Organic Photoconductors for Digital Plain Paper Copiers

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1. Introduction

With the recent trend toward digitalization there has also been an increase in digital products in the copier market. In accordance with this increased digitalization, copier technology is trending towards colorization and higher speeds, higher image quality, better stability and lower cost than conventional analog copiers. Accordingly, photoconductor characteristics such as sensitivity, durability, environmental stability and reliability are being improved.

Fuji Electric supplies organic photoconductors (OPCs) as a type 9 series for use in analog copiers and a type 10 series for use in digital copiers. This paper presents an overview of the type 10 series of OPCs for use in digital copiers.

2. Product Overview

Copiers that use OPCs can be categorized according to their copying speed as low-speed copiers (up to 20 sheets-per-minute), medium-speed copiers (20 to 50 sheets-per-minute) and high-speed copiers (50 sheets-per-minute and above). Fuji Electric is developing three types of OPCs (10A, 10B and 10C) to support these different types of digital copiers. Typical characteristics of these types of OPCs are listed in Table 1. The applicable sensitivity range differs for each type of OPC and customers are free to select a desired type to meet their needs.

Figure 1 shows a block diagram of the OPC structure and operating principle. A multilayer OPC having distinct functional layers is formed by applying an undercoat layer (UCL) on top of a cylindrical conductive substrate made of aluminum or the like, and then by applying a charge generation layer (CGL) on top of the UCL, and finally by applying a charge transport layer (CTL) on the CGL as the top surface.

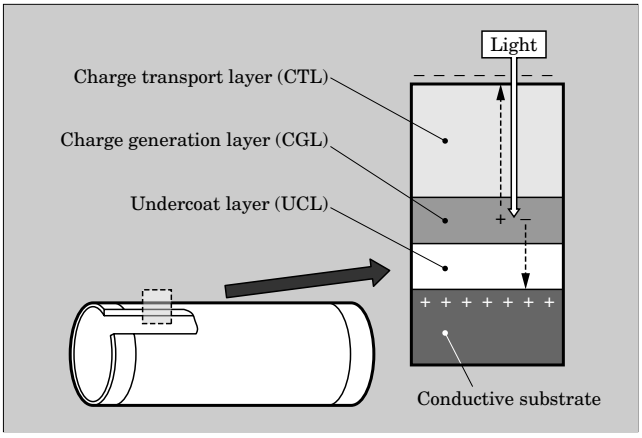
3. Product Characteristics

With the migration from analog to digital technology, copiers have achieved higher speeds, higher image quality and higher reliability. As such, an increasingly diverse and higher level of characteristics are being required of OPCs and new materials are being developed to support these required characteristics.

Table 1 Typical characteristics

Type	Half decay exposure for adopted sensitivity band ($\mu J/cm^2$)	Half decay exposure ($\mu J/cm^2$)	Retentivity [after 5 s] (%)	Residual potential (–V)	Applied range of copying speed (sheets /min)
10A (low sensitivity)	0.20 to 0.60	0.37	97.5	52	Up to 40
10B (medium sensitivity)	0.12 to 0.24	0.17	95.8	21	20 to 60
10C (high sensitivity)	0.06 to 0.14	0.07	96.1	6	Over 40

Fig.1 Structure and operation principle of OPC for digital copiers



Fuji Electric's copier-use OPCs can be installed in low-speed, medium-speed and high-speed copiers and are provided with the following features.

(1) High sensitivity
(2) High responsiveness
(3) High durability
(4) High environmental stability
(5) High reliability

3.1 High sensitivity

Because digital copiers use lasers or light emitting diodes (LEDs) as exposure sources, their OPCs are required to be sensitive to wavelengths ranging from 600 to 800 nm. Fuji Electric uses a phthalocyanine pigment which exhibits good sensitivity characteristics in this wavelength range. Figure 2 shows the spectral sensitivities of the low-speed type 10A, medium-speed type 10B and high-speed type 10C OPCs.

Figure 3 shows the photo-induced discharge characteristics of these OPCs. High-speed OPC type 10C has higher sensitivity than types 10A or 10B by 50 % and 30 %, respectively. Moreover, each type exhibits a sharp reduction in the vicinity of the residual potential and this is advantageous for the design of the digital copying process in a copier.

3.2 High responsiveness

Within a wide lineup of digital copier machines, from low-speed machines to high-speed machines, higher responsiveness is especially required of OPCs for super high-speed machines having greater than 100 sheets-per-minute capacity and which target the on-demand copying market, the point of purchase (POP) advertising field and the like.

The key points to enhancing responsiveness are mobility of the material, a consistent ionization potential among materials, and purity. Therefore, in order to realize high responsiveness, Fuji Electric investigated high mobility charge transport materials (CTMs) and developed a high mobility CTM having a mobility of 7×10^{-5} cm²/V·s, which is greater than 10 times the performance of a conventional product. Figure 4 shows the dependence of surface potential after exposure on the exposure-development time and Fig. 5 shows the development characteristics when installed in a copier. A highly responsive OPC that employs high mobility CTM stabilizes within an exposure-development time of 0.05 seconds. This performance provides sufficient support for high-speed processes of 45 sheets-per-minute or more in the case of an OPC having an external diameter of 30 mm or 105 sheets-per-minute or more in the case of an OPC having an external diameter of 100 mm. Also, the copy quality (black density) is improved compared to prior products, thereby enhancing reproducibility.

Fig.2 Spectral sensitivities

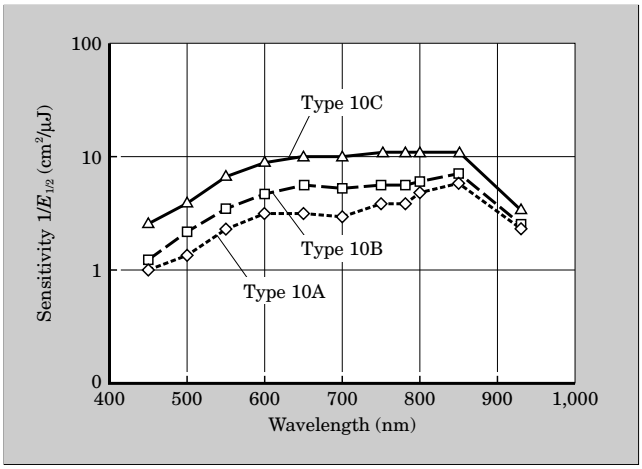


Fig.3 Photo-induced discharge characteristics of OPC

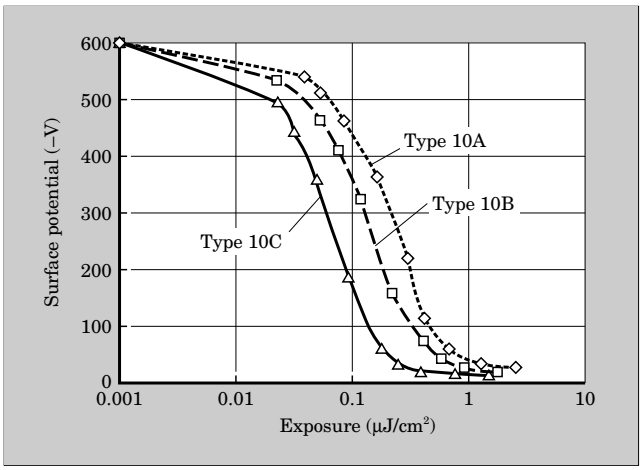


Fig.4 Time dependence of exposure-development (surface potential after exposure)

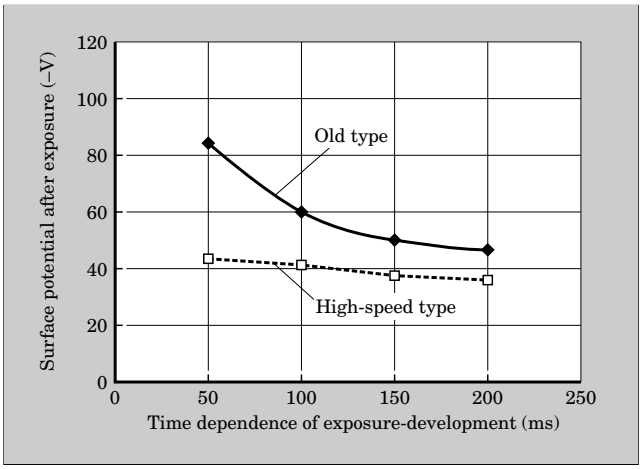


Fig.5 Developing characteristics

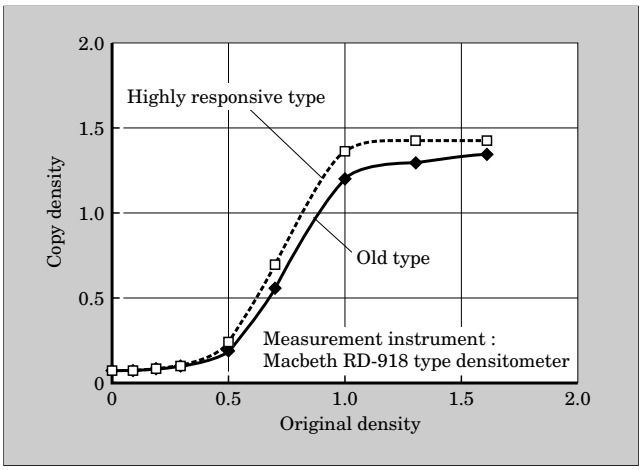


Fig.6 Running characteristics (charge acceptance)

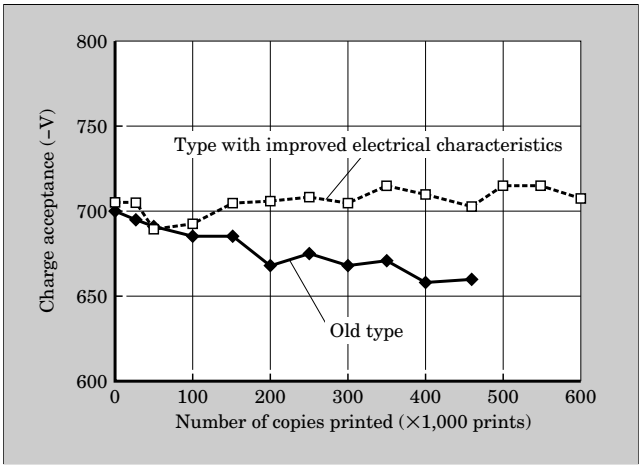


Fig.7 Running characteristics (surface potential after exposure)

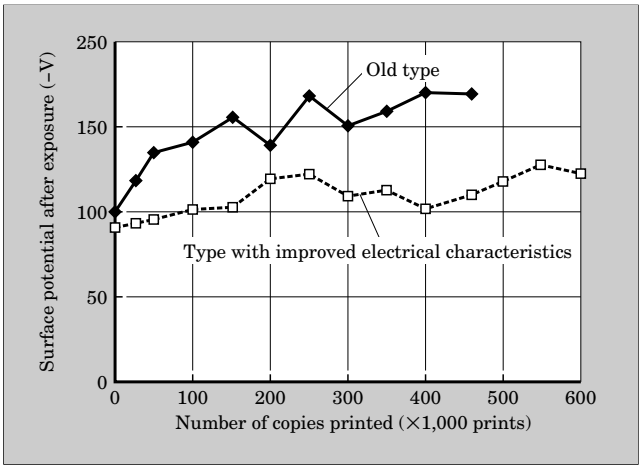


Fig.8 Mechanical characteristics

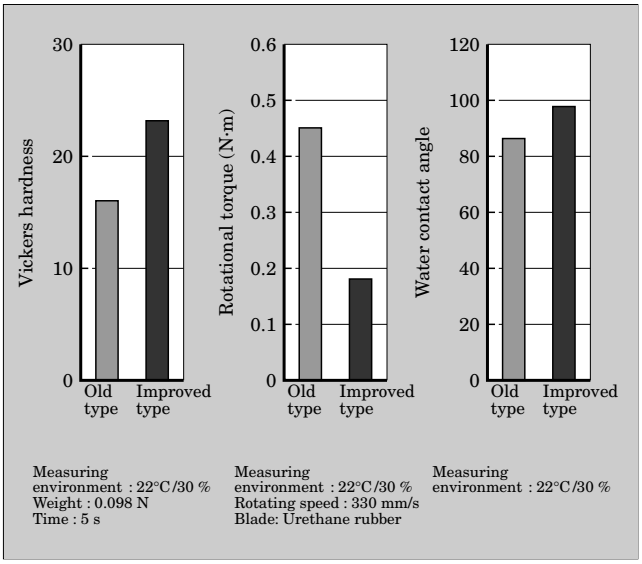
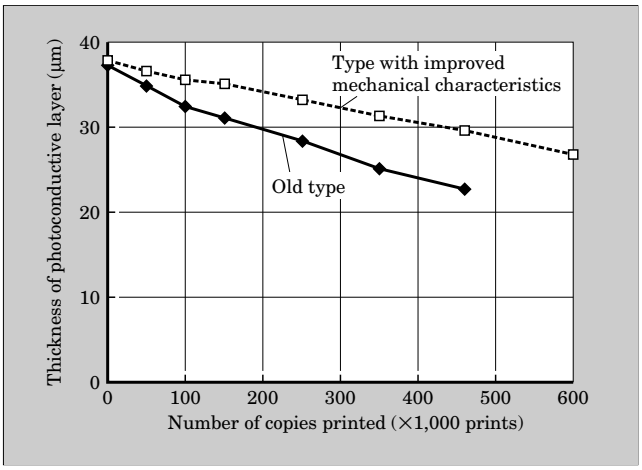


Fig.9 Running characteristics (abrasion)



3.3 High durability

Because OPCs have a high frequency of use, and in order to simplify the maintenance of a copier in which an OPC is installed, OPCs for digital copiers are required to have approximately 2 to 10 times higher durability than printer-use OPCs. This higher durability is realized through improvements to the electrical and mechanical characteristics of the OPC.

(1) Improvement of electrical characteristics

The repeated exposure of the OPC to ozone generated by the corona discharge during the charging process and to light during the exposure process causes the functional material to undergo a change in its chemical properties. As a result, electrical characteristics deteriorate, for example, a decrease in charge acceptance or a rise in residual potential occurs, causing such problems as blank pages or low print density. By developing a proprietary charge control agent that suppresses the occurrence of electrical defects in the photoconductive layer and by maintaining a consistent ionization potential among the OPC layers, Fuji Electric is able to suppress this decrease in charge acceptance and increase in residual potential and to supply an OPC that operates stably in various machine processes.

Figures 6 and 7 show the change in surface potential for an OPC evaluated in a digital copier in which a high degree of durability (a guaranteed OPC service life of 460,000 printed sheets) is required. As can be seen, the OPC having improved electrical characteristics exhibits less fluctuation in potential than a conventional OPC, indicating excellent operating stability and minimal change in the picture quality.

(2) Improvement of mechanical characteristics

Contact between the OPC and the charging roller, toner, paper, transfer roller, cleaning blade and the like degrades the physical and mechanical characteristics of the OPC by causing wear and scratching of the photoconductive layer and the adhesion of toner or paper dust particles. The degree to which this degradation occurs varies according to the machine process, but is largely dependent on the properties of

Fig.10 Environmental surface potential characteristics

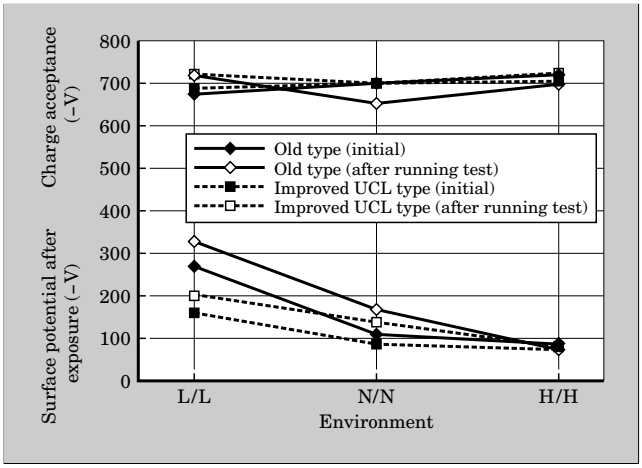


Table 2 Environmental reliability tests

Item	Condition
Ozone exposure test	100 ppm, 2 h
Light-induced fatigue test	1,000 lx, 5 min
High temperature exposure test	45°C, 1,000 h
High humidity exposure test	40°C, 90 %RH, 1,000 h
Low temperature exposure test	–20°C, 1,000 h
Cyclic test of temperature and humidity (5 cycles)	20°C, 1 h →Normal temperature, normal humidity, 0.5 h →45°C, 1 h →Normal temperature, normal humidity, 0.5 h –20°C, 1 h

the binder, which is a component of the CTL. By installing durability test equipment to evaluate the binder performance within a short time interval and by performing an accelerated evaluation test, Fuji Electric has successfully achieved a dramatic increase in binder performance.

Because the binder in the CTL has a polymer structure and uses material having excellent lubricating properties, it increases film hardness while reducing the frictional coefficient between the OPC and the cleaning blade. Figure 8 shows the mechanical characteristics (Vickers hardness, OPC rotational torque and water contact angle) and Fig. 9 shows an example of the improved wear characteristics of the photoconductive layer in a digital copier. By reducing the friction with other contact parts, wear and scratching of the photoconductive layer have been reduced and the service life of the OPC has been increased by approximately 50 %. Fuji Electric is working to further increase the OPC service life as an environmental measure to reduce the amount of used OPC that is discarded as waste.

3.4 High environmental stability

The OPC is desired to be environmentally stable in order to support usage in a variety of copier environments.

Table 3 Ozone resistance characteristics (type 10C)

Measurement time	Half decay exposure ($\mu J/cm^2$)	Retentivity (after 5 s) (%)	Residual potential (–V)
Before exposure	0.07	96.0	6
Immediately after exposure	0.07	94.4	10
24 hours after exposure	0.07	95.2	8

Table 4 Light-induced fatigue of OPC (type 10C)

Measurement time	Charge acceptance (–V)
Before exposure	610
Immediately after exposure	585
1 hour after exposure	590
24 hours after exposure	607

Fuji Electric has optimized the UCL filler and binder and suppressed fluctuations in volume resistivity due to the environment in order to ensure stability in normal temperature and normal humidity (N/N), low temperature and low humidity (L/L) and high temperature and high humidity (H/H) environments. Figure 10 shows measured data of the initial potential and the potential after printing 600,000 sheets. The figure shows good characteristics with little change in any of the abovementioned environments.

3.5 High reliability

Environment testing was performed as shown in Table 2 in order to assess OPC reliability. Ozone resistance characteristics were tested in an environment of ozone which was assumed to be generated by the corona discharge in a copier. Test results are shown in Table 3. There is almost no change in characteristics after 2 hours of exposure at an ozone concentration of 100 ppm. The light-induced fatigue test assumes that the OPC is exposed to light while maintenance is performed, and test results are shown in Table 4. The various characteristics remain stable after exposure for 5 minutes to a fluorescent light at an intensity of 1,000 lx.

4. Conclusion

In the copier market digitalization is driving a trend toward multifunctional machines that combine printer, copier and facsimile capabilities in a single unit and is eliminating the distinction between printers and copiers in the low and medium-speed fields. In the high-speed field, however, operating stability of twice to 10 times that of printers is required. Fuji Electric intends to continue to develop desirable OPCs by accurately assessing required characteristics in accordance with market needs.