Organic Photoconductors for Printers

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1. Introduction

With changes in the printer business such as the growth of inkjet printers as personal-use low-speed printers and the arrival of the network age, the market for high-speed, MFP (multifunction peripheral) and full color electro-photographic printers is expected to expand, and in contrast, the market for low-speed printers with simple functions will contract as shown in Fig. 1.

In keeping with this market trend, requirements of functionality and quality for photoconductors as major printers components are increasing year by year. Fuji Electric has developed and manufactured negative-charging and positive-charging OPCs (organic photoconductors) to meet these various needs.

This paper presents a general overview and describes the performance of negatively-charged OPC products including facsimile machines, plotters and MFPs.

2. Overview of Negatively-charged OPC

Figure 2 shows the layer structure of a negatively-charged OPC composed of aluminum conductive substrate, a resin UCL (under coat layer) to block positive charge and to prevent exposure interference, a CGL (charge generation layer) and a CTL (charge transport layer) layered in turn one above the other.

The CGL is composed of CGM (charge generation material) and binder resin, and provides a charge generation function when exposed to light from a laser or LED (light emitting diode). The CTL is composed of CTM (charge transport material) and binder resin, and functions to transport charges generated in the CGL to the CTL surface.

Fuji Electric provides a series of three products, having low-, medium- and high-sensitivities, corresponding to the CGM's characteristics. This enables correspondence to the various exposure quantities shown in Table 1.

Half decay exposure can be adjusted within the range of 0.08 to 0.60 μJ/cm², in addition to strict control of the CGL layer thickness as shown in Table 1.

Figure 3 shows the respective spectral sensitivities of the low-, medium- and high- sensitivity types. Every type provides flat panchromatic characteristics in the wavelength range of 600 to 800 nm and is suitable for generic lasers or LED light sources. By

Fig.1 Market trend

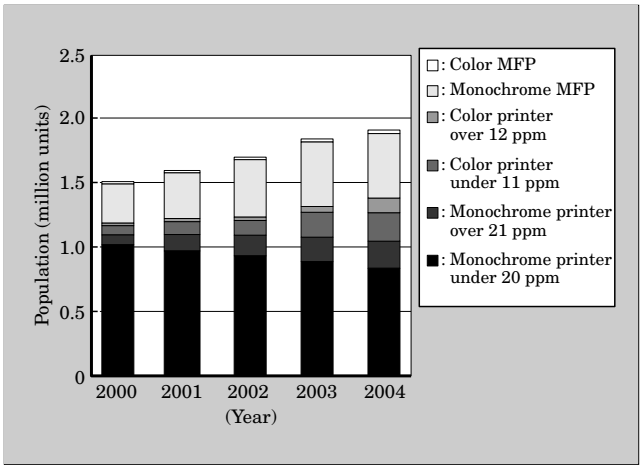


Fig.2 Layer structure

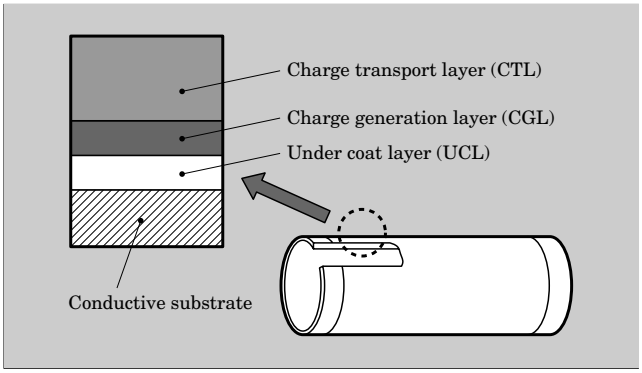
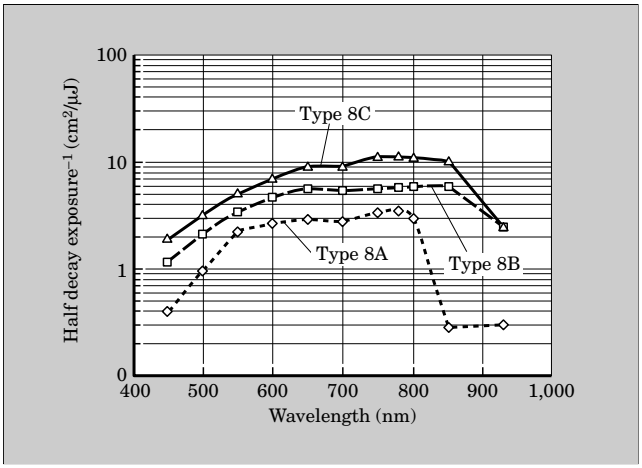


Table 1 Product outline

Type	Sensitivity (Half decay exposure)	Print speed
8A (Low sensitive)	0.20 to 0.60 μJ/cm²	Up to 20 ppm
8B (Mid. sensitive)	0.13 to 0.20 μJ/cm²	Up to 40 ppm
8C (High sensitive)	0.08 to 0.13 μJ/cm²	40 ppm≦

Fig.3 Spectral sensitivity



combining these CGL and CTL, OPCs can be provided that are suitable for printers having a wide range of speeds, from 20 pages per minute (ppm) or less to 40 ppm or more.

Since OPCs can be provided with outer diameter ranging from 24 mm to 262 mm and length ranging from 246 mm to 1,000 mm, a wide range of products from A4 size page-printers to A1 size plotters has been developed.

3. Performance of Negatively-charged OPCs

In order to supply OPCs that satisfy the three major requirements of the printer market, namely high-speed, multifunction and full-color, Fuji Electric has classified the OPC requirements as shown in Fig. 4, and has undertaken the challenge of solving the respective technical problems. The respective performance of each characteristic is described below.

3.1 Technology for high sensitivity

In order to satisfy the requirements for A4 size laterally-fed high-speed printers having speeds of 40 ppm or more, although there is a dependence on the process layout, the optical sensitivity must be flat during a processing time of 80 ms or less, from exposure to development. To fulfill this requirement, Fuji Electric has developed CTMs with 5×10^{-5} cm^2/V·s that are suitable for high-speed printers.

Figure 5 shows the dependency of exposed surface potential versus the processing time from exposure to development. For a high-speed type CTM, the exposed surface potential is almost flat down to a 60 ms processing time from exposure to development, and therefore this CTM provides performance that is suitable with the above process. In addition, as shown in Fig. 6, environmental fluctuation of the exposed surface potential of this OPC is excellent since it is not more than 20 V.

Fig.4 Performance and quality required by OPC

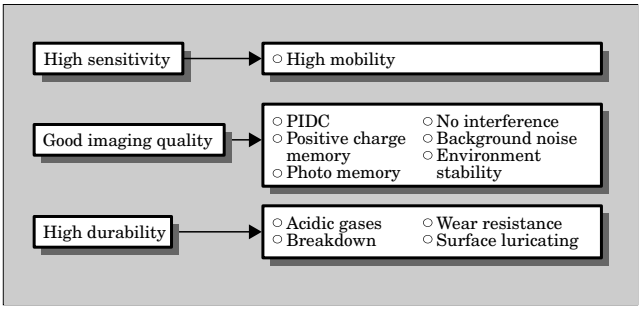


Fig.5 Photo response

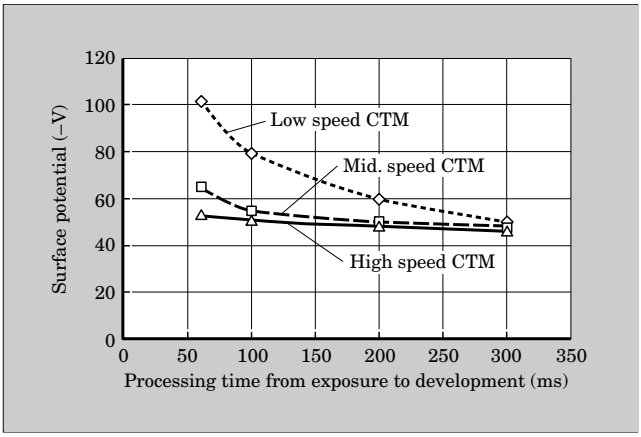
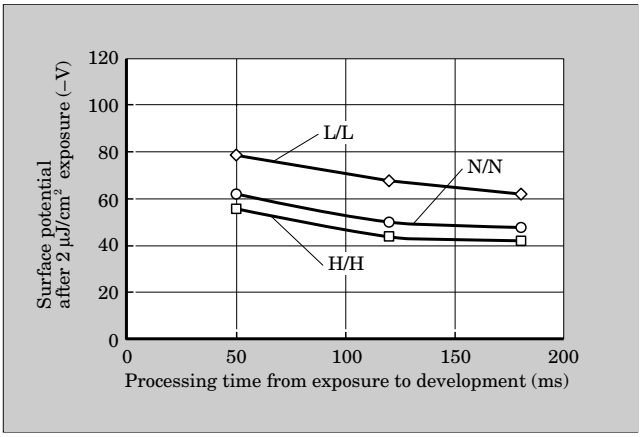


Fig.6 Environmental stability of photo response



3.2 Technology for good imaging quality

3.2.1 Photo-induced decay characteristics

For MFPs having a copying function, tone reproducibility is required similarly as for the OPCs for digital PPCs.

Printers are advancing toward higher resolutions, from 600 dpi (dots per inch) to 1,200 dpi or more, and together with advances in peripheral processes such as the fabrication of finer toner or implementation of the fine control of laser beam emission, improvements in graphical imaging quality are being sought more and more. Fuji Electric has developed and manufactured OPCs whose photo-induced decay characteristics are

optimized to various machine processes so that high imaging quality, and in particular high resolution, is achieved.

Figure 7 shows an example of the photo-induced decay characteristics for each type of OPC made by Fuji Electric. Because this characteristic highly depends on carrier injection efficiency from the CGL to CTL, the characteristic may be adjusted by combining CGL and CTL.

3.2.2 Resistance to opposite polarity charge

Negatively-charged OPCs are charged with a positive charge on a drum at the transfer section. Depending on the process conditions, a positive charge-induced memory condition may occur in which half-tone images are shaded due to the effect of the positive charge. As the imaging quality of printers advances, the shading of printed letters has come to be easily reproduced by small potential differences, and thus the requirements for resistance to positive charge have increased more than before.

Fuji Electric has endeavored to reduce the affect of positive charge by optimizing the materials utilized in each layer of ULC, CGL and CTL based on the knowledge accumulated thus far.

Table 2 lists the positive charge characteristics of the improved and conventional type products. The surface potential difference at on/off of positive charge is improved to less than 1/3 of the conventional type, and therefore the positive charge-induced memory does not occur even for half-tone images at the 600 dpi MFP copy mode.

Fig.7 Photo induced decay

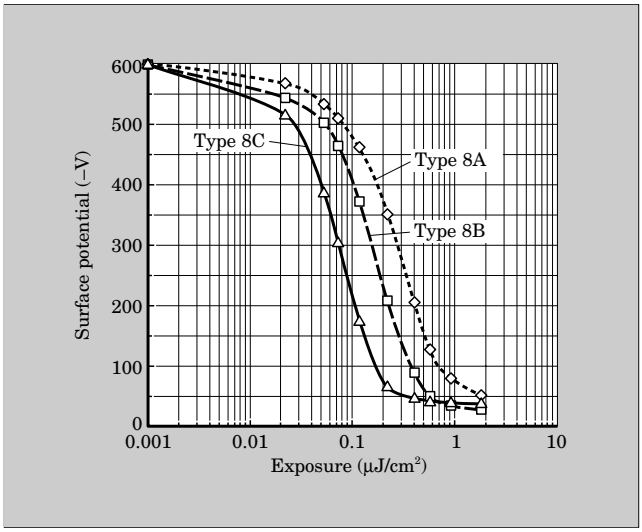


Table 2 Positive charge-induced memory characteristics

Type	Surface potential at non positive charge	Surface potential at positive charge add	Δ	Print quality
Old type	–610 V	–575 V	35 V	Poor
New type	–615 V	–605 V	10 V	Good

3.2.3 Control of fatigue characteristics after strong exposure

Even minute differences of potential may disturb the image of a photo-induced memory due to the same reason as a positive charge induced memory, and therefore OPCs having low exposure-fatigue characteristics are required. Figure 8 shows a comparison of strong exposure fatigue characteristics of OPCs made by Fuji Electric and other manufacturers. In both the cases of strong exposure at 1,000 lx and long-term weak exposure at 200 lx, excellent characteristics of almost no potential drop are observed.

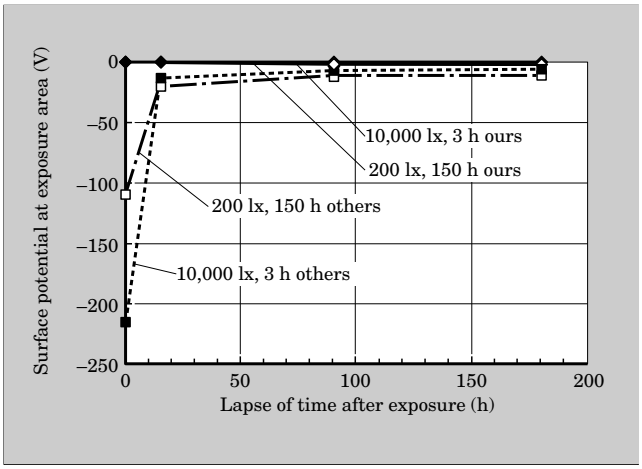
3.2.4 Control of interference for exposure light

In the case of a laser light source, there will be interference in the incident light if the reflectivity of the conductive substrate surface is high. Because this interference causes shading to appear on half-tone images, a function to control the interference of exposure light is necessary to for OPCs used in printers. In general, interference control is implemented by fine machining of the substrate surface, but Fuji Electric realizes a light interference countermeasure by providing sufficient interference control function in the UCL, without machining the surface of the raw tube. On the other hand, Fuji Electric possesses unique technology for finely machining the substrate surface in order to support processes of modern color printers in which even minute interference is imaged.

3.2.5 Control of background noise

Requirements are increasing for better control of background noise than in conventional printers. This trend is especially noticeable for OPCs used in full-color printers that employ a color superimposing process. Background noise is a phenomenon in which toner adheres to an area of white paper and is caused by the charge potential drop on a drum surface due to the injection of charge at a small area from the substrate side. Fuji Electric is striving to control background noise by reducing the minute defects that cause charge injection from the substrate side. These defects can be prevented by selecting the optimum

Fig.8 Fatigue characteristics after strong exposure



substrate material and by unrestrained use of substrate cleaning technology, UCL material technology and painting technology.

3.2.6 Environment stability and durability of printing

OPCs are required to be unaffected by the environment during their prescribed life in order to maintain the initial imaging quality.

Figures 9 to 11 show measured data of the surface potential of commercially available MFPs equipped with an OPC having a diameter of 30 mm. These measurements were performed for 25,000 A4 size vertically-fed prints in the 2-print intermittent mode under conditions of normal temperature and normal humidity environment (N/N), low temperature and low humidity environment (L/L), and high temperature and high humidity environment (H/H) respectively, and the potential was measured every 5,000 prints. The measured results show excellent characteristics in every environment with no large potential fluctuation.

Fig.9 Surface potential stability by printing (N/N)

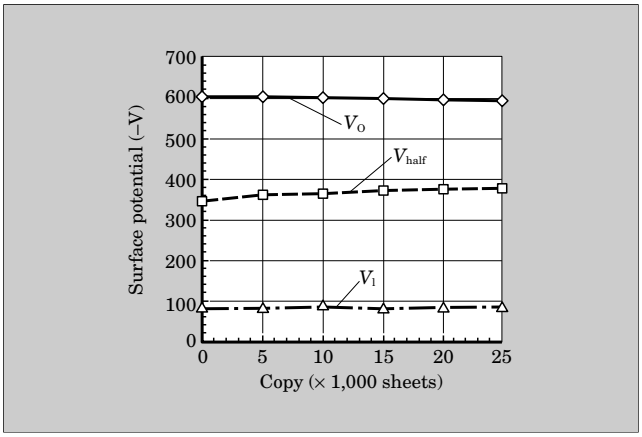


Fig.10 Surface potential stability by printing (L/L)

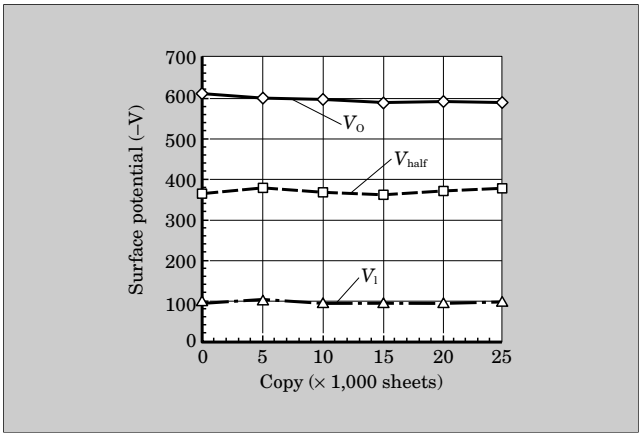
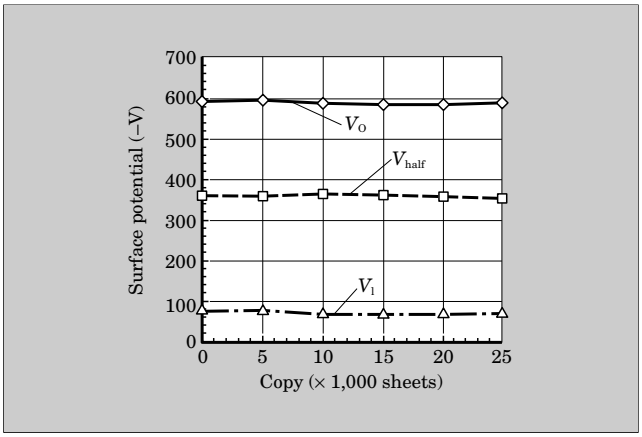


Fig.11 Surface potential stability by printing (H/H)



3.3 Technologies for high durability

3.3.1 Resistance to acidic gases

The contact charging method with rollers and brushes is the leading technology for page printers or personal-use MFPs, on the other hand, the corona charging method is still popular in large size printers or plotters and resistance to acidic gases such as ozone is required.

Various anti-oxide agents are used in OPCs, however, although increasing the quantity of agent improves the resistance to acidic gases, it leads to adverse electrical characteristics such as residual potential rise. Fuji Electric ensures sufficient resistance to acidic gases by utilizing material with deep ionization potential in the CTM, and also by combining appropriate anti-oxide agents. Specifically, appropriate anti-oxide agents having various actions are combined in the CTM for the purpose achieving maximum effect with least quantity.

3.3.2 Resistance to dielectric breakdown

The contact charging method is the leading technology for medium speed printers or MFPs as mentioned in section 3.3.1, and resistance to dielectric breakdown is required strongly compared with the corona charging method. Fuji Electric has developed and manufactured a UCL that provides resistance to dielectric breakdown which is equivalent to that of an anodized layer membrane (ALM). Table 3 shows the evaluated results of resistance to dielectric breakdown measured by fixing a charging component connected to an external power source on the drum surface. It is clear that resistance to dielectric breakdown of the

Table 3 Resistance to dielectric breakdown

Type	Supplied voltage to contact film (–kV)				
	6.0	6.5	7.0	7.5	8.0
ALM-Sample 1	Good	Good	Good	Good	Poor (breakdown)
ALM-Sample 2	Good	Good	Good	Poor (breakdown)	Poor (breakdown)
ALM-Sample 3	Good	Good	Good	Good	Good
UCL-Sample 1	Good	Good	Good	Poor (breakdown)	Poor (breakdown)
UCL-Sample 2	Good	Good	Good	Good	Poor (breakdown)
UCL-Sample 3	Good	Good	Good	Good	Good

UCL, similar to the case of the ALM, is provided up to 7 kV or higher.

3.3.3 High wear resistance

Life of the OPC is affected by the imaging system, through wear due to contact components such as the cleaning blade and paper, scratches that cause printing trouble and adhesion of toner or paper powder to the surface of the OPC (filming). Although the extent of these factors differs widely according to the respective component of the OPC or process design, high wear resistance, high hardness and low filming characteristics are required for OPCs.

Fuji Electric has also developed a resin having high wear resistance and lubricity through novel structural design of the OPC for digital PPC, and has endeavored to incorporate this resin into various process by adjusting its composition.

4. Conclusion

The characteristics required of photoconductors will advance much more in the future as electrophotographic printers evolve toward multi-functionality and high quality, and the functional classification between printers and PPCs will disappear. Fuji Electric will endeavor to provide excellent products that are friendly to the environment by pioneering development and manufacture of OPC products to meet market needs, together with promoting consistent development and manufacturing that includes cartridges.

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