

Organic Photoconductors for Digital Plain Paper Copiers

Takahito Miyamoto [†]
Shuichi Hamada [†]

1. Introduction

In recent years, the development of new analog products by copier manufacturers has essentially ceased, and electrophotographic copiers have entered an era of digital expansion and evolution. Accompanying this trend toward digitalization, copier technology is trending toward colorization, higher speeds, higher image quality, and better stability than conventional analog copiers. In order to increase added-value, each copier manufacturer is promoting solutions. In response to these market trends, photoconductors, which are the key imaging devices in electrophotographic machines, must be improved to attain higher sensitivity, higher durability, environmental stability and higher reliability.

Fuji Electric provides a type 9 series of organic photoconductors (OPCs) 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 plain paper copiers.

2. Product Overview

Copiers that use OPCs can be categorized according to their copying speed as low-speed copiers (up to 25 ppm), medium-speed copiers (25 to 50 ppm) and high-speed copiers (50 ppm and above). Fuji Electric continues to advance the development of materials and design of the photoconductive layer in order to provide OPCs that are compatible with these digital copiers and that satisfy customer specifications. A separated-function type multilayer OPC is formed by applying an undercoat layer (UCL) on a cylindrical conductive substrate typically 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 top surface.

Digital copier-use OPCs are used with a laser diode (LD) light source. The materials employed in laser printer-use OPCs (type 8 series) can be shared, and the knowledge base of materials technology and coating

technology acquired with the type 8 series can be applied to the type 10 series OPCs.

3. Product Features

With the present migration from analog to digital technology, copiers are advancing toward higher speeds, higher image quality and higher reliability. As such, increasingly diverse and more sophisticated levels of performance are being required of OPCs, and materials development is being advanced in response to these requirements.

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

- (a) High sensitivity
- (b) High responsivity
- (c) High durability
- (d) High environmental stability
- (e) High reliability

3.1 High sensitivity

As with laser printers, digital copiers also use lasers or light emitting diodes (LEDs) as exposure sources, and therefore digital copier-use OPCs are required to be sensitive to wavelengths in the 650 to 800 nm range. To accommodate a variety of customer process designs, Fuji Electric provides the three types of digital copier-use OPCs listed in Table 1: low-sensitivity (type

Table 1 Basic characteristics

Type	Half decay exposure in applied sensitivity band ($\mu\text{J}/\text{cm}^2$)	Half decay exposure ($\mu\text{J}/\text{cm}^2$)	Dark decay ratio [after 5 sec] (%)	Residual potential (–V)	Applied range of printing speed (ppm)
10 A (low sensitivity)	0.20 to 0.60	0.38	98	50	< 30
10 B (medium sensitivity)	0.12 to 0.24	0.18	96	25	20 to 60
10 C (high sensitivity)	0.06 to 0.14	0.08	96	10	40 <

[†] Fuji Electric Device Technology Co., Ltd.

Fig.1 Spectral sensitivity characteristics

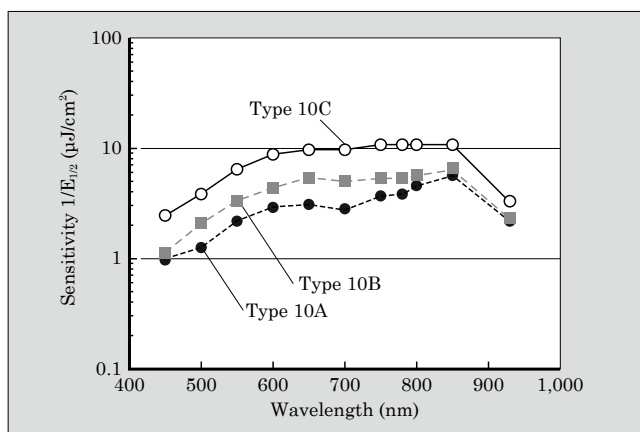
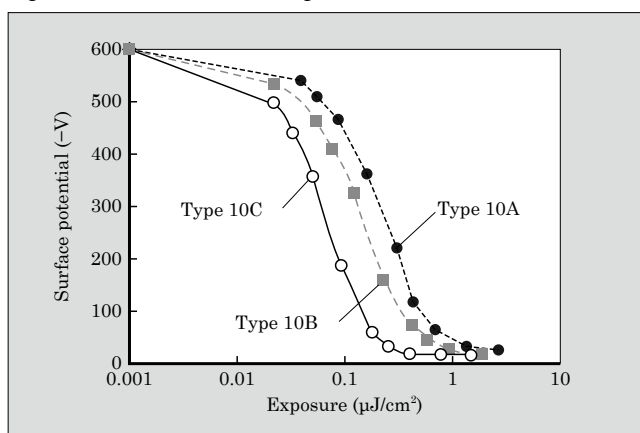


Fig.2 Photo-induced discharge characteristics



10A), medium-sensitivity (type 10B) and high-sensitivity (type 10C). Figure 1 shows the spectral sensitivity of each type.

Figure 2 shows the photo-induced discharge characteristics of each type. High-sensitivity 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 responsivity

Digital copier manufacturers offer a wide lineup of digital copiers, from low-speed machines for small offices/home offices (SOHOs) and for personal use to high-speed machines for business use. Within this lineup, higher responsivity is especially required of OPCs for super high-speed machines having greater than 100 ppm capacity and that target the on-demand copying market and high-volume printing applications such as in the advertising field.

The material mobility, consistency of the ionization potential among materials, and purity are key factors for enhancing responsivity. In order to realize high responsivity, Fuji Electric researched high mobility charge transport materials (CTMs) and de-

Fig.3 Dependence on time from exposure to development (for surface potential after exposure)

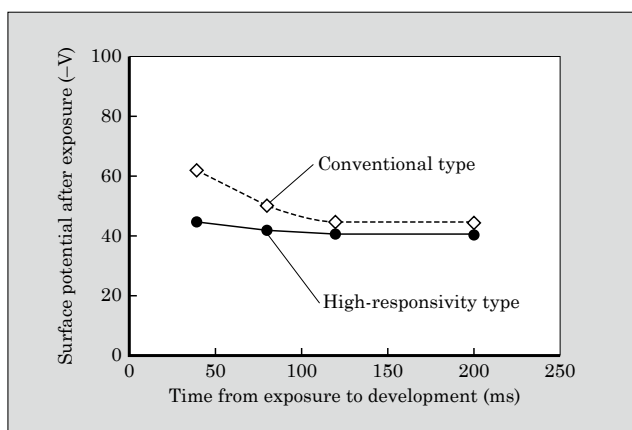
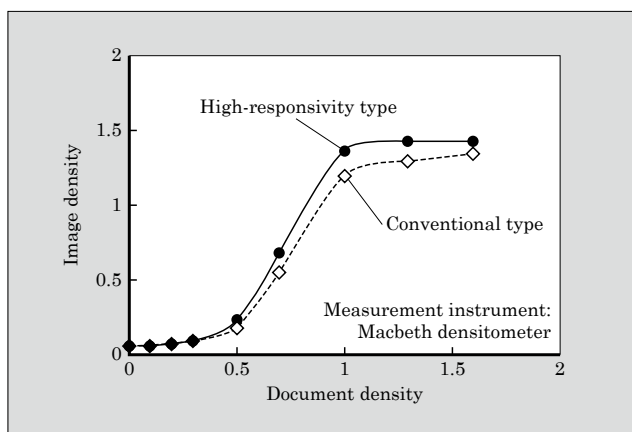


Fig.4 Developing characteristics



veloped a high mobility CTM having a mobility that is several times higher than that of the conventional material. Figure 3 shows the dependence of surface potential after exposure on the exposure-development time and Fig. 4 shows the development characteristics when installed in a copier. The surface potential after exposure of the high-responsivity type that uses high mobility CTM stabilizes in an exposure-development time of approximately 40 ms. This performance provides sufficient support for high-speed processes of 50 ppm and above in the case of an OPC having an external diameter of 30 mm and 120 ppm and above in the case of an OPC having an external diameter of 100 mm. Moreover, a comparison of the image density (black density) to that of the conventional type reveals a higher degree of reproducibility when using the high-responsivity type CTM.

3.3 High durability

In consideration of the frequency of copier use and in order to simplify maintenance, OPCs for digital copiers are required to provide approximately 10 times higher durability than OPCs for laser printer-use.

(1) Improvement of electrical characteristics

The repeated exposure of the OPC to ozone gener-

Fig.5 Durability characteristics (electric potential in actual copier)

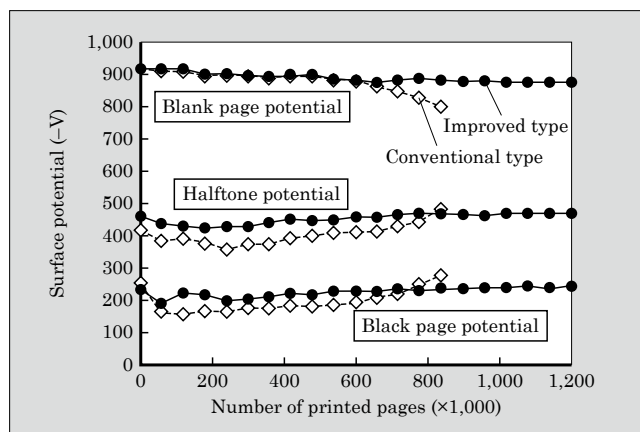
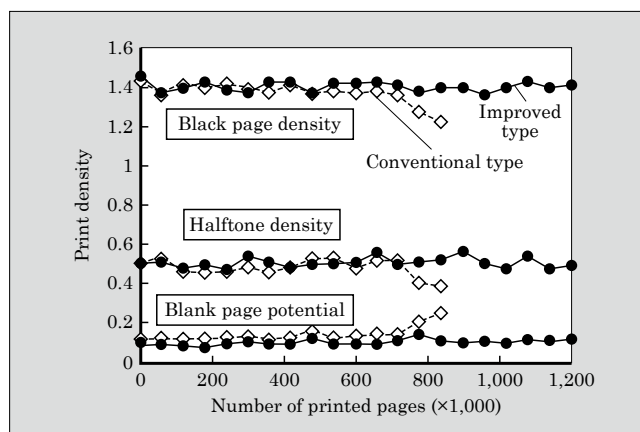


Fig.6 Durability characteristics (print density of actual copier)

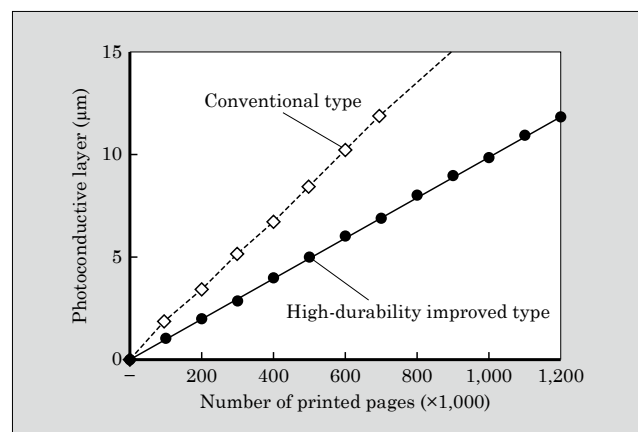


ated by corona discharge during the charging process and to light during the exposure process causes chemical changes in the functional material. The result is a deterioration in electrical characteristics such as, for example, a decrease in charging potential or an increase in residual potential, causing such image problems as low print density or fog.

To suppress this decrease in charging potential and increase in residual potential, Fuji Electric has developed 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 is able and to supply OPCs that operate stably in various machine processes.

Figures 5 and 6 show the change in surface potential and image density for OPCs evaluated in a digital copier in which a high degree of durability (a guaranteed OPC service life of 1.2 million pages) is required. With the conventional type, a large change in image density due to a decrease in charging potential and an increase in residual potential can be seen after copying approximately 800,000 pages, but the improved OPC exhibits little change in surface potential and image quality and excellent operating stability through the

Fig.7 Durability characteristics (wear)



end of its guaranteed service life of 1.2 million pages.

(2) Improvement of mechanical characteristics

Contact between the OPC and the charging roller, developing roller, toner, paper, transfer roller, cleaning blade and the like degrades the physical and mechanical characteristics of the OPC by causing wear and scratches on the photoconductive layer and by causing the adherence 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 the binder, which is a component of the CTL, and on the combinational ratio of CTM and binder.

Fuji Electric has installed a durability tester capable of evaluating the binder performance within a short time, and has implemented an accelerated evaluation which has verified a dramatic improvement in the binder performance.

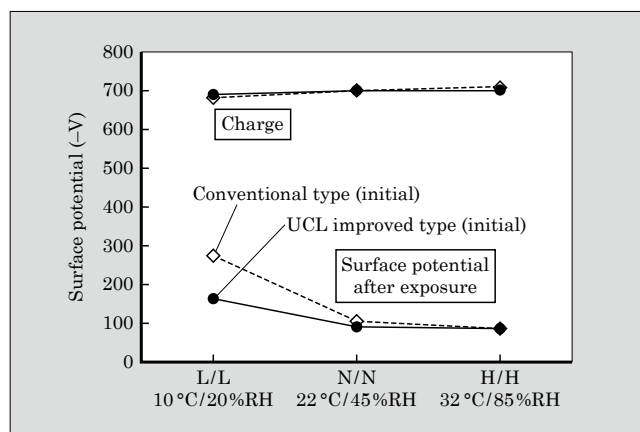
The binder material in the CTL is molecularly designed to have a polymeric molecular structure and have excellent lubricating properties, and this binder material increases the film hardness while reducing the frictional coefficient between the OPC and the cleaning blade. As is shown in Fig. 7, by reducing 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 1.7 times as compared a conventional OPC. As a result, the improved OPC is suitable for use in the fields of high-speed and light printing.

3.4 High environmental stability

OPCs are desired to be environmentally stable so as to be compatible with a variety of copier environments.

Fuji Electric has optimized the UCL filler performance 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 8 shows data from a process simula-

Fig.8 Environmental surface potential characteristics



tion of the environmental dependency of surface potential. The improved OPC exhibited minimal fluctuation and good characteristics in all environments.

3.5 High reliability

Fuji Electric carried out the reliability testing listed in Table 2 in order to verify the reliability of OPC products. Product development was advanced after confirming that the characteristics associated with each evaluation item were free from abnormalities.

4. Postscript

This paper has discussed OPCs for digital plain paper copiers.

In the copier market, nearly the entire installed

Table 2 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

base of machines has changed over from analog to digital technology. Moreover, digitalization is driving a trend toward multifunctional (MF) machines that combine printer, copier and facsimile capabilities into a single unit and is eliminating the distinction between printers and copiers in the low and medium-speed fields, and market demand is centered on MF machines. Fuji Electric is refining the technology needed to address these market trends. Moreover, in the high-speed copier field, higher operating stability in the range of approximately several to 10 times that of a laser printer is required, and further improvements in the OPC characteristics are required. Fuji Electric intends to continue to develop desirable OPCs by accurately assessing required characteristics in accordance with market needs.



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