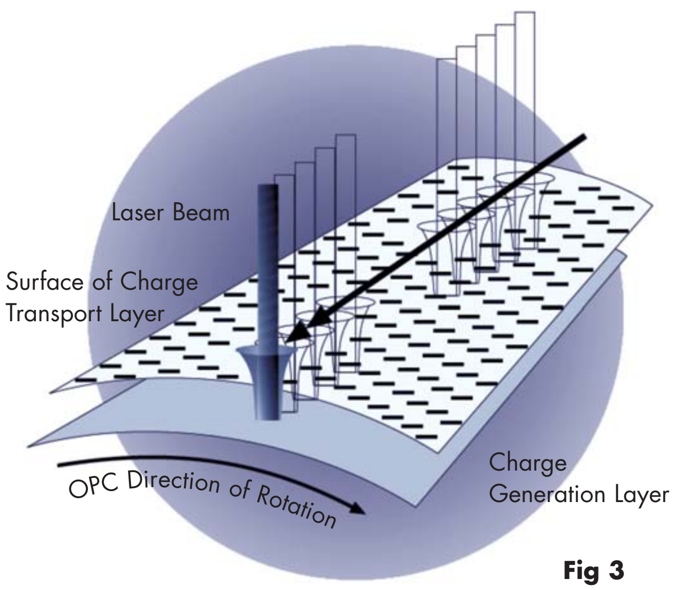


Fig 3

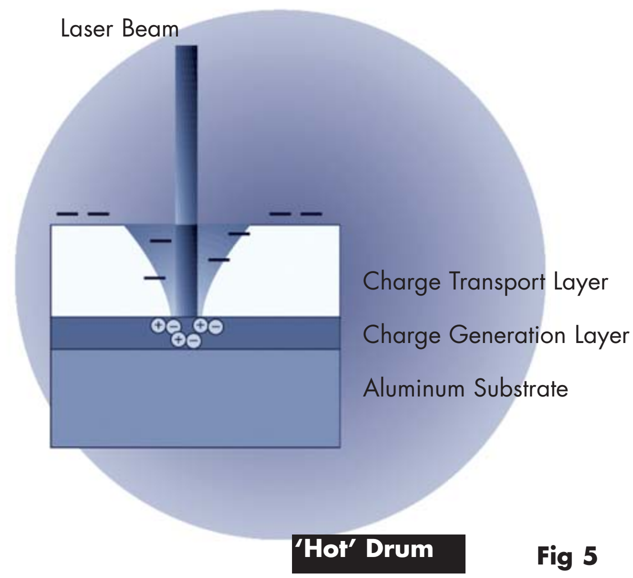


Fig 5

affect the print quality. If the residual voltage is too high then the image density will
decrease.

Chemistry of the OPC Coating

The CGL (Charge Generating Layer) consists of a photoactive molecule in a polymer matrix. The polymer is needed to provide both film forming and adhesion properties. The layer is very thin, usually less than 0.1 µm. Phthalocyanine based compounds are commonly used giving this layer a bluish (cyan) color. The thickness of the coating must be carefully controlled since the sensitivity of the OPC must be constant. Very little of the photoactive material is used, but it is expensive due to the manufacturing and purification techniques required. The specific molecules selected depend on the type of laser light and in many cases patent restrictions. The CTL (Charge Transfer Layer) consists of a mixture usually about half and half polycarbonate (or similar polymer) and a hydrazone compound. The ratio of the mixture often depends on a trade-off between wear resistance and electrical properties. To assure an acceptable discharge the layer must have high charge mobility. The layer must also be transparent to the laser light so that the CGL will be activated.

OPC Life Expectancy

An OPC will degrade from frictional wear, chemical degradation, light fatigue and electrical fatigue. Background, wear lines and light print will indicate the end of photoreceptor life. The CTL surface naturally wears as it is in contact with the developing toner, the paper at transfer, the wiper blade during cleaning and the charge roller during charging. It is also subject to physical mishandling, light fatigue and additional chemical degradation during the remanufacturing process.

In general the toner and wiper blade contribute most to the wear. A toner formulated without the proper lubricating additives will more rapidly degrade a drum. Specific additives are used to both prevent the toner from sticking to the drum and to lubricate the drum so that the wiper works effectively. High iron oxide toners, such as MICR toners, will wear a drum more rapidly. Using rough paper, excessively thick paper and envelopes will also wear the drum more rapidly.

Wiper blades with rough or wavy edges will wear and scratch the drum surface allowing toner to adhere. Higher wiper blade pressure on the drum is normally used with small particle size "micro" toners to clean the drum. This will usually result in higher wear rates. At the transfer step frictional contact between the drum and paper causes wear.

The toner transfer efficiency is the ratio of toner transferred to the paper to toner developed on the drum. It will directly affect drum wear. For example, a toner with only 88% transfer efficiency will leave twice as much toner on the drum as a toner with 94% transfer efficiency. It is this toner remaining after transfer which must be cleaned by the wiper blade. The type of image printed, text or graphics, and the percent coverage of print on the page will significantly affect the transfer efficiency and wear of the drum. A drum will show signs of physical wear about half way through its normal life. There is usually a slight decrease in density and toner usage. Generally, aftermarket drums are designed to be more sensitive to laser light, or "hotter", than the OEM drum. This property gives the drum its "longlife" feature as the normal wear affects will not be observable to the user until later in the life of the drum.

Light and electrical fatigue occurs when the OPC no longer fully discharges the surface with exposure to the laser beam. The dark area print density becomes lighter and the text characters appear "thinner". The drum appears to become less sensitive to light or "cooler" as the carrier generation efficiency and the charge mobility are decreased.

Principles of Laser Printing

Each printer operates at a specific imaging process speed. This is easily determined by measuring the speed of the paper exiting the printer. For the HP printers series LX, SX, NX the process speed is 24 mm/sec, 48 mm/sec and 96 mm/sec. The process speed cannot be exactly calculated from the published "pages per minute" since there is a space, or time, between sheets needed for registration and stacking in the output tray.

It is this process speed that determines the time allotted for each process step: erasure/charging, exposure, development, transfer, fusing and cleaning. As the process speed increases each step has less time. The charging step requires that the corona or primary charge roller (PCR) supply an equal amount of surface charge to the OPC at each speed. Charge per unit time (electrical current) must therefore increase with increasing process speed. For example, an EX (LJ4) PCR must provide twice the electrical current of an LX PCR, while and NX PCR must supply 4 times the LX electrical current. In addition if there is an AC voltage assisting in the charge transfer from the PCR to the drum, the AC frequency must be increased at the same ratio. During the exposure step, the charge at each image pixel must be dissipated. As the process speed increases there is less time for each laser scan. If the laser energy is not increased, then the sensitivity of the OPC to light must be increased to assure the same charge dissipation. In general printer engines (and cartridges) are designed to operate at the highest process speed, although the initial printer introductions may operate at a slower process speed. For example the Hewlett Packard LaserJet 4 was introduced at 8 pages per minute (48 mm/sec) with the next version, the LaserJet 4 Plus, at 12 pages per minute (72 mm/sec) More recently the Apple 1600 was introduced using the same EX engine at 16 pages per minute (96 mm/sec). This progression of increasing process speed could be expected since the OPC in the EX engine is about 8 times more sensitive to laser energy than the typical SX or NX OPC. The exposure system is capable of even higher process speeds. One should expect additional EX based printers to have 24 or even 32 pages per minute. The printer resolution, more precisely the dot size and placement, has been increasing from 300 to 600 and more recently to 1200 dots per inch. The OPC must be capable of producing smaller and smaller image dots with minimal laser energy. This is accomplished by using relatively "cooler" drums with thinner charge transport layers. This increase in total pixels per page challenges the development system as well as the memory capabilities and data transfer speed of the printer controller. A 300 dpi 8" x 10" print area requires 7.2 Mb of memory and transfer rate, while the same page at 1200 dpi requires 115.2 Mb of memory.

Drum wear should be measured in terms of drum rotations. Short print runs of one or two pages can result in more drum rotations per page than long print runs and give the effect of shorter drum life. A general rule may be 75,000 - 100,000 drum rotations for a typical drum before failure. The concept that an aftermarket drum will operate "acceptably" for a specific number of remanufacturing cycles is difficult to understand from a technical point of view. It is, of course, critical from the business point of view. The variety of factors discussed here which may affect the degradation of the drum and the difficulty in defining "failure" has made this a constant issue between drum suppliers and remanufacturers.

Drum Coating

Overcoating the drum with an aftermarket "hardcoating" is done when the drum is otherwise not usable. This practice, of course, in not advisable, nor is it usually cost effective. Recoating a drum will not bring the drum back to its original condition. The overcoating does not replace the specific hydrazone/polymer coating of the original drum and cannot operate as a normal CTL. Because this overcoated layer is usually very thin it is relatively harmless. However, if the overcoated layer is thick, then the charge and discharge of the drum and may be adversely affected. Any colorant or IR (infrared) absorbing materials in the overcoating will absorb laser light needed for charge carrier generation.

Improperly formulated or incompletely cured overcoatings can affect the wiper blade's cleaning process. The lubricating properties of the toner may not longer work with a specific overcoating and a new toner formulation may be required. The overcoated layer can trap charge and increase the residual voltage.

About the Author

Dr. John Wyhof is the Technical Director of the Imaging Supplies Division of Static Control and heads the system development laboratories. Dr. Wyhof's responsibilities as Technical Director encompass product development, system matching, quality control, technical vendor relationships and technical support.

The Future of OPCs

The OPC will continue to be the most critical part of the electrophotographic process in cartridge based printers. Understanding of the OPC properties and their relationship to other cartridge parts will become more important in the future. The printer resolution, process speed and cartridge life will be extended by the printer engine manufacturers. This will require the remanufacturer to follow.