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ORGANIC PHOTOCONDUCTORS FOR PLAIN PAPER COPYING MACHINES

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1. INTRODUCTION

Organic photoconductors (OPCs) were brought to the market place because of a unitized peripheral process which aims at low cost and maintenance free. In recent years, their sensitivity and durability have been improved greatly by a construction consisting of several layers, each having their own function and composed of a wide variety of organic material. As a result, photoconductors of this type have come to be used in high-speed Plain Paper Copying machines (PPCs) as well as how- and medium-speed PPCs. To meet these market needs, Fuji Electric has developed organic photoconductors suitable for various speed PPCs in addition to those previously developed for Printers. Printers.

2. OUTLINE OF FUJI ELECTRIC'S OPCs FOR PPCs

Fuji Electric's organic photoconductors for PPCs are classified into two types. The first is for low- and medium-speed PPCs (less than 40 copies/min) and the second is for high-speed PPCs (40 copies/min or more). *Table 1* shows typical characteristics for each type. *Figure 1* shows the layer structure for these multilayer photoconductors, consisting of an Under Coat Layer, a Carrier Generation Layer and a Carrier Transport Layer. Each layer has their own function and is coated on an aluminum tube (conductive substrate).

3. PROPERTIES OF FUJI ELECTRIC'S OPCs FOR PPCs

Fuji Electric's organic photoconductors for PPCs can be used in various speed PPCs. The properties are shown below.

(1) High sensitivity
(2) Quick photo response
(3) High durability
(4) High reliability

3.1 High sensitivity

Since PPCs utilize visible light as an exposure source, the photoconductor should be highly sensitive to light in the 450 through 600 nm in wavelength range. Azo pigment which has high carrier generation efficiency at the above wavelength range, is utilized as the carrier generation material. *Figure 2* shows the spectral sensitivity of the organic photoconductor for PPC utilizing the azo pigment. When a halogen lamp is used as the PPC's exposure source, a photoconductor with these spectral sensitivity characteristics will have poor red copy reproducibility (the reproducibility depends on color temperature). As a result, the exposure source needs a filter which excludes red light (longer than the 600 nm in wavelength). *Figure 4* shows the dynamic sensitivity when a filter with the trans-

Fig. 1 Layer structure

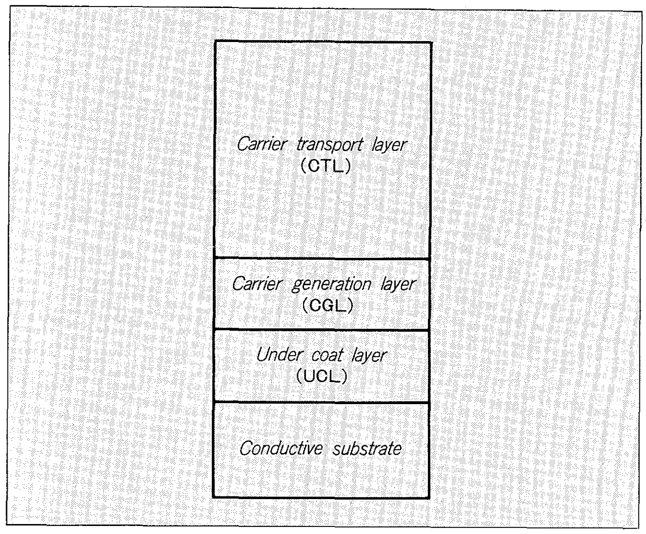


Table 1 Typical characteristics

Type	Surface potential (V)	Retentivity (5 sec. after charging) (%)	Sensitivity (lx·s)	Residual potential (V)	Thickness (μm)
OPC for high-speed PPCs	−852	94.9	0.65	−21	35.7
OPC for low- and medium-speed PPCs	−846	93.7	0.99	−33	26.7

mittance characteristics shown in *Fig. 3* is added to the exposure source. As shown in *Fig. 2* and *Fig. 4*, the organic photoconductor for high-speed PPCs has a 30% higher sensitivity than that for low- and medium-speed PPCs. To achieve such high sensitivity, material design must be optimized as follows.

(1) Enhancement of the carrier generation efficiency by optimizing an organic pigment (crystal structure, particle size, particle shape and surface condition).

Table 2 Reliability tests

Test	Test condition
Fatigue test for strong light exposure	Fluorescent lamp 1,000 lux, 10 min.
Ozone proof test	19 ppm, 11 hours
High temperature storage test	45°C, 1,000 hours
High temperature and high humidity storage test	60°C, 90%RH, 1,000 hours
Low temperature storage test	–20°C, 1,000 hours
Temperature and humidity cyclic test	–20°C, 1h → Room temperature 0.5h → 45°C, 1h → Room temperature 0.5h → –20°C, 1h (Repeat 5 times)

Fig. 2 Spectral sensitivity

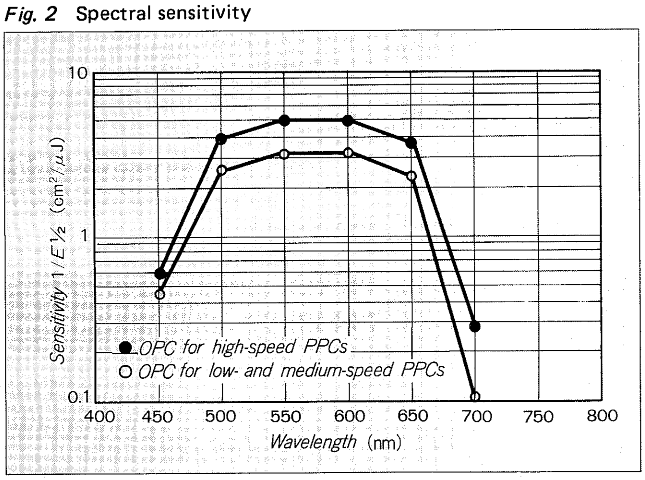
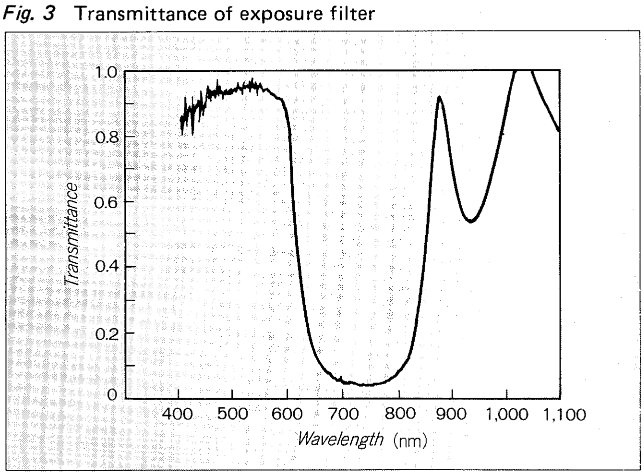


Fig. 3 Transmittance of exposure filter



(2) Matching of ionization potential between carrier generation layer and carrier transport layer

(3) Development of carrier transport material with high mobility

(4) Increasing thickness of carrier transport layer [(3) is essential for (4)]

3.2 Quick photo response

Carrier transport in an organic photoconductor is dispersive, and therefore, the carrier mobility is slower than that of the selenium-tellurium photoconductor (Type 4) and the same as for the As_2Se_3 photoconductor (Type 5). If carrier·transport time was equal to or greater than the time between exposure and development, the apparent residual potential would rise. As a result, rotation speed of the photoconductor, that is, copy speed, is restricted by mobility in the carrier transport layer. The photo response becomes worse at low temperatures because the carrier mobility becomes slower.

Figure 5 and *Figure 6* show the photo response of the organic photoconductor. *Figure 5* shows the time between exposure and development versus surface potential at a low temperature (5°C). Even though the organic photoconductor for high-speed PPC has a thick (35 μm) photo-

Fig. 4 Dynamic seusitivity

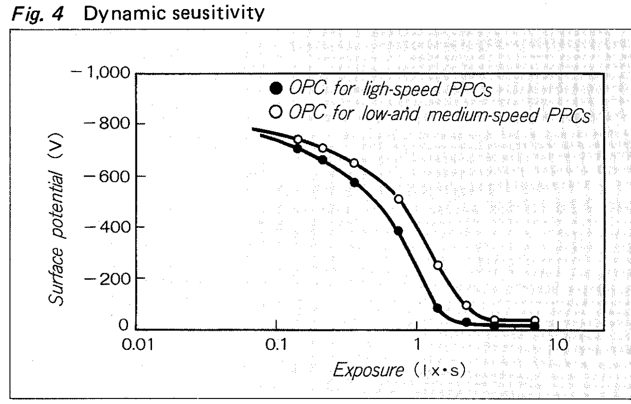


Fig. 5 Quick photo response (5°C)

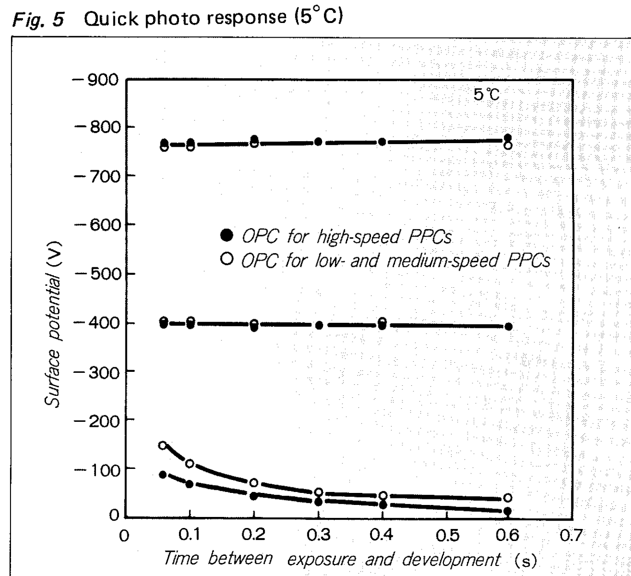


Fig. 6 Temperature dependency of quick photo response

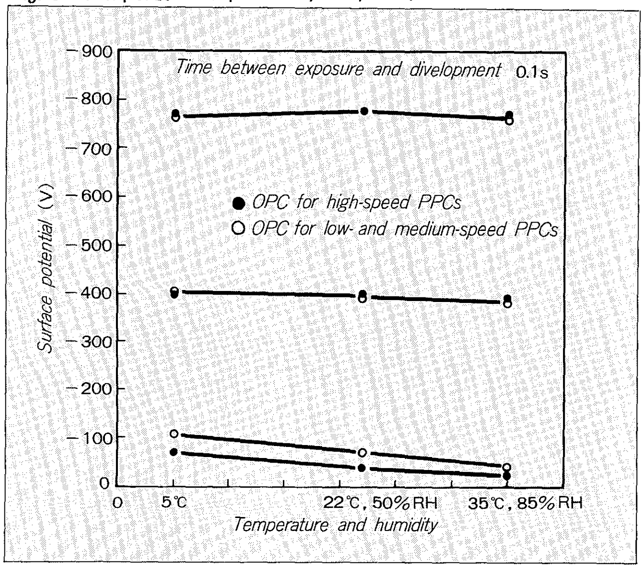
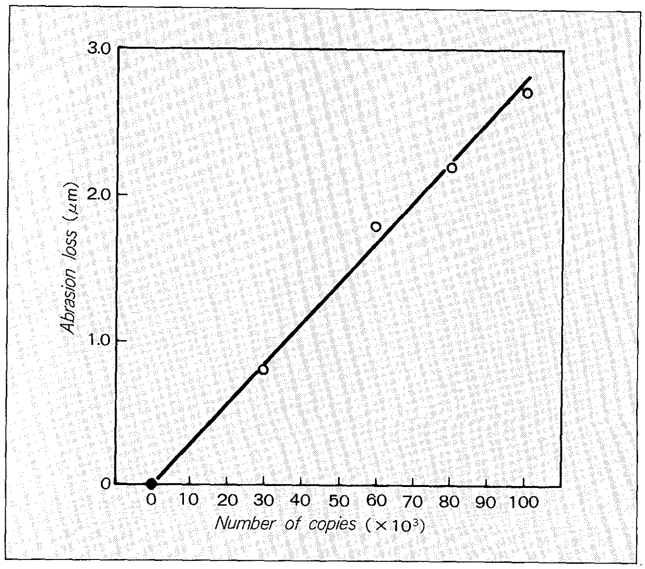


Fig. 7 Abrasion loss vs the number of copies



conductive layer, it has equal or better photo response than that of the low- and medium-speed PPC. *Figure 6* shows the temperature dependence of the surface potential, which is found to be stable when the time between exposure and development is 0.1 s. To enhance photo response, the following must be carefully considered when selecting the materials.

(1) Carrier transport material with high mobility
(2) Purified carrier transport material
(3) Additives which do not create traps

Regarding (2) and (3), it is essential that the ionization potential depth is not less than that of the carrier transport material.

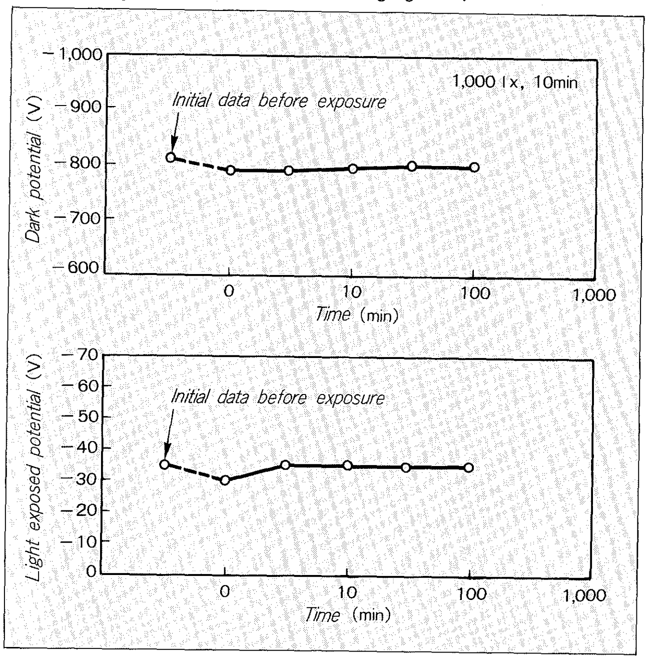
3.3 High durability

The durability of the photoconductor, in other words, copy life, is expressed by the number of high quality copies which may be obtained. The copy life is determined mainly by the following factors.

(1) Deterioration of electrical characteristics (results in copy background defects)
  - Decrease in charge acceptance:
    Decrease in copy density
  - Decrease in sensitivity:
    Gray cópy background
  - Increase in residual potential:
    Gray copy background
(2) Surface deterioration (results in partial copy defects)
  - Scratch
  - Toner filming, paper dust filming

The surface of the organic photoconductor should be abraded, that is, refined during use. Too much abrasion decreases the photoconductive layer, which results in the deterioration of electrical characteristics. On the other hand, not enough abrasion causes filming. Compatibility between the photoconductor and copying process determines the durability. The following are effective to

Fig. 8 Fatigue characteristics for strong light exposure



enhance the durability of the photoconductor.

(1) Abrasion of photoconductive layer
  - Increase in photoconductive layer thickness
  - Use of stronger binding resin
(2) Deterioration of organic functional material
  - Use of an antioxidant (against ozone, ultraviolet light, heat, electric current, etc.)

Deterioration is the disadvantage of organic materials. In the PPC, organic materials are deteriorated by light, ozone, temperature and electric current, creating traps. As a result, these traps deteriorate the electrical characteristics. Durability is largely determined by the copying process. *Figure 7* shows the abrasion loss versus the number of copies.

3.4 High reliability

Table 2 shows the reliability tests for the organic photoconductor. *Figure 8* shows the fatigue test results for a strong light exposure. The organic photoconductor does not change its electrical characteristics even after exposure to fluorescent light of 1,000 lux for 10 min.

4. AFTERWORD

Over the years, the properties of organic photoconductors have been greatly improved. Particularly noteworthy is their sensitivity, which surpasses that of As_2Se_3 photoconductors (Type 5). Durability, however, is not yet quite equal to that of Type 5. Therefore, we will continue to make efforts to enhance the properties of organic photoconductors by investigating materials of high quantum efficiency, high mobility and high durability.