

Present Status and Future Prospects for Photoconductors

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1. Introduction

In today's changing business environment, the social responsibilities of corporations with regard to globalization, deregulation, structural reform and environmentally friendly practices are becoming more important. Under these circumstances, the provision of new products and valuable product services is important in order to compete successfully in the global market. For these types of business activities, IT is becoming an increasingly important tool to be used, and the popularization of the Internet is driving rapid advances in IT. Consequently, network-connected offices and home environments are also changing, and the importance of information transmission and reception capability is increasing.

For example, the network functions of image input/output-capable devices such as cell phones, personal computers, printers, digital copiers, electronic paper and scanners are rapidly being advanced. Under these circumstances, printers and copiers that display and record color information and images provide a role of growing importance.

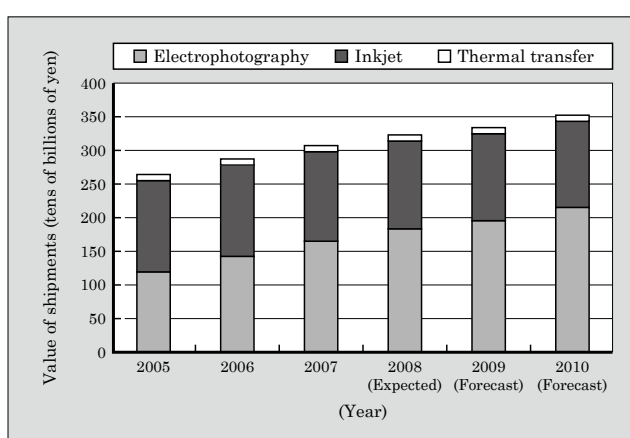
This paper describes the market trends of these printers and copiers and, as a subset thereof, the trends of electrophotographic printers and copiers, and also provides an overview of Fuji Electric's photoconductors that correspond to these trends.

2. Market Trends of Printers and Copiers

As a means of communicating text and images, soft copies (displayed images) and printed hard copies (printouts of the information) have been used.

Technology for soft copies, as typified by liquid crystal and organic EL (electroluminescence) displays, has made amazing advances and will come into even wider use in the future. Hard copies use paper media, the consumption of which is continuing to grow steadily, and various reasons can be given to explain this continued growth, but the major factors are believed to be paper's ability to combine various functions such as

Fig.1 Changes in worldwide value of shipments of color hard-copy machines



display, write, save and transmission, and also paper's inherent characteristics of being a lightweight and easy-to-use media.

In the computer output sector, hard copy methods are broadly classified into an inkjet method which is popular for personal use and an electrophotographic method which is popular for office use. The inkjet has the features of inexpensive device cost, color compatibility and special-use paper, while the electrophotographic method has the features of low running cost, speedy operation and of compatibility with ordinary paper.

Figure 1 shows the market forecast for various types of color hard copy machines. In 2007, the overall color hard copy market exhibited an approximate 7% year-on-year increase. The electrophotography market, however, driven by increased demand for color printers and color copiers, experienced even larger growth of approximately 16%. Large future growth is forecast for electrophotography. Inkjet printers and electrophotography will become competing technologies in the future, but by fully utilizing the advantages of each, future growth is expected for both methods.

3. Trends of Electrophotography

The demand for color electrophotographic printers

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and copiers has been trending upwards for the past several years, and especially due to the aforementioned advances in networking, colorization is progressing and demand for both types is continuing to increase. Also, structural changes in these printers and copiers are expected in the future in order to extend applications to the high-speed light printing field and to provide reduced power consumption and other technological advances in response to changes in the business environment.

3.1 Printers

Trends for shipments of electrophotographic-type monochrome printers, color printers, monochrome copiers and color copiers are shown in Fig. 2. In 2007, the shipment volume increased by 8% year-on-year for monochrome printers, but even more rapid was the 25% year-on-year increase for color printers. Large future increases in the shipment volume of color printers are forecast, and the market is expected to expand.

Fig.2 Changes in worldwide volume of shipments of electrophotographic devices

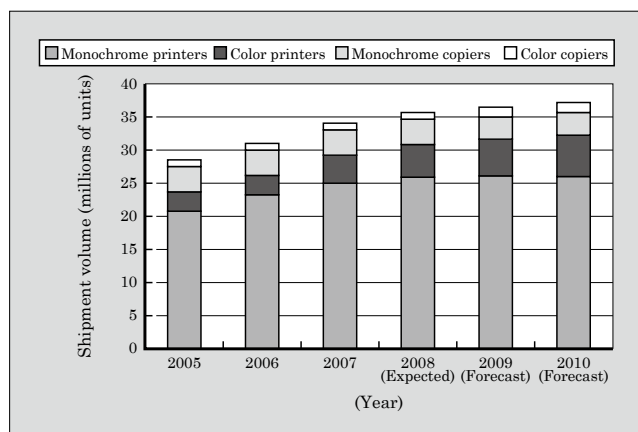
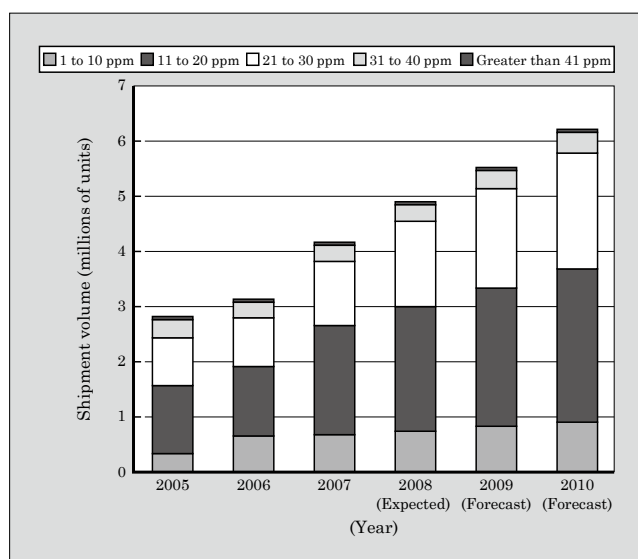


Fig.3 Changes in worldwide volume of shipments of color laser printers by speed



As can be seen in Fig. 3, color printers having output speeds of 10 ppm (pages per minute) and less experienced little growth, and 11 ppm and higher speed printers are expected to become the mainstream in 2007 and beyond. In this scenario, rather than the printing method used by low-speed copiers (4 cycle engine method) wherein a single photosensitive drum sequentially prints 4 colors, the method used by high-speed copiers (tandem engine method) wherein four photosensitive drums are arranged in series and each photosensitive drum prints a single color is expected to become the mainstream method.

The photoconductors used in color printers are required to provide high image quality, and in particular, high resolution and the required stable light attenuation characteristics for good color reproducibility. Moreover, especially in the tandem method above, the photoconductors are required to provide high dimensional accuracy in order to suppress color drift by the four colors.

Another trend in the printer industry is the progress toward light printing. On-demand printing is becoming more prevalent with increased information networking. Specifically, on-demand printing is used for small lot printing of newspapers, magazines, catalogs, and for onsite printing, and this is a new field that leverages the high-speed and convenience of electrophotographic printing. The photoconductors used in this field are required to provide high sensitivity and high-speed response corresponding to the printing speed, a suitable durability for the service life, and the high resolution sought for offset printing. Positive charge single-layer photoconductors, having a degree of resolution that does not deteriorate even if their outer film is removed, have been reported as the optimal photoconductors. Also, high resolution printers that use liquid toner instead of conventional dry toner have been announced, and photoconductors suitable for these printers are also being developed.

3.2 Copiers

The trend toward digitization is also advancing in the copier field. Figure 4 shows the changes in the worldwide volume of copier shipments. The overall shipment volume is trending toward saturation. Within this overall trend, however, shipments of color digital copiers are increasing while shipments of monochrome digital copiers are decreasing. The saturation is a result of printers being increasingly provided with MFP (multifunction peripheral) capabilities, and being positioned in the marketplace as an alternative to copiers. Figure 5 shows changes in the worldwide volume of shipments of copiers by speed. High-speed printers having image output rates of 21 cpm (copies per minute) and above show healthy growth, but those having output rates of 20 cpm and below exhibit a decreasing trend. The photoconductors used in copiers are required to provide such characteristics as high-speed re-

Fig.4 Changes in worldwide volume of shipments of copiers

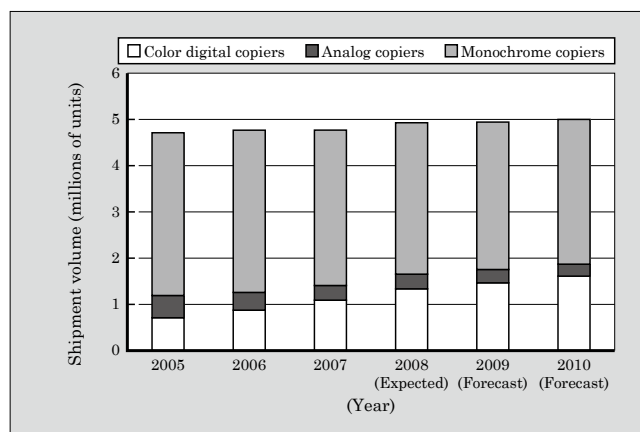
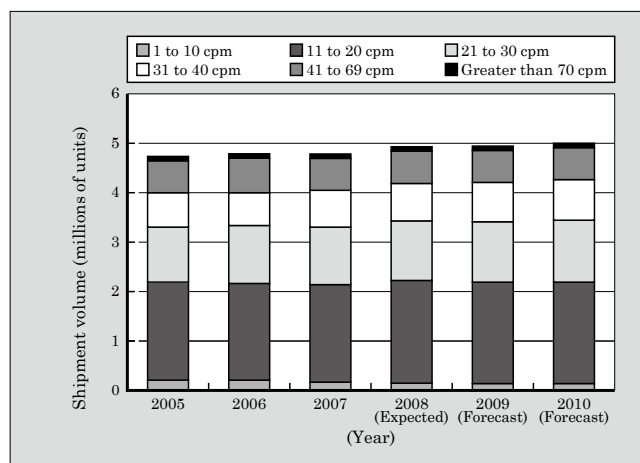


Fig.5 Changes in worldwide volume of shipments of copiers by speed



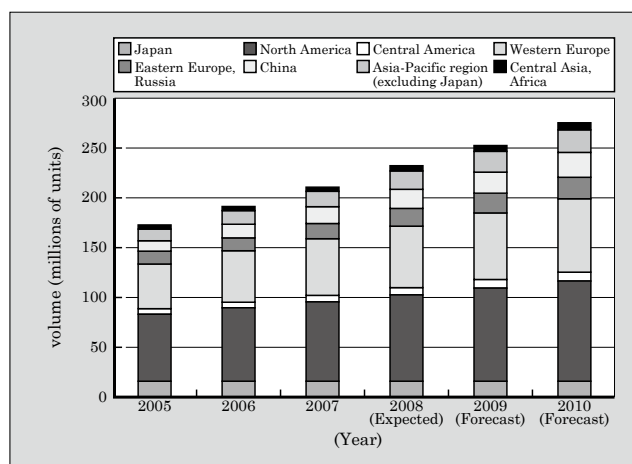
sponse, high durability and a wide range of gradation levels for reproducing half tones in graphic images, and to realize light attenuation characteristics suitable for copier processes.

3.3 Photoconductors

The types of photoconductors used in the above-mentioned electrophotographic printers and copiers include organic photoconductors (OPC), selenium photoconductors, amorphous silicon photoconductors and so on. Figure 6 shows the changes in worldwide volume of production of these photoconductors. Healthy growth at an annual rate of approximately 8% is shown. Moreover, the majority of consumption is presently concentrated in North America and Western Europe, but in the future, demand is expected to increase in Eastern Asia, Russia, China and the Asia Pacific regions. Driven by the increasing usage of color printers, on-demand printers and digital copies, in the future, a new market may be formed for electrophotographic devices that use these photoconductors, and further growth is anticipated.

The photoconductors characteristics necessary to support future new advances are summarized below.

Fig.6 Changes in worldwide volume of production of photoconductors



- (a) Color printers: High resolution, color reproducibility, high precision
- (b) On-demand printing: High sensitivity, high-speed response, high durability
- (c) Digital copiers: High-speed response, high durability, wide range of gradation levels

4. Overview of Fuji Electric's Products

Fuji Electric commercialized and began selling selenium photoconductors in 1973 and OPCs in 1988. Subsequently, Fuji Electric quickly and flexibly responded to the rapid advances in electrophotographic technology and expanded its business globally to include the development, production and sales of photoconductors, which are the core parts of printers and copiers, and to the peripheral devices.

Fuji Electric has three production sites, a domestic site in the Matsumoto area of Japan, U.S. Fuji Electric Inc. in the US, and Fuji Electric (ShenZhen) Co., Ltd. in the ShenZen area of China. In the first half of 2006, OPC production was integrated into the ShenZen area production work to support worldwide demand more efficiently.

Fuji Electric (ShenZhen) Co., Ltd. is the site of production for magnet rollers, toner cartridges and other peripheral products. At present, many printer manufacturers and copier manufacturers have located their equipment assembly operations in China and other Asian countries, and the production of photoconductors and their peripheral components in China is thought to provide considerable convenience.

4.1 OPCs

Fuji Electric is poised to respond to the diversified needs of customers and has prepared a product lineup of various types of photoconductors compatible with the light source wavelengths of printers and copiers so that clear images can be obtained.

Table 1 lists Fuji Electric's OPC product line-up.

Table 1 OPC product lineup

Type	Features		Uses
	Charging polarity	Layer structure	
Type 8	Negative	Stacked-layer type	Printer, facsimile, multifunction device
Type 9	Negative	Stacked-layer type	Analog copier
Type 10	Negative	Stacked-layer type	Digital copier, multifunction device
Type 11	Positive	Single-layer type	Printer, facsimile, multifunction device, light printing

(1) OPCs for use in printers

Fuji Electric has commercialized the type 8 OPC for use in printers, and has prepared a product lineup capable of supporting a wide range of potential responses and sensitivities, for low-speed printers to high-speed printers. For organic material (charge generating material, charge transporting material, and so on) in particular, Fuji Electric continues to work toward developing computer-assisted molecular design technology and other material design technologies, dispersion techniques for coating and liquefying material and coating technology for finishing OPCs, and is able to support a wide range of customer needs such as providing the high level of resolution and color image reproducibility characteristics required for color printers.

In order to reduce the amount of toner consumption, Fuji Electric focused on the adhesion of the photoconductor and toner and proposed various physical properties from the perspectives of both the photoconductor and the toner.

As for the dimensional accuracy of the drum, advances in element tube processing technology and the high precision design of the gears have enabled the realization of excellent rotational stability.

(2) OPCs for use in copiers

Two series of photoconductor products have been commercialized, type 9 for use in analog copiers and type 10 for use in digital copiers.

For copier-use, Fuji Electric has arranged a lineup of OPC products that satisfy the requested high-speed response, high durability and range of gradation levels, and is working to develop and design new materials in order to further improve the characteristics of these OPCs. In particular, OPCs for use in digital copiers are strongly requested to provide a long service life and good electric potential stability, and as a result of molecular design technology for OPC binder material and various additive technologies for electric potential stability, high performance photoconductors have been commercialized.

(3) Positive charge single-layer OPC

While expanding the series of photoconductor products compatible with the negative charge method, Fuji Electric is also working to develop a positive charge

type photoconductor that facilitates the realization of higher picture quality and helps reduce the amount of ozone emission in the environment. To realize such a photoconductor, the development of electron transport material having high mobility was essential. Fuji Electric succeeded in independently synthesizing the materials, and then commercialized them in 1999.

As is well known, positive charge type OPCs generate low amounts of ozone, even when corona discharge is used for the charging process, and because light absorption and charge generation occur at the surface of the photoconductor, positive charge type OPCs enable higher resolution.⁽¹⁾ Furthermore, compared to the stacked-layer type, positive charge single-layer OPCs have better response and environmental characteristics, and use a simple coating process that improves their ease of manufacture. To fully utilize these characteristics, applications to monochrome printers, color printers and on-demand printers are being advanced, improvements are being made to realize higher sensitivity and the application range is being expanded to also include high-speed printers.

4.2 Peripheral products

Using electrophotographic process technology which has been cultivated over many years, Fuji Electric designs, develops and produces process units that integrate the charging unit, of which a photoconductor is the core component, the developing unit and the cleaning unit for electrophotographic printer and copiers. In particular, owing to advances in element tube processing technology for photoconductors, and advances in miniature surface processing technology and thin film coating technology, the developing sleeve used for the developing unit is being installed in both monochrome printers and color printers.

5. Postscript

As a result of the evolution and progress of the Internet, the use of electrophotographic technology in digital and color applications is increasing by leaps and bounds. Performance expectations are increasing for photoconductors to achieve more vivid image quality and higher durability. In response to these market requests, Fuji Electric will undertake the challenge of improving material design technology, commercialization techniques and production technology, and intends to develop technology that is beneficial to our customers. We will also concentrate the collective power of all the Fuji Electric groups to strengthen our technical capabilities, and provide high performance and highly reliable products in response to customer needs.

Reference

- (1) Aizawa, K. et al. A Study of 1-dot Latent Image Potential". IS&Ts NIP17 International Conference on Digital Printing Technologies. 2001, p.572.



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