

# Organic Photoconductors for Digital Plain Paper Copiers

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## ABSTRACT

Fuji Electric provides type 10A (low sensitivity), type 10B (medium sensitivity) and type 10C (high sensitivity) OPCs for digital copiers. The OPCs are sensitive in the 600 to 800 nm wavelength range of laser and LED light used as the light source for copiers. The Charging characteristics of the OPCs have been improved in accordance with the shortening of the first copy time of the copiers. Computer-aided molecular design has been utilized to develop a binder for a highly durable charge transport layer and prevent the charging characteristics from deteriorating. As a result, printing durability has been improved by at least a factor of 2, contributing to a reduction in the running costs of the copier.

## 1. Introduction

In fiscal 2009, the copier industry's shipment volume plummeted by 10% year on year, due to the effects of the worldwide recession precipitated by the financial crisis. Although it is predicted that major growth will not be seen moving forward either, there is a trend in the industry away from monochrome devices with high added value, and toward color devices. Manufacturers have been acquiring independent distributors, and entering the production market as well.

As a consequence to the abovementioned industry trends, copiers are increasingly becoming faster, supporting color imaging, and providing higher resolution, more stable operation, and maintenance-free operation (being provided as a single unit). The photoconductor is a key component for the image formation of electrophotographic devices. In order to respond to these trends in the copier industry, photoconductors require such improvements as higher sensitivity, better printing durability, better operating stability, and higher reliability.

Fuji Electric is committed to helping to reduce waste, lower running costs, and contribute to the conservation of the global environment by improving the durability of organic photoconductors (OPCs). The focus of this paper is an overview of durable OPCs for copiers.

## 2. Product Overview

Copiers that use OPCs can be categorized according to their copying speed: 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 develop materials and design photoconductive layers for all speed categories, in order to offer digital copiers that meet the specifications demanded by its customers.

A separated-function multilayer OPC is formed by applying an under coat layer (UCL) to a cylindrical conductive substrate typically made of aluminum or the like, then applying a carrier generation layer (CGL) on top of the UCL, and finally applying a carrier transport layer (CTL) on the top surface.

OPCs for digital copiers can use the Type 8 series of materials used in printer OPCs. Fuji Electric also offers a Type 10 series, which applies such proprietary technologies as improved durability for digital copiers.

## 3. Product Features

As a consequence to advances in electronics, copiers are gaining increased functionality, higher speed, and higher reliability. The characteristics demanded of OPCs have also become quite diverse.

Fuji Electric is developing materials to deliver these required characteristics. Fuji Electric's OPCs for digital copiers can be used in all copiers, from low-speed to medium and high-speed. They include the following features:

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

High chargeability and high printing durability are particularly necessary for achieving high durability.

### 3.1 High sensitivity

Digital copiers use laser diodes (LDs) or light-emitting diodes (LEDs) as exposure sources. Organic photo-

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toconductors must therefore have high sensitivity to wavelengths in the 600 to 800 nm range. Fuji Electric uses phthalocyanine pigment, which has high sensitivity in this wavelength range. As shown in Table 1, Fuji Electric offers three types of OPC, in accordance with its customers' process design: low sensitivity (Type 10A), medium sensitivity (Type 10B), and high sensi-

Table 1 Basic Characteristics

Character- istic  Type	Half-decay exposure in applied sensitivity band ( $\mu\text{J}/\text{cm}^2$ )	Half-decay exposure ( $\mu\text{J}/\text{cm}^2$ )	Charging retention ratio [after 5 sec] (%)	Residual potential $V_r$ (-V)	Applied range of printing speed (ppm)
Type 10A (low sensitivity)	0.20 to 0.40	0.38	98	50	< 30
Type 10B (medium sensitivity)	0.12 to 0.24	0.18	96	25	20 to 60
Type 10C (high sensitivity)	0.06 to 0.14	0.08	96	10	40 <

Fig.1 Spectral Sensitivity Characteristics of Photoconductors for Digital Copiers

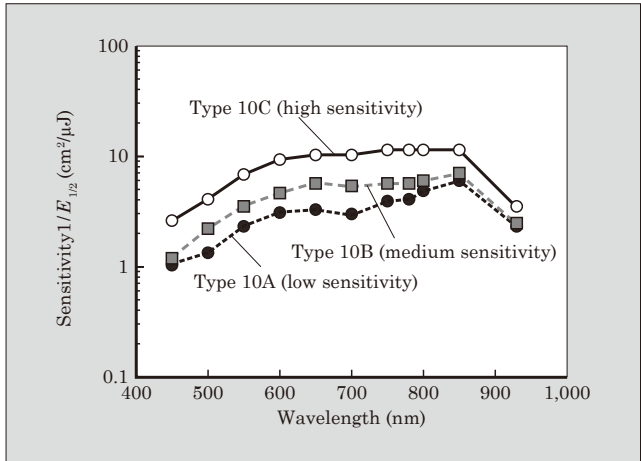
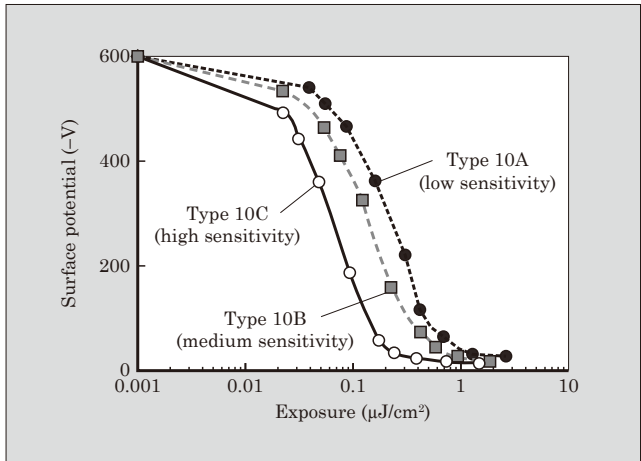


Fig.2 Photo-induced Discharge Characteristics of Photoconductors for Digital Copiers



tivity (Type 10C). Figure 1 shows the spectral sensitivity of each type.

Figure 2 shows the photo-induced discharge characteristics of each type. Type 10C, the high-sensitivity type, has about 50% greater sensitivity than Type 10A, and about 30% greater sensitivity than Type 10B. It also helps improve the energy efficiency of the exposure source.

### 3.2 High chargeability

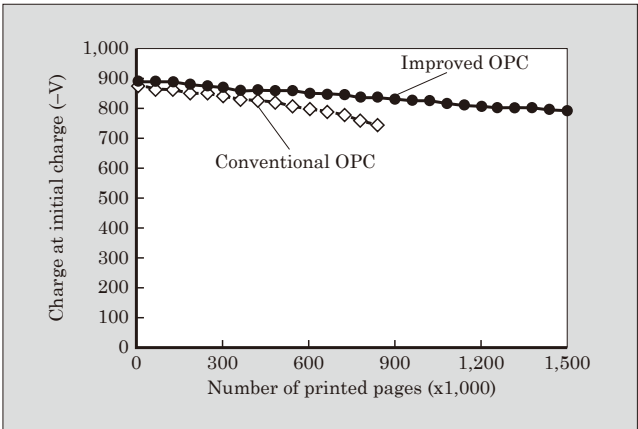
Digital-copier manufacturers offer a wide lineup of digital copiers, from compact, low-speed copiers for small offices/home offices (SOHOs) and personal use, to large, high-speed copiers for office and business use. Manufacturers are working to reduce the first-copy time in their high-speed copiers, in order to provide better on-demand performance. Consequently, OPCs must have high charge performance from the first charge.

The thermally excited carriers in the CGL and carriers resident in each layer and the junctions upon initial charge increase as the number of printed pages increases, and the chargeability decreases correspondingly. Fuji Electric is working to improve the UCL and CTL, in order to improve chargeability, and has sought to optimize the selection and combination ratios of materials with optimum resistance for the UCL. It has developed a charge transport material (CTM) with high charging potential for the CTL, and that optimizes the ionization potential between the CGL and CTL.

As shown in Fig. 3, this greatly improved the charge performance upon initial charge.

Conventionally, a copier would idle for about three to five cycles before beginning the copying process, in order to make up for the lack of charge in the OPC. The improved OPC provides high resolution from the first revolution, which should make it possible to eliminate wasteful idling, improve speed, and conserve energy.

Fig.3 Charge Characteristics of Photoconductors for Digital Copiers upon Initial Charge



### 3.3 High printing durability

OPCs for digital copiers must have high printing durability; it must be several to ten times higher than that of OPCs for laser printers, in light of the using frequency of copiers and the need for ease of maintenance. Fuji Electric is developing highly durable CTL binders using computational molecular design, in order to commercialize high-durability OPCs that reduce running costs.

#### (1) Improved electrical characteristics

The repeated exposure of an OPC to corona discharge from the charge-exposure process and to ozone and light generated by that discharge causes chemical changes in the functional materials. This results in deterioration in charging potential or an increase in residual potential, which causes such image defects as low print density and fog.

Fuji Electric has developed a proprietary charge-control agent that suppresses the occurrence of electrical defects in the charge generation layer (CGL) and CTL, in order to reduce the deterioration of charge characteristics and the increase in residual potential.

Fig.4 Printing Characteristics (Surface Potential) of Photoconductors for Digital Copiers

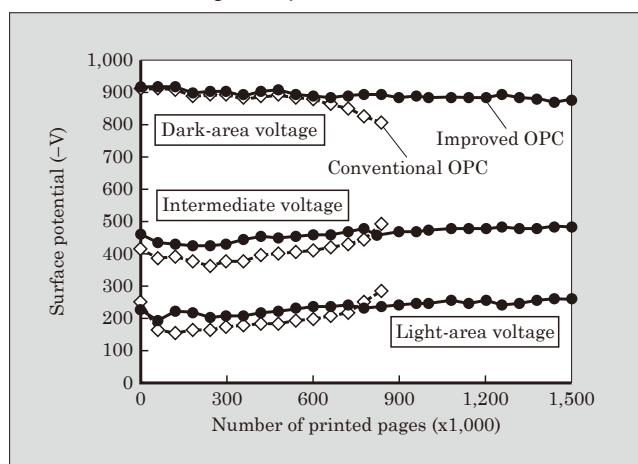
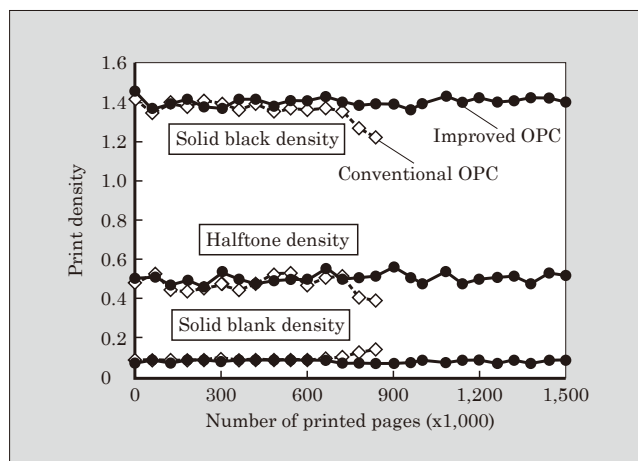


Fig.5 Printing Characteristics (Print Density) of Photoconductors for Digital Copiers



This enables it to offer OPCs that operate stably in a wide range of machine processes.

Figs. 4 and 5 show trends in surface potential and print density when evaluated in typical digital copiers. Fuji Electric has developed OPCs with outstanding operating stability, and less potential fluctuation and fewer changes in image quality than conventional types.

#### (2) Improved mechanical characteristics

Contact between the OPC and the cleaning blade, charging roller, transfer roller, paper, and toner degrades the mechanical characteristics of the OPCs by causing wear and scratches on the photoconductive layer, and by causing the adherence of toner and paper dust particles. Although the photoconductive layer's susceptibility to degradation varies according to the machine process, it is largely dependent on the performance of the CTL binder, which is a component of the CTL. The performance of the CTL binder is a large factor in determining the useful service life of the OPC. Fuji Electric has introduced equipment for rapidly evaluating the performance of CTL binders, including abrasion and friction testers. With faster evaluation, it has succeeded at greatly improving the performance of its CTL binders.

The binder material in the CTL is molecularly designed to have a polymeric molecular structure and have excellent lubricating properties. This binder material increases the film hardness while reducing the frictional coefficient between the OPC and the cleaning

Fig.6 Frictional Coefficient of Photoconductors for Digital Copiers

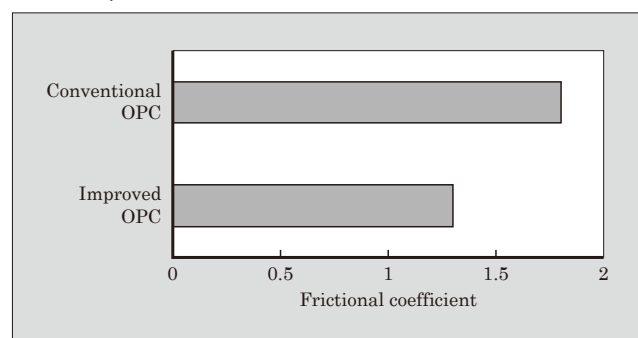


Fig.7 Printing Characteristics (Wear) of Photoconductors for Digital Copiers

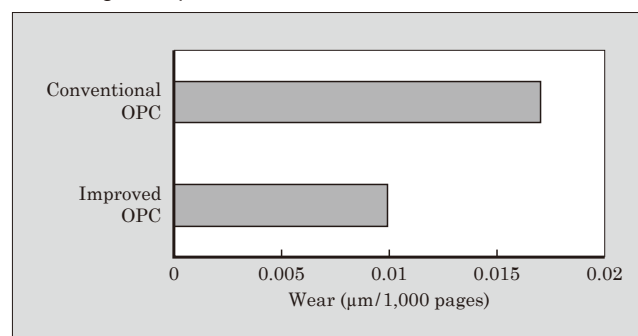
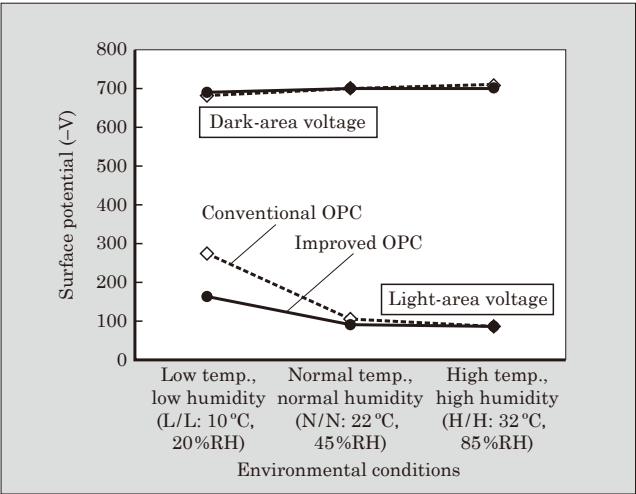


Fig.8 Environmental Dependence of Surface Potential via Process Simulator



blade. As shown in Fig. 6, friction with other contact parts is reduced, thus reducing wear and scratching. As shown in Fig. 7, this OPC has about 40% less abrasion than conventional OPCs. As a result, Fuji Electric's OPCs are suited to the high-speed printing field, as well as light printing.

3.4 High environmental stability

OPCs must have environmental stability in order to support the use of copiers in a wide range of environments. Fuji Electric optimized the UCL filler performance and binder, and suppressed fluctuations in environment-induced electrical resistance. This ensures that its OPCs remain stable in environments of low temperature and low humidity (L/L), normal temperature and normal humidity (N/N), and high temperature and high humidity (H/H). Figure 8 shows data on the environmental dependency of surface potential from a process simulator. The improved OPC exhibits low fluctuation and favorable characteristics in all environments.

Table 2 Reliability Tests

Test	Description
Electrical characteristics	Ozone exposure test
	Strong light-induced fatigue test
	High-temperature exposure test
	High-humidity exposure test
	Low-temperature exposure test
Mechanical characteristics	Cyclic test of temperature and humidity
	Creep test
	Oil adherence test
	Scratch test

3.5 High reliability

Fuji Electric is performing the reliability testing listed in Table 2 in order to verify the reliability of its OPCs. Each test item conforms to actual copier use. The company develops products after confirming that there are no abnormalities in the characteristics for each test item.

4. Postscript

This paper has described OPCs for digital copiers (Type 10), with a focus on high-durability OPCs developed with the goal of conserving the global environment. The focus of technical development in the copier market is shifting from monochrome to color copiers, and OPCs must also support color copiers. Additionally, as environmental awareness increases, OPCs are being used that reduce waste through improved durability, and reduce the power consumption of the photographic fixing unit by matching low-melting point toners. Fuji Electric is committed to accurately assessing the required characteristics, and developing attractive, environment-friendly OPCs that meet the needs of its customers and the market.



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