Present Status and Future Prospects for Photoconductors

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1. Introduction

In the future, information and communication technologies will continue to advance, and NGNs (next generation networks) will be deployed to link various types of devices. Accordingly, office and home environments linked to these networks will also change and the external transmission of information will become increasingly important.

The network functionality of image input and output devices, such as the familiar examples of digital still cameras, cell phones, scanners, printers and digital copying machines has increased rapidly, and the distribution of color image information over the Internet is rapidly becoming prevalent.

Under these circumstances, the role of printers and copiers that display and record color information and images will increase in importance, and color images may become the norm in the near future.

This paper discusses the market trends of these printers and copiers, especially the trends of electrophotographic-type printers and copiers, and describes Fuji Electric's photoconductors that support these devices.

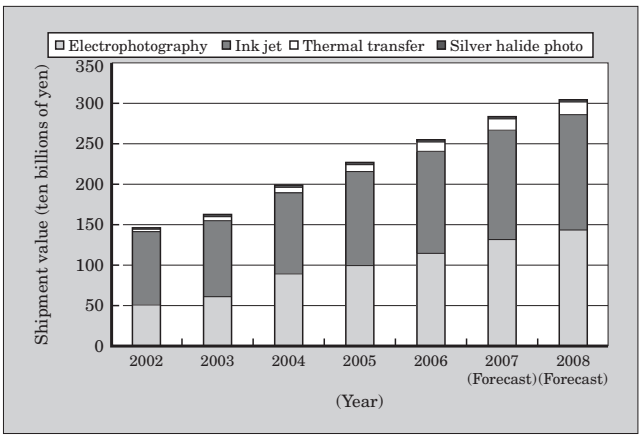
2. Market Trends of Printers and Copiers

Fuji Electric has used soft copies (displayed images) and hard copies (printouts of that information) as a means for transmitting text and images.

Soft copies, as typically shown on liquid crystal and organic EL (electroluminescence) displays, have made remarkable progress and will become even more prevalent in the future. Hard copies, as a paper medium, have continued to exhibit solid growth in their volume of consumption, and this growth is believed to be attributable to the many functions of paper, i.e., display, writing, storing and transmission, and because paper is a lightweight and highly convenient media.

Meanwhile, as a third technology that is a successor to paper and displays, electronic paper and other new technologies are being advanced. In the mid- and long-term, these electronic media are expected to increase relative to paper media. Also, due to the synergistic effects of both media, the amount of information handled will continue to increase, and as a result, continued growth is forecast for both types of media.

Fig.1 Changes in worldwide value of shipments of color hardcopy machines



The hardcopy output from computers or the like can be broadly categorized as an inkjet method that is dominant in the personal-use sector and an electrophotographic method that is dominant in the office-use sector. The inkjet method which uses special paper has the advantages of inexpensive equipment cost and color-compatibility, while the electrophotographic method which uses plain paper has the advantages of inexpensive running cost and speediness.

Figure 1 shows the market forecast for color hardcopy machines. Shipments of electrophotographic color printers and color copiers have risen rapidly since 2004, and have been increasing by approximately 16 % over the past several years, and significant future growth is also predicted. The inkjet and electrophotographic methods will continue to compete against one another in the future, but their markets will also continue to grow as the individual characteristics of each are best utilized.

3. Trends of Electrophotography

The demand for color electrophotographic printers

and copiers has been increasing over the past several years, and particularly with the above-described developments in networking, colorization is advancing for both electrophotographic printers and copiers.

It is also thought that environmental changes will drive technological evolution and changes in structural models.

3.1 Printers

The volume trends of electrophotographic type monochrome printer and color printer shipments are shown in Figs. 2 and 3. In 2003, the shipment volume of monochrome printers was approximately 11.8 million units, while the color printer shipment volume remained at approximately 1.2 million units. Over the past several years, however, the color printer shipment volume has exhibited growth on the order of 20 % annually, and this market is expected to expand in the future.

Fig.2 Changes in worldwide volume of shipments of electrophotographic monochrome printers and color printers

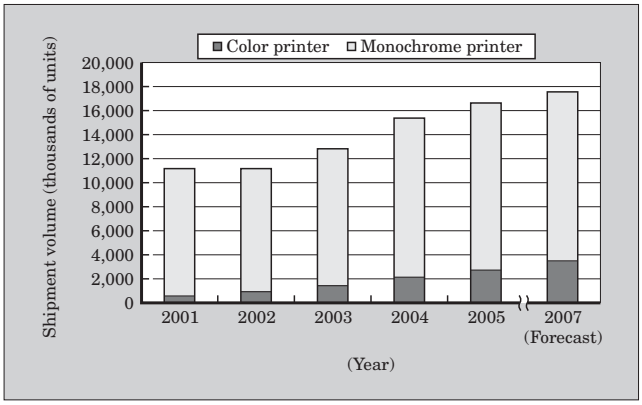
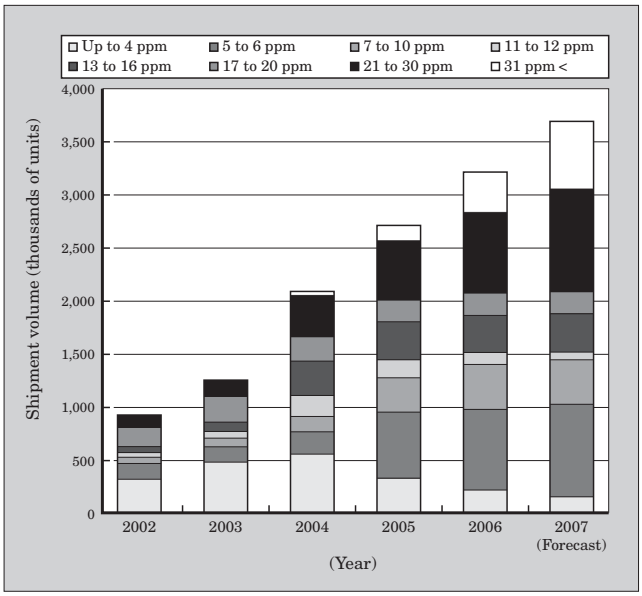


Fig.3 Changes in worldwide volume of shipments of color laser printers by speed



As can be seen in Fig. 3, shipments of low-speed color printers having image output speeds of 4 ppm (pages per minute) or slower are decreasing, and 5 ppm and faster printers have become the mainstream type of printer since 2005. Low-speed printers use a printing method whereby four colors are printed with a single photosensitive drum (4-cycle engine), while medium-speed and high-speed printers have four photosensitive drums arranged in series and use a method of printing one color with each drum (tandem engine). The tandem engine method is expected to become the mainstream printing method.

The photoconductors used in color printers are required to improve image quality, especially the image resolution, and to have stable optical attenuation characteristics which are necessary for good color reproducibility. Also, among the abovementioned processes, in the tandem engine process in particular, photoconductors are required to have high dimensional precision in order to suppress color drift among the four colors.

Another trend in the printer sector is the progress toward quick printing. The networking of information is driving widespread use of on-demand printers. Specifically, quick printing is used for newspapers, magazines, catalogs and other types of small-lot printing and onsite printing jobs, and this is a new market sector that utilizes the high-speed performance and convenience of electrophotography. The photoconductors used in these applications are required to have high sensitivity that supports the printing speed, high-speed responsiveness and good durability, i.e., long service life, and high resolution near that of offset printing. The optimal photoconductor has been reported to be a positive charge monolayer-type photoconductor that does not decrease in resolution even if the film is trimmed away. Also, there have been some announcements made of high resolution printers that use liquid toner instead of the conventional dry toner, and photoconductors that support these printers are being developed.

3.2 Copiers

The trend toward digitization is also advancing in the market sector for copiers. Figure 4 shows the changes in volume of copier shipments. The overall shipment volume is decreasing, and although monochrome digital copiers are exhibiting a rapid decrease, shipments of color digital copiers are increasing. This trend is due to printers becoming MFPs (multifunction peripherals) and replacing copiers. Figure 5 shows the changes in volume of shipments of digital copiers according to speed. Shipments of medium- and high-speed copiers having an image output rate of 21 cpm (copies per minutes) or faster are exhibiting solid growth, but shipments of 20 cpm and slower copiers are decreasing.

The photoconductors used in digital copiers are re-

Fig.4 Changes in worldwide volume of shipments of copiers

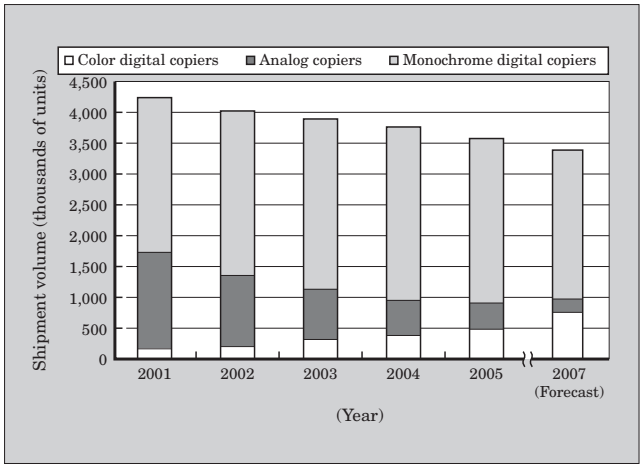
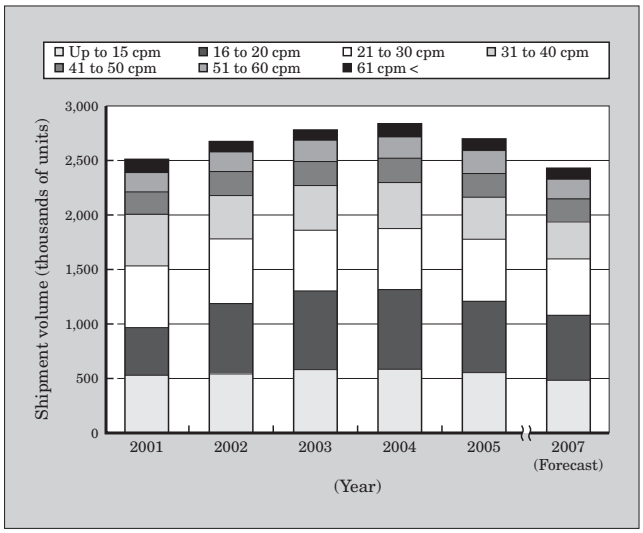


Fig.5 Changes in worldwide volume of shipments of monochrome digital copiers by speed

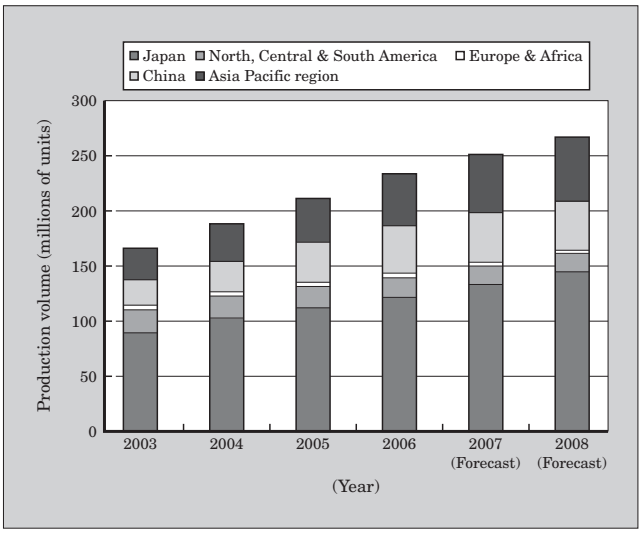


quired to have the characteristics of high-speed responsiveness, good durability, grayscale capability to reproduce halftones in a graphic image and the like, and the capability to realize optical attenuation suitable for the copier process.

3.3 Photoconductors

The photoconductors used in the above-mentioned electrophotographic printers and copiers are OPCs (organic photoconductors), selenium photoconductors, amorphous silicon photoconductors and the like. Figure 6 shows the changes in production of photoconductors according to region. It can be seen that production is increasing at a solid annual growth rate of 5 to 10 %. Also, although Japan is presently the site of the majority of production, in the future, the majority of production is expected to come from China and the Asia Pacific region. As electrophotographic equipment that uses these photoconductors, the widespread usage

Fig.6 Changes in worldwide volume of production of photoconductors



of color printers, on-demand printers and digital copiers is anticipated, potentially forming a new market, and further growth is expected.

The following characteristics are required of photoconductors to support new developments in the future.

(1) Color printers: High resolution, color reproducibility and element tube precision are required
(2) On-demand printers: High sensitivity, high-speed responsiveness and durability are required
(3) Color digital copiers: High-speed responsiveness, durability and grayscale capability are required

4. Overview of Fuji Electric's Products

Fuji Electric commercialized and began to sell selenium photoconductors in 1973 and OPCs in 1988. Then, quickly and flexibly responding to the rapid advances in electrophotographic technology, Fuji Electric deployed a global business for developing, manufacturing and marketing photoconductors, the core component of printers and copiers, and their peripheral equipment.

Three sites of production, in Japan (Matsumoto area), in the United States by U.S. Fuji Electric in the United States, and in China (ShenZhen area) by Fuji Electric (ShenZhen) Co., Ltd., will be integrated into the ShenZhen area site during the first half of 2006 in order to meet global demand more efficiently.

Fuji Electric (ShenZhen) Co., Ltd. manufactures various peripheral products including developing sleeve and toner cartridges. Many printer manufacturers and copier manufacturers are assembling equipment in China and other Asian countries, and it is thought that manufacturing photoconductors and their peripheral components in China provides significant convenience.

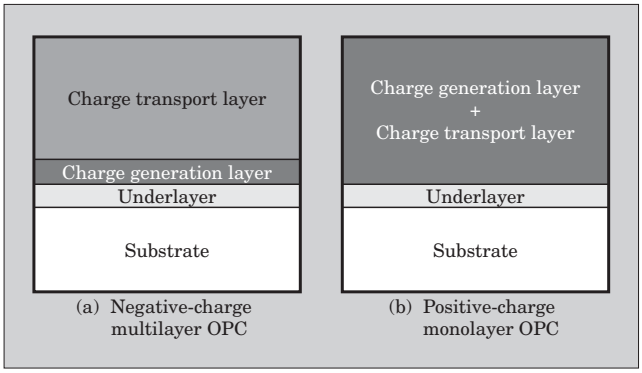
4.1 OPC

Fuji Electric is poised to respond to individual re-

Table 1 OPC product lines

Type	Characteristic feature		Use
	Charge polarity	Layer structure	
Type 8	Negative	Multilayer	Printers, facsimile machines, multifunction devices
Type 9	Negative	Multilayer	Analog copiers
Type 10	Negative	Multilayer	Digital copiers, multifunction devices
Type 11	Positive	Monolayer	Printers, facsimile machines, multifunction devices, quick printing devices

Fig.7 OPC layer configuration



quests from a diversity of customers, and in order to obtain sharp images, Fuji provides a product line of various photoconductors with wavelengths suitable for various printer and copiers.

Table 1 lists a lineup of four types of OPC product lines. Figure 7 shows the OPC layer structure.

(1) OPCs for printers

The type 8 product line has been commercialized for printer-use OPCs; it supports a wide range of potential differences and a wide range of sensitivities, for low-speed to high-speed devices. For organic materials (charge generating material, charge transport material, and the like) in particular, development continues day and night into many types of material design techniques including the computer-based molecular design of materials, dispersion techniques for applying coating solutions to the material, and coating techniques for the OPC. The high resolution, color image reproducibility and so on required by color printers make it possible to support a wide range of customer requests.

Also, the dimensional precision of the drum maintains excellent rotational stability due to advances in element tube processing technology and a high precision design.

(2) OPCs for copiers

OPCs for copiers are commercialized with two product lines, the type 9 OPC line for use in analog copiers and the type 10 OPC line for use in digital copiers.

Product lines are arranged to satisfy the copier requirements for high-speed responsiveness, high durability and grayscale capability, and new materials are being designed and developed to improve performance further. In particular, because long service life and potential difference stability are required for OPCs used in digital copiers, molecular design technology and various potential difference stabilization agents are applied to the OPC binder material in order to commercialize higher performance photoconductors.

(3) Positive charge monolayer OPCs

While expanding OPC product lines appropriate for the negative charge method, Fuji Electric also worked to develop positive charge type photoconductors able to realize high image quality with ease and to reduce the amount of ozone generated. The development of high mobility electron transport material was indispensable for realizing these photoconductors. Fuji Electric successfully synthesized proprietary materials, and in 1999 realized those products. The OPC layer configuration is shown in Fig. 7.

As is well known, the generation of ozone by positive charge-type OPCs is small, even when using a charging process based on corona discharge. Also, positive charge-type OPCs are able to provide high resolution since light absorption and charge generation occur at the photoconductor surface. Additionally, compared to a multilayer structure, because responsiveness and environmental performance are better, and because the coating process is simple, manufacturability is also better. These various characteristics will be fully applied to develop positive charge monolayer OPCs for monochrome printers, color printers and on-demand printers, to make improvements to achieve higher sensitivity, and to expand the range of applications to encompass high-speed devices.

4.2 Selenium photoconductors

Leveraging its wealth of experience with selenium materials technology, selenium refining technology, vacuum deposition technology and the like, Fuji Electric has constantly been the leader in this product sector, and has continued to meet customer needs. However, due to a drop in demand, Fuji Electric plans to cease production of selenium photoconductors and to withdraw from the selenium business in 2007.

4.3 Peripheral products

Based on electrophotographic process technology acquired over many years, Fuji Electric has developed, designed and even manufactured process units that integrate a charging part for which a photoconductor is the main component, a developing part and a cleaning part. In particular, the developing sleeve used in the developing part is being applied to both monochrome printers and color printers due to its advanced surface micro-processing technology and thin film coating technology enabled by element tube processing technology for photoconductors.

Most of these products are manufactured at the aforementioned Fuji Electric (ShenZhen) Co., Ltd. in China.

5. Conclusion

With the development of the Internet, applications of electrophotographic technology are increasing rapidly as the use of digital and color images becomes more widespread. Photoconductors are expected to provide sharper images, greater durability and so on, and their level of performance is continuing to increase. Fuji Electric intends to respond to these market requests, to take on the challenge of improving materials design, product development and production technology, and to develop attractive products for its customers.

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.