

Present Status and Future Prospects for Photoconductors

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1. Introduction

The improvement in performance of personal computers and peripherals and their rapid popularization has recently been remarkable. The influence that development of these information devices brings into our lives can be expressed with three keywords: digitalization, colorization and networking. For example, imaging devices, including cameras and videos, are advancing at a rapid pace and the transmission of color images via internet is already a daily occurrence. It is significant that these phenomena are seen not only in offices but also widely in homes.

Under these circumstances, the importance of the role of printers and PPCs, which display and record the information and images, is increasing more and more, and their expected level of performance is becoming higher.

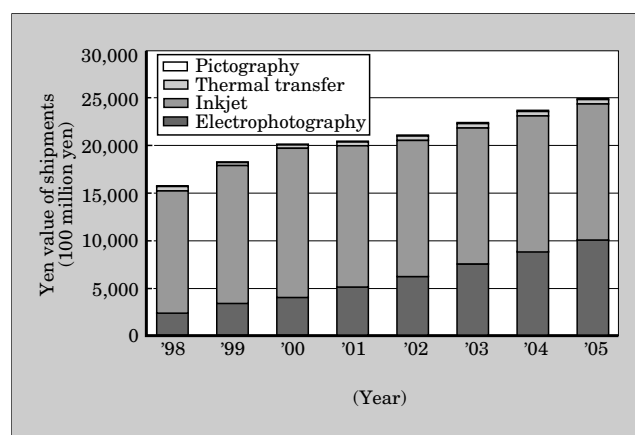
In this paper we are going to explain the market trends for printers and PPCs, discuss the trends of printers using electrophotographic technology and of PPCs, and present an overview of corresponding Fuji Electric photoconductors and their peripheral devices.

2. Market Trend of Printers and PPCs

Despite the progress of thin model displays as typified by liquid crystal displays, the consumption of paper as an information medium continues to grow steadily. The main reason for the increasing consumption of paper is thought to be attributable to the fact that, above all, paper combines multiple functions such as the displaying, writing, storing and transmitting of data, and also is a lightweight and very serviceable medium.

On the other hand, new technologies, including electronic books and electronic paper, are being developed as media alternatives to paper. In the mid- and long-term horizons, the percentage of these electronic media relative to paper is estimated to increase continuously. For the moment, the increase in information quantity itself is thought to be due to the synergistic effect of both media, resulting in the continued growth of both media⁽¹⁾.

Fig.1 Forecast of shipment amount for color hard copying devices



In computer image output devices, the inkjet method is used mainly for personal-use devices and the electrophotographic method is mainly for office-use devices. The inkjet method has features of low device price, color printing and good printing quality for coated papers, and the electrophotographic method has features low running cost, high printing speed and good printing quality for plain papers. Figure 1 shows a market forecast for color hard copy devices. Although electrophotographic color printers and color PPCs are only at the beginning of their real popularization, future large-scale growth is expected. The inkjet method and electrophotographic method are expected to compete with each other and yet to continue growing together, benefiting from their respective advantages. At present, the ratio of printed sheets by the inkjet method compared to the electrophotography method (including monochrome images) is said to be approximately 1 : 3 (inkjet: electrophotography).

3. Trend of Electrophotographic Devices

The shipped quantities of electrophotographic printers and PPCs have in the last several years exhibited a trend of saturation, showing only a small increase of several percent. But with the progress of

technologies and change in device composition, a new market is now opening up corresponding to the change in business environment represented by the abovementioned three keywords.

3.1 Electrophotographic printer

The introduction of color printing in electrophotographic printers lagged the development of colorization in other information devices. Figure 2 and Fig. 3 show the trends in shipment quantities for monochrome electrophotographic printers and color electrophotographic printers respectively. In the estimates for 2001, the shipment of monochrome printers is about 10 million units, while the shipment of color printers is only 700 thousand units. However, in the last several years shipments of color printers have grown by about 30 % per year, suggesting rapid growth of the market in coming years.

As seen in Fig. 3, at present most of the shipped color printers are low-speed machines having printing speeds not higher than 6 pages per minute (ppm). However, owing to the rapid progress of technological development and the ongoing application of that technology into products, medium- and high-speed

Fig.2 Transition of shipment units for monochrome electrophotographic printers

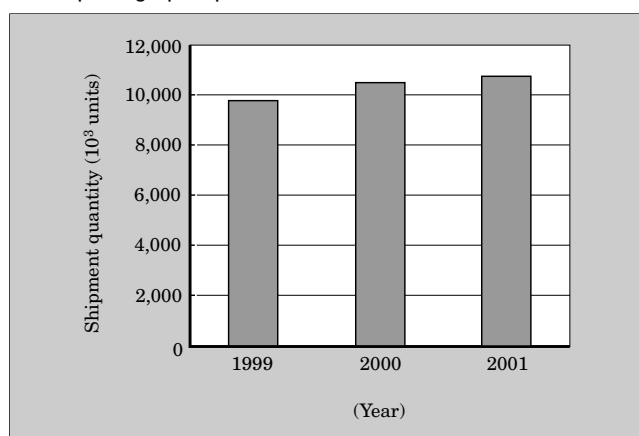
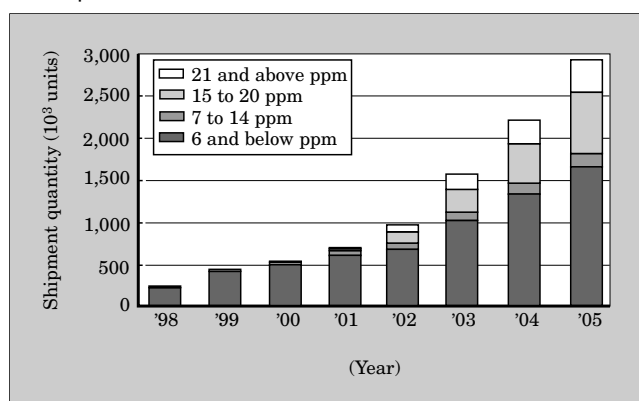


Fig.3 Forecast of shipment units for color electrophotographic printers



machines having printing speeds in excess of 15 ppm are expected to become the major products. In this scenario, the one-drum rotary system which prints 4 colors sequentially with a single drum, will be utilized in low-speed machines, while the four-drum system which prints each of 4 colors with 4 individual photoconductor drums, will be chiefly adopted for medium- and high-speed machines. The potential for expanding the market for electrophotographic devices depends upon the extent to which products can be provided at lower prices.

The requested improvements in properties of photoconductor drums for color printers are enhanced printing quality, especially higher resolution, and the stable photo-responsibility necessary for color reproduction. Of the abovementioned processes, especially in a 4-drum system, high dimensional accuracy is required of substrates for the purpose of controlling discrepancy in colors.

Another new trend is the popularization of on-demand printers with the advance of networking of information. Of the total quantity of printing on paper media, 70 % is occupied by newspapers, books, magazines and catalogs. Offset printing and photogravure printing are applied at present as the printing method for these paper media, of which the on-demand-printer targets small-lot printing or on-site printing. Their market image is not clear in some aspects, but the on-demand printer is a new application that leverages the features of electrophotographic printers, i.e. high-speed and flexibility.

For photoconductor drums used in these applications, high sensibility and high photo response for supporting the printing speed, durability for achieving a long useful life of the photoconductors, and high resolution approaching the level of offset printing are required. Some trials are reported to have achieved improved resolution by using liquid toner instead of the conventional dry toner, and photoconductors corresponding to this method are also being developed⁽²⁾.

3.2 PPCs

Figure 4 shows the trend of shipments of PPCs. Although the total number of shipments has nearly leveled off, shipments of digital PPCs show a rapid growth of 20 % per year, overtaking the lead from analog PPCs. Especially multifunction peripherals, which combine the functions of printers, PPCs and facsimile machines, show a steady increase with medium- and high-speed types as their main products. On the other hand, it is also estimated that low-speed machines having an image output speed of lower than 10 ppm will gradually be replaced by printers.

The characteristics requested of photoconductors for digital PPCs, in addition to high-speed photo response and durability, are the realization of photo-responsibility adapted to the printer process including tonal characteristics for reproduction of half tones.

Fig.4 Transition of shipment units for PPCs

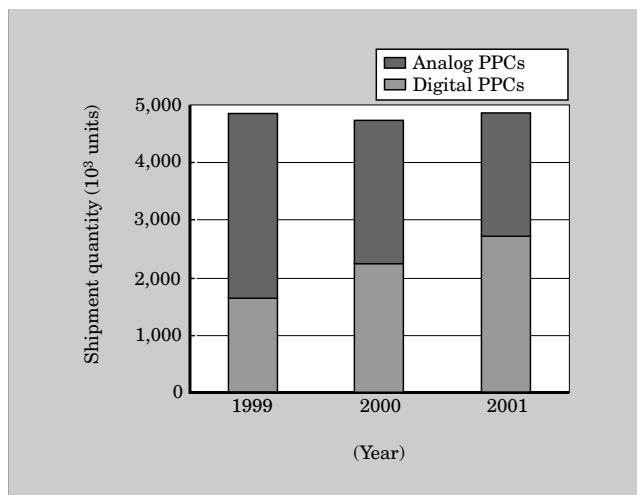
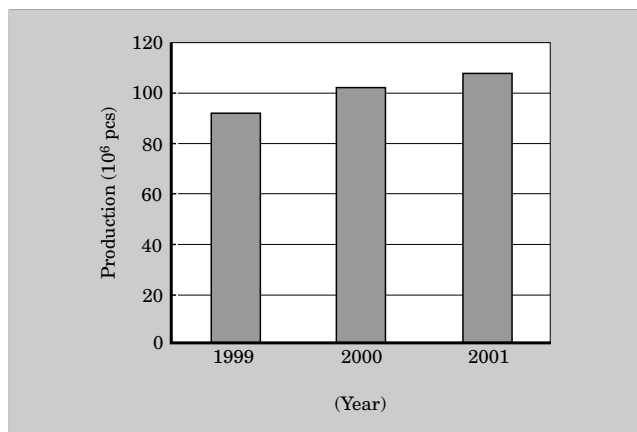


Fig.5 Transition of production for photoconductors



3.3 Photoconductors

Organic photoconductors (OPCs), selenium photoconductors and amorphous silicon conductors are used as the photoconductors for electrophotographic printers and PPCs. Figure 5 shows the trend of total production of these photoconductors, exhibiting steady annual increase rates of 6 to 10 %. As was already mentioned, the formation of new markets in the future is expected, including the popularization of color printers and on-demand printers, for which further growth is forecast.

The required characteristics for coping with these new developments are summarized as follows:

- (1) For color printers: high-resolution, color reproducibility and material tube precision
- (2) For on-demand printers: high-sensitivity, high-speed response and durability
- (3) For digital PPCs: high-speed response, durability and tone

In addition, improvement of various components, including developers, rollers and blades, and improve-

Table 1 Outline of Fuji Electric's OPCs

Type	Feature		Application
	Charging polarity	Layer structure	
8	Negative	Multilayer	Printer, Facsimile, Multifunction peripheral
9	Negative	Multilayer	Analog PPC
10	Negative	Multilayer	Digital PPC, Multifunction peripheral
11	Positive	Monolayer	Printer, Facsimile, Multifunction peripheral

ment in process conditions (low temperature fixing, advanced image-transfer conditions) are being advanced, and application of these improvements to existing processes is an important task.

4. Overview of Fuji Products

Fuji Electric has established an independent company, Fuji Electric Image Devices Co. Ltd., uniting the businesses of electrophotographic photo conductor and related areas, and has built up a system to cope speedily with drastic environmental changes. As production bases for photoconductors, in addition to the domestic Fuji Electric factory in the Matsumoto area, Fuji has subsidiary companies, i.e. U. S. Fuji Electric in USA and Hong Kong Fujidenki in Hong Kong, and is able to meet worldwide demand effectively. Also in the Shenzhen area of China, Fuji has Fusui Electric, a subsidiary company of Hong Kong Fujidenki, as a production base for various peripheral devices including process cartridges and toner cartridges. At present, many printer suppliers assemble printers in the Asian region including China, and we believe that the production of photoconductors in Hong Kong and of peripherals in Shenzhen will provide great convenience.

4.1 OPC

Fuji Electric has the 4 types of OPCs shown in Table 1 as a product series.

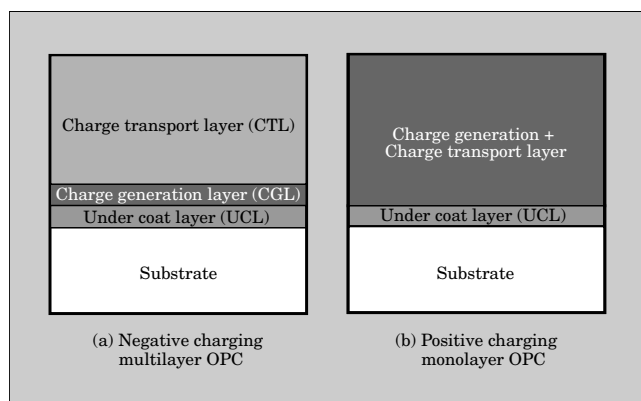
(1) OPC for printers

As OPCs for printers (Type 8), Fuji Electric has various products which correspond to a wide sensitivity range from low-speed machines to high-speed machines. Especially for the series of organic material products we provide many kinds of materials (charge generation material, charge transport material, etc.) and can satisfy diverse customer requirements. The color reproducibility can also be controlled for a wide range as required by color printers. In addition, the dimensional precision of drums is also enhanced by improving the finishing method.

(2) OPC for PPCs

We have 2 product series of photoconductors, type 9 for analog PPCs and type 10 for digital PPCs. We

Fig.6 Layer structure of OPC



offer a full range of products to satisfy requirements for high-speed response, high durability and tone as requested especially for PPCs, and we are improving the characteristics further by developing and designing new materials.

(3) Positive monolayer OPCs

The realization of positive charging monolayer OPCs, which have low ozone generation, excellent resolution, response and environmental stability, has long been expected. The layer structure thereof is shown in Fig. 6. As is known well, positive charging OPCs have the advantage of low ozone generation even when using a charging process with corona charging, and additionally are able to achieve intrinsically high resolution because photo absorption and charging occurs on the surface of the photoconductors. They have higher response and environmental characteristics than multilayer types and, in addition, require only a simple dipping process resulting in a high productivity. Based upon these advantages, positive charging monolayer OPCs are being applied to medium-speed page printers and on-demand printers, and improvements in sensitivity are further extending their application range.

4.2 Selenium photoconductors

The product series of selenium photoconductors is shown in Table 2. We have 2 types of products, Se-Te and Se-As. Fuji Electric always leads this product area based upon its abundant experience which includes selenium material technology, selenium purifi-

Table 2 Outline of Fuji Electric's Se photoconductors

Type	Material	Application
4	Se-Te	Medium- and low-speed PPC, Laser diode printers
5	Se-As	High-speed PPC, Laser diode printers

cation technology and vacuum evaporation technology, and Fuji Electric's proven track record in meeting customer requirements.

4.3 Peripheral products

On the basis of electrophotographic process technology cultivated over many years, Fuji Electric develops, designs and manufactures integrated process units, each of which contains a core photoconductor, and charging, development and cleaning components. Furthermore, we are endeavoring to develop a Fuji Electric original unit that realizes small-size and high image-quality. Many of these products are manufactured at the above-mentioned Fusui Electric facility.

5. Conclusion

With the advent of a highly information-oriented society, the performance expected of photoconductors is becoming higher and higher, including clearer image quality and higher durability. To meet these requirements, Fuji Electric endeavors to develop the most attractive products in the world, and to develop the most advanced materials, products and production technology. We are firmly determined to further build up our technology through concentrated effort by the entire company and all of its groups, and to supply products having high performance and reliability corresponding to customers' needs.

References

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