Organic Photoconductors for Digital Plain Paper Copiers

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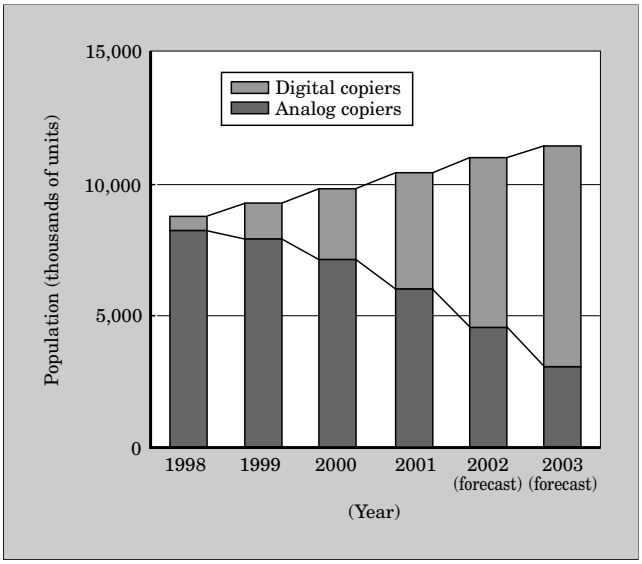
1. Introduction

Following the technical trends of the copier market each manufacturer has sought to realize higher speed, less maintenance and lower cost. In order to satisfy these requests, they have improved the sensitivity characteristics, stability and durability of photoconductors. Organic photoconductors (OPC) have developed especially rapidly because they are suitable for miniaturizing (diameter), can be manufactured at low cost, and furthermore they can be easily disposed of.

With the recent digital boom, digitalization has been progressing in the copier market too. Figure 1 shows the change in population of digital and analog copiers in USA market. The percentage of digital copiers was just under 30 % in 2000, but is estimated to grow to about 75 % in 2003.

Fuji Electric provides the type 9 series OPC for analog copiers and the type 10 series OPC for digital copiers. In this paper, we shall introduce an outline of the type 10 series OPC for digital copiers.

Fig.1 Population of digital copiers and analog copiers



2. Outline of the Product

Copiers that employ OPCs are classified as low-speed copiers (3 to 12 prints/min), medium-speed copiers (13 to 39 prints/min) and high-speed copiers (more than 40 prints/min) according to their copying speed. Fuji Electric has developed 3 types of OPCs that can be utilized in these copiers and applies them roughly in accordance with Fig. 2. Typical characteristics of these OPCs are shown in Table 1. Their applied ranges of sensitivity are different for each type but can be selected freely according to the customer's request.

The general structure of an OPC is shown in Fig. 3. The OPC shown in Fig. 3 is a layer-type OPC having separated function layers, and is formed from a

Fig.2 Applied range of copying speed, outer diameter of OPC and each type

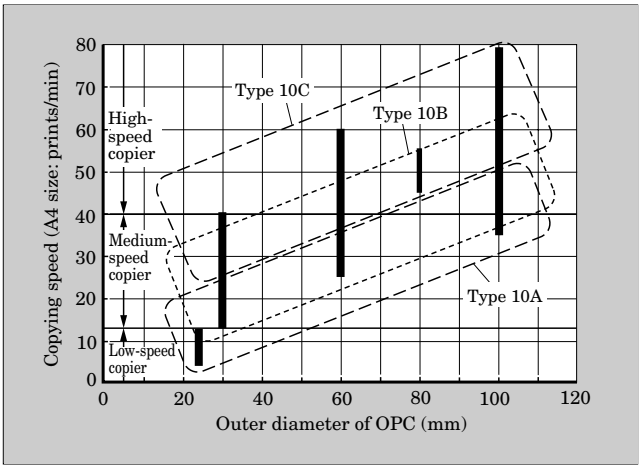


Table 1 Electrical characteristics

Item / Class	Half decay exposure in adopted sensitivity band ($\mu J/cm^2$)	Charging potential V_0 (V)	Retentivity (After 5 s) (%)	Half decay exposure ($\mu J/cm^2$)	Residual potential V_r (V)
Type 10A	0.30 to 0.50	–605	97.1	0.41	–35
Type 10B	0.15 to 0.30	–603	97.5	0.20	–21
Type 10C	0.07 to 0.15	–603	97.2	0.08	–9

Fig.3 OPC structure for digital copiers

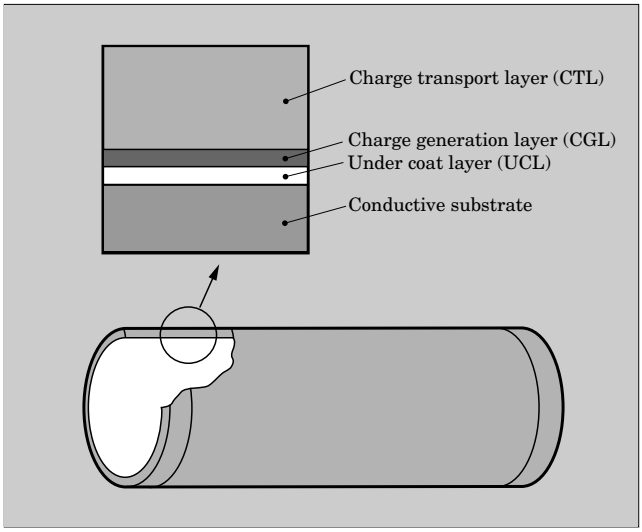


Fig.4 Spectrum sensitivity of OPC

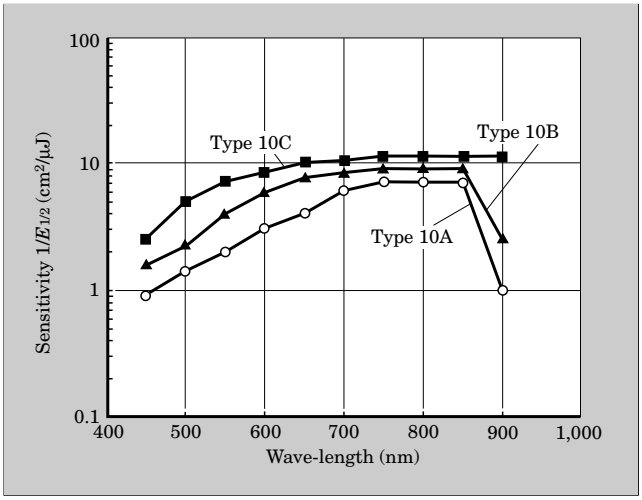
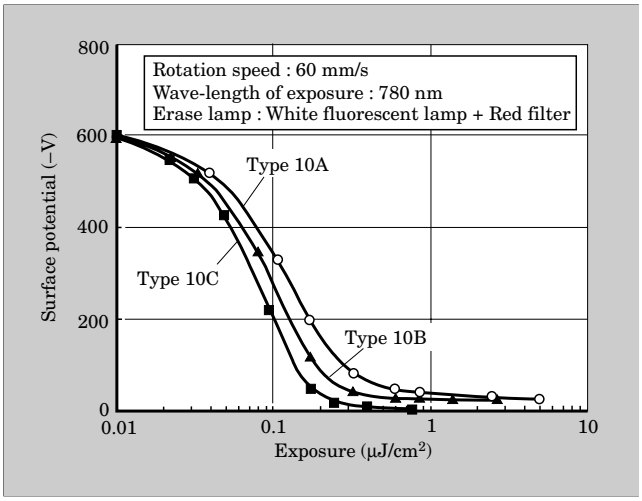


Fig.5 Photo-induced discharge characteristics of OPC



cylindrical conductive substrate coated, in succession, with a first under coat layer (UCL), a charge generation layer (CGL), and then a charge transport layer (CTL) which is the outermost surface.

The OPC for digital copier-use can utilize materials (type 8 series) that are also used in the OPC for printer-use. Therefore the technology accumulated for the type 8 series can be adapted to the type 10 series.

3. Special Features of the Product

By shifting from analog to digital copiers, the copier market is progressing toward multi-functionality, higher speeds and higher reliability. With these trends, the required characteristics for copiers are many and diverse. Therefore, we are advancing the development of materials in order to satisfy the required characteristics.

Fuji Electric's OPCs for digital copiers are suitable for all copiers, from low-/medium-speed copiers to high-speed copiers, and have the following features.

(1) High sensitivity
(2) High responsiveness
(3) High durability
(4) High reliability

3.1 High sensitivity

As a result of using a laser or LED (light emitting diode) as the exposure source, the digital copier requires sensitivity in the 600 to 800 nm of wavelength band. Fuji Electric utilizes a sensitive phthalocyanine pigment in this wavelength band. Figure 4 shows the spectrum sensitivities of types 10A, 10B and high sensitive type 10C. In the case of a digital copier, the wavelength of the exposure source is monochromatic light, and consequently we can design the OPC without consideration for color reproduction, as would be manifest in an OPC for an analog copier.

Figure 5 shows the photo-induced discharge characteristics observed in an actual copier. Comparison to types 10A, 10B, and to high sensitive type 10C shows about 50 % and 30 % higher sensitivity, respectively. Further, each type exhibits a sharp reduction in the region of residual potential, and therefore is favorable for the process design of copiers.

3.2 High responsiveness

There is a wide range of digital copiers, from low-speed to high-speed copiers. Among them, the high-speed copier, having printing speeds above 100 prints/min, which targets the on-demand copying market and POP (point of purchase) advertisement field, requires higher responsiveness in OPCs.

In order to improve the responsiveness, coordination of mobility and ionized potential between materials and their purities is very important. For improving the responsiveness, Fuji Electric has undertaken the challenge of developing charge transport materials (CTM) and has developed and produced a high mobility CTM that has a mobility of 5×10^{-5} cm²/V·s and that has about 10-times higher performance characteristics

Fig.6 Developing characteristics

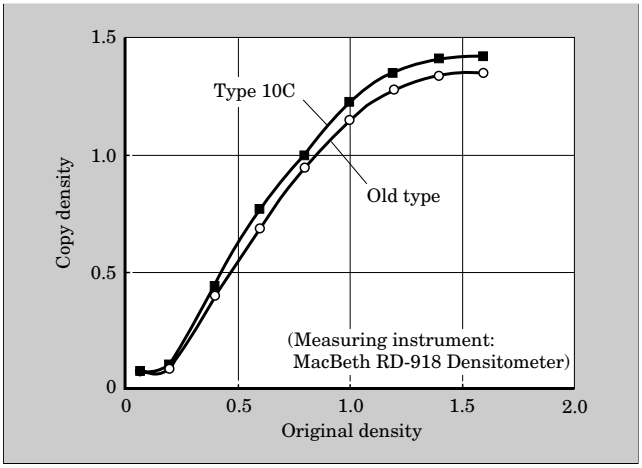
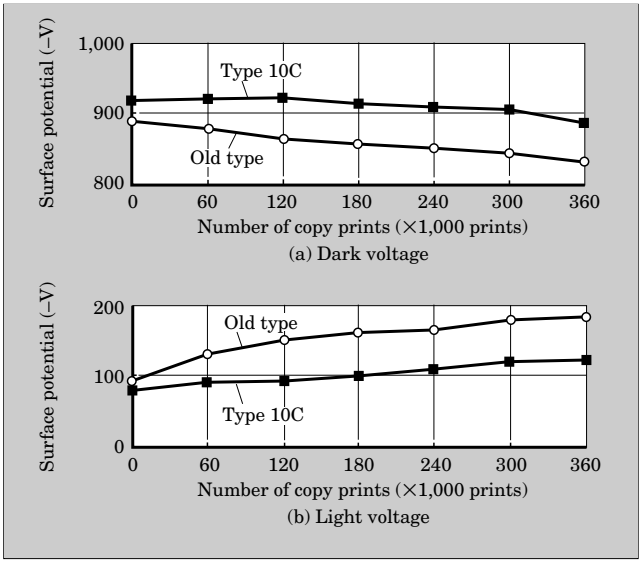


Fig.7 Running characteristics



than the old type. Figure 6 shows an example of an actual copier with enhanced developing. As a result of the improved responsiveness, print density (black density) was able to be improved compared to the old type.

3.3 High durability

The general modes of OPC's life-decreasing factors are classified in the following two categories:

(1) Life-decrease by electrical stress
  (a) Decrease of charge acceptance (Background)
  (b) Rise of residual potential (Decrease of copy density)

(2) Life-decrease by mechanical stress
  (a) Cut (Black line, white line)
  (b) Abrasion of photoconductive layer (Decrease of copy density, background)

3.3.1 Improvement of electrical characteristics

Functional material in the OPC undergoes a chemical change due to repeated exposure from corona discharge in the charging-exposure process, from ozone

Fig.8 Mechanical characteristics of OPC

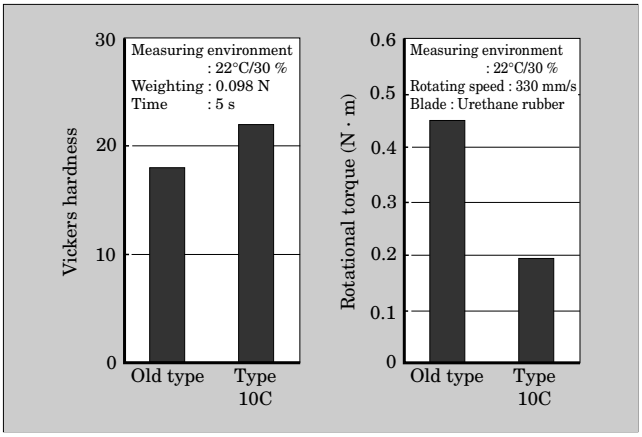
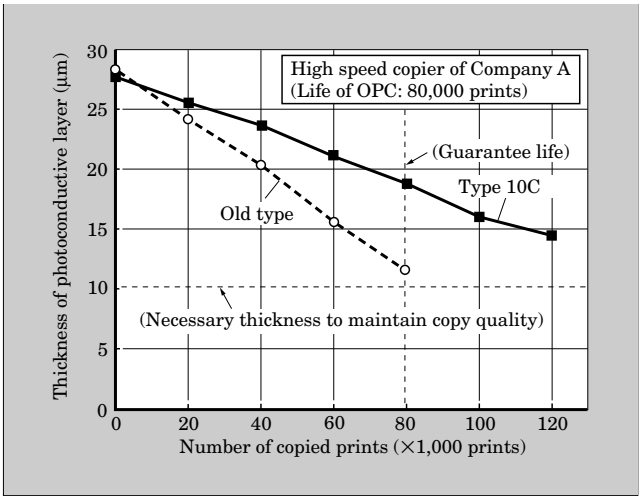


Fig.9 Abrasion of OPC



generated by the corona discharge process and from light. Consequently, characteristics become degraded, such as a decrease in charge acceptance or rise in residual potential, and these phenomena cause a decrease in print density and the background.

In order to control the degradation of charge acceptance and of print density, Fuji Electric has developed an original charge control agent for suppressing the generation of electrical defects in CGL and CTL, and has supplied OPCs that operate stably in several processes.

The change in surface potential of our typical digital copier is shown in Fig. 7. Compared to prior types, this new type exhibits only small changes in potential and print quality, and realizes an excellent OPC having stable operation.

3.3.2 Improvement of mechanical characteristics

In OPCs, life-decreasing physical and mechanical characteristics may occur due to contact with the cleaning-blade, charging roller, transfer roller, paper and toner, and consequently result in wear or cuts in the exposing layer and substance adhesion of toner or paper dust. The potential for each of these phenomena to occur differs according to the machine process, but

Table 2 Environmental test

Item	Condition
Ozone exposure test	100 ppm, 2 h
Light-induced fatigue test	1,000 lx, 5 min
Exposure test under high temperature	45°C, 1,000 h
Exposure test under high humidity	40°C, 90 % RH, 1,000 h
Exposure test under low temperature	–20°C, 1,000 h
Cycle test of temperature and humidity (5 cycles)	–20°C, 1 h → N/N, 0.5 h → 45°C, 1 h → N/N, 0.5 h → –20°C, 1 h (N/N: Normal temperature and normal humidity)

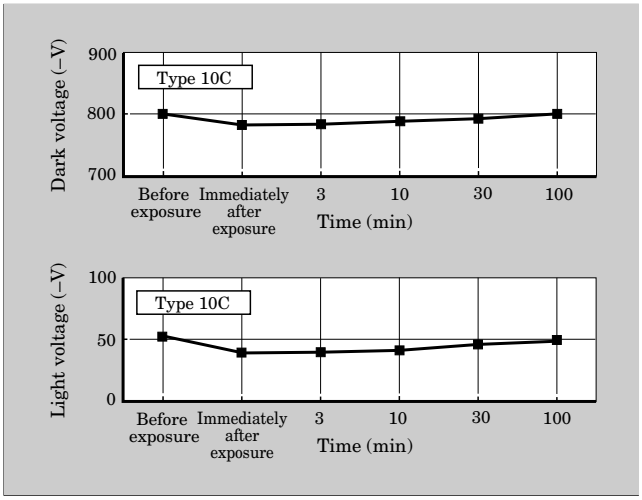
Table 3 Ozone-resistance characteristics of OPC

Class \ Item		Charging potential V_0 (V)	Retentivity (After 5 s) (%)	Half decay exposure (μJ/cm^2)	Residual potential V_r (V)
Type 10A	Before exposure	–603	97.4	0.42	–34
	After exposure	–602	94.8	0.43	–38
Type 10B	Before exposure	–601	97.1	0.18	–22
	After exposure	–603	95.1	0.18	–23
Type 10C	Before exposure	–601	97.3	0.08	–8
	After exposure	–603	95.6	0.09	–12

depends greatly on the performance of binder, which is a component of CTL. The binder performance is a big factor in determining the life of the OPC. Therefore the development of binder is important. Fuji Electric has introduced durability test equipment which is able to quickly estimate the binder performance, has promoted acceleration evaluation, and consequently has succeeded in achieving large improvement in the binder's performance.

Figure 8 shows mechanical characteristics (Vickers hardness, rotational torque of OPC) and Fig. 9 shows an example of improved wear and abrasion performance on exposed layers in a specific copier. By decreasing the friction with other contact parts, wear or abrasion of exposed layers are improved, and can lead to an approximate 50 % extension of OPC life. Fuji Electric tries to cut down the quantity of OPC waste by improving the life of the OPC.

Fig.10 Light-induced fatigue of OPC



3.4 High reliability

To quantify OPC reliability, the environmental tests shown in Table 2 have been carried out. The ozone-resistance test assumes an ozone atmosphere generated by corona discharge in the copier, and test data are shown in Table 3. Each characteristic is little affected even after 2 hours of exposure in a 100 ppm ozone atmosphere. The light-induced fatigue test assumes that the OPC is exposed to light during maintenance. Test data is shown in Fig. 10. The OPC was little affected after 5 minutes exposure to 1,000 lx of fluorescent light.

4. Conclusion

We have introduced Fuji Electric's OPCs for digital copiers, and described the high sensitivity OPC (Type 10C) in detail.

In the copier market, digital copying is becoming mainstream, so it is estimated that almost all copiers will be replaced by digital copiers after several years. Further, in the replacement by digital copiers, the trend toward multi-functionality requires printer, copy and facsimile functions to be integrated within the same machine, and consequently the boundary between printers and copiers will disappear gradually. Fuji Electric will continue to develop superior OPCs that provide required characteristics and precisely conform to the needs of market.