Photoconductors: Current Status and Future Outlook

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ABSTRACT

From the perspectives of energy and the environment, energy savings is also needed in the field of electrophotography. The market for electrophotography-based printers and copiers is forecast to grow at an annual rate of approximately 8%. Accordingly, that same growth rate is also forecast for photoconductors, which are key electrophotographic devices. Fuji Electric is consolidating its OPC production facilities in Shenzhen, China in order to meet worldwide demand. Also, newly adding positive electrification multi layer-type photoconductors for greater energy savings, Fuji Electric offers five lines of photoconductor products, i.e., negative electrification type photoconductors for printers, analog copiers and digital copiers, and monolayer type and multi layer-layer type positive electrification photoconductors for printers, and delivers products that are well suited for energy savings and that are friendly to the global environment.

1. Introduction

Advances in information technology, the rise of the emerging economies, and other factors have given access to information networks to huge numbers of people around the world. There has been a concomitant massive increase in the numbers of running computers, mobile phones, and other networked devices, as well as printers and digital copiers. There are concerns that the energy consumed by these devices will have a large impact on the global environment, creating a strong demand for energy efficiency (energy conservation) in the field of information devices as well.

In reaction to this situation, Fuji Electric wants to be friendly to people and the environment. It aims to contribute to society through energy and environmental businesses, in order to create harmony between the Earth and society. This includes mitigating global warming, creating a closed-loop economy, and ensuring biodiversity.

In its photoconductor business as well, it is contributing to the energy efficiency of printers, copiers, and other electrophotographic devices, by developing energy-efficient photoconductor products that are friendly to the global environment.

This paper describes the trends in the printer and copier markets; highlight the latest energy-efficient technologies and products using photoconductors as key device for electrophotographic technologies; and describe the outlook for Fuji Electric's photoconductors in the global environment.

2. Trends in the Printer and Copier Markets

There are two methods for displaying text and image information: soft copy (shown on a display) and hard copy (printing). There have been remarkable advances in soft-copy technology, most notably in LED and organic light-emitting diode (OLED) displays, and the adoption of these technologies is expected to continue to increase.

Meanwhile, hard copies consume paper as their medium. In 2009, a keynote address at NIP25 (IS&T's NIP25: Imaging Science & Technology's 25th International Conference on Digital Printing Technologies) reported that printing both sides of a sheet of A4 paper resulted in the same level of carbon-dioxide emissions as reading the equivalent A4 document on a computer screen for five minutes[(1)]. The production of paper has a long history. Its manufacture has been made extremely energy efficient, and it is likely to continue to be used as a lightweight and highly convenient medium.

Computer output devices that produce hard copy

Fig.1 Trends in Worldwide Color Hard-copy Devices by Shipment Value

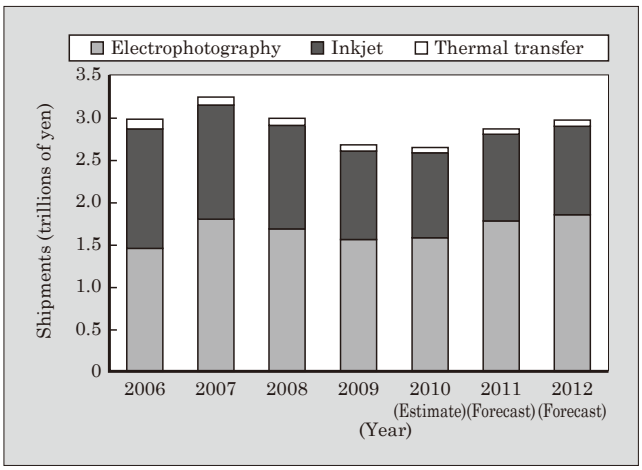

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Fig.2 Trends in Worldwide Electrophotographic Devices by Units Shipped

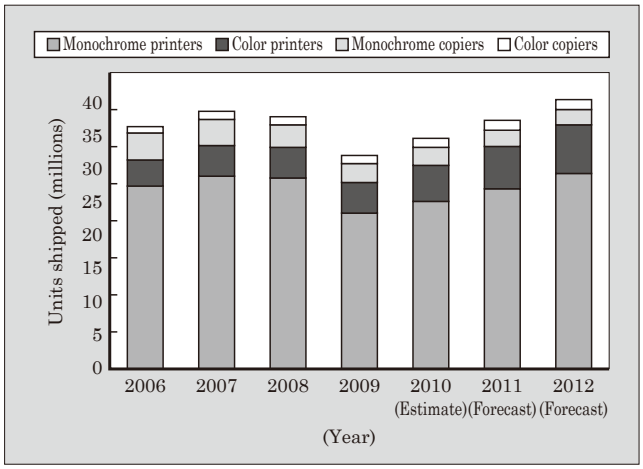
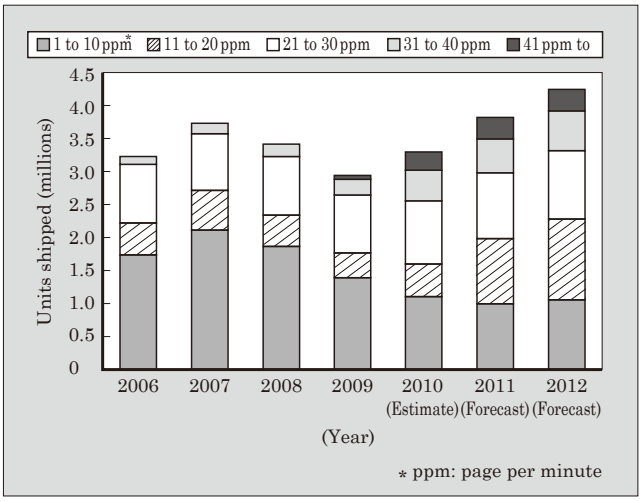


Fig.3 Trends in Worldwide Color Laser Printers by Speed and Units Shipped



can be classified into two types: inkjet printers, which are popular for personal use, and electrophotographic printers, which are popular for office use. Inkjet printers are inexpensive, support color, and use special inkjet paper. Meanwhile, electrophotographic printers have lower running costs, are fast, and support ordinary paper.

Figure 1 shows the trends in the market for color hard-copy devices of each category, by shipment value[2]. In 2011, the overall color hard-copy market is expected to grow by about 8% year on year. In particular, the electrophotographic market is expected to grow by a large margin of about 13%, driven by growth in color printers and color copiers, and the market is expected to continue to grow moving forward.

3. Trends in Electrophotography

Figure 2 shows the trends in numbers of electrophotographic printers and copiers shipped. In 2009, the year after the global financial crisis precipitated by the collapse of the Lehman Brothers, shipments plummeted by 15% year on year, to 29 million units. The markets of China and the other emerging economies subsequently recovered, and manufacturers launched products meeting the specifications of these markets, resulting in 8% year-on-year growth worldwide in 2010. As document expression becomes increasingly diverse and sophisticated, there has been a growing trend toward color electrophotography, and a year-on-year growth of about 16 to 17% is expected. It is also expanding into the light printing field, as it expands into production printing.

As a technical trend, more energy-efficient electrophotographic printers, copiers, and other devices are being developed as a measure for the global environment. In particular, manufacturers are working actively to improve the energy efficiency of the process for fusing toner on paper, as this consumes about 60% of the total electric power. One example is the switch from thermal-heater fusing to belt fusing, using electromagnetic induction heating. This enables operation without preheating, greatly reducing both standby time and power consumption. Another example is the development of low-temperature toner, which can fuse at lower temperatures. In response to these trends in electrophotography, the trend in photoconductor technology is toward helping to reduce rotation torque, and ensuring durability and high lubrication that resists filming, even when low-temperature toners are used. Fuji Electric is committed to quickly developing and marketing highly environment-friendly photoconductors.

3.1 Printers

As shown in Fig. 2, shipments of monochrome printers are expected to grow by 5% year on year by units shipped in 2011, while shipments of color printers are expected to grow by a massive 16%. This high rate of growth in numbers of color printers shipped is expected to continue.

Figure 3 shows trends in shipments of color laser printers by speed and units shipped. As shown in Fig. 3, there has been almost no growth in shipments of color printers with an output speed of 10 pages per minute (ppm) or lower, and printers with speeds of 11 ppm and higher are expected to become the norm starting in 2010. Low-speed devices employ a method of printing four colors, using one photoconductor at a time (four-cycle method), while medium-speed devices largely use the tandem method, where four photoconductive drums are arranged in an array, and each drum prints one color.

One of the features required of photoconductors for color printers is stable light attenuation, which is required in order to ensure image quality, and high resolution and color reproducibility in particular. High dimensional accuracy is particularly required of photoconductors using the tandem method, in order to su-

Fig.4 Trends in Worldwide Copiers by Units Shipped

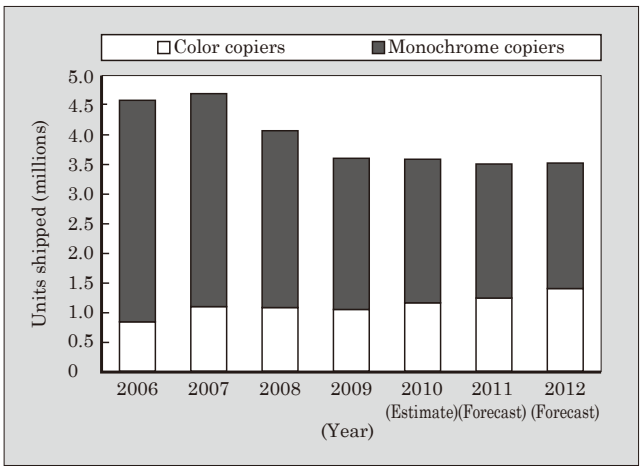
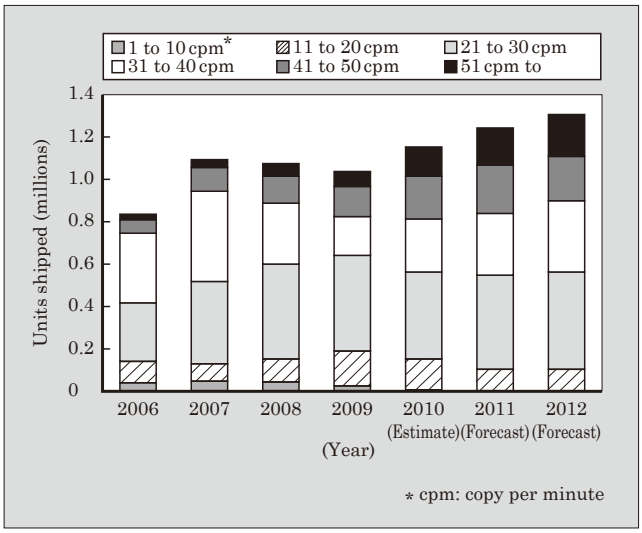


Fig.5 Trends in Worldwide Copier Market by Copying Speed



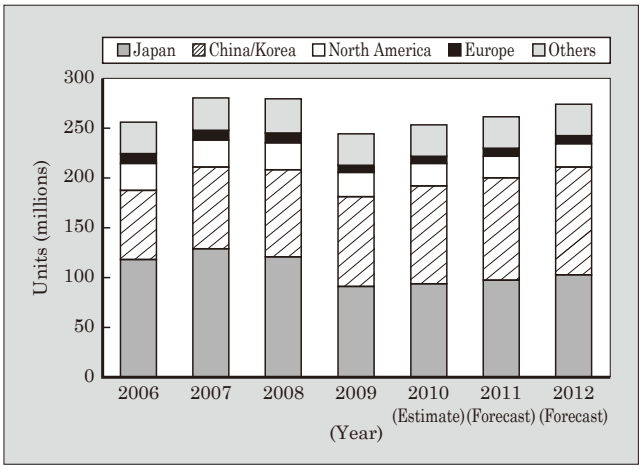
press color drift by the four colors.

One trend in the printer field is expansion into the light printing field. As electrophotographic technology becomes more advanced, electrophotography is expanding into the printing field. In particular, toner-fusing methods and printer paper have advanced to the point where they offer the same quality as printed images. Photoconductors used in the light printing field must have high resolution and durability. The papers in this special issue describe photoconductors for digital copiers and latent-image evaluation techniques in detail.

3.2 Copiers

Copiers are also becoming increasingly energy efficient and digital. Figure 4 shows trends in shipments of copiers by numbers of units. Although the overall number of units shipped is declining, shipments of color copiers are increasing. Figure 5 shows shipments of color copiers by copying speed and numbers of units. Shipments of medium and high-speed copiers with speeds of 21 copies per minute (cpm) and above are

Fig.6 Trends in Worldwide Organic Photoconductors by Region and Units Produced



strong, while shipments of 20 cpm and lower copiers are falling. Shipments of 51 cpm and higher copiers are also growing. Particular focus is being placed on energy efficiency, and more copiers are changing from thermal fusing to induction-heat fusing in order to improve the fuser, and are using toners that fuse at lower temperatures.

Some of the features demanded of photoconductors for copiers are high responsiveness, durability, and light attenuation suited to the copier processes, such as gradations that can reproduce halftones in graphical images.

3.3 Photoconductors

Some of the photoconductors used in electrophotographic printers and copiers include organic photoconductors (OPCs), selenium photoconductors, and amorphous silicon photoconductors.

99.6% of all photoconductors produced are OPCs. Figure 6 shows trends in numbers of OPCs produced by region[3]. After the global financial crisis, the production volume in Japan plummeted by about 25% in 2009, while produciton levels in China and Korea remained nearly unchanged and reached the same volume as Japan. The economy subsequently stabilized, and production is growing at a strong rate of about 8% per year. North America and Western Europe account for the majority of consumption. Moving forward, demand is expected to grow in such regions as Eastern Europe, Russia, China, Asia, South America, and Africa (the BRICs and VISTA). In the field of electrophotographic devices using photoconductors, demand will be captured by low-priced, compact monochrome printers. Products will also need to match the distinctive characteristics of each market country. For example, a distinctive type of paper is used in China that has rougher surfaces that in Japan, and printers sold there must have an internal structure that supports this type of paper.

Table 1 Organic Photoconductor (OPC) Product Series

Type	Features		Applications
	Electric charging polarity	Layer composition	
Type 8	Negative	Multilayer	Printers, facsimiles, multifunctional devices
Type 9	Negative	Multilayer	Analog copiers
Type 10	Negative	Multilayer	Digital copiers, multifunctional devices, convenience printings
Type 11	Positive	Single layer	Printers, facsimiles, multifunctional devices
Type 12	Positive	Multilayer	Printers, facsimiles, multifunctional devices, convenience printings

4. Overview of Fuji Electric Products

Fuji Electric developed and began marketing selenium photoconductors in 1973, and OPCs in 1988. OPCs are a key device for printers and copiers. Fuji Electric develops, produces, and markets OPCs and peripheral devices on a global scale, responding swiftly and flexibly to the rapid advances in electrophotographic technologies.

The company had three bases of production: one in Japan, one in the United States, and one in China; but in early 2006, production was consolidated in Shenzhen, China, responding efficiently to worldwide demand.

Fuji Electric (Shenzhen) is a production site for peripheral products, such as mag sleeves and toner cartridges. Currently, many manufacturers of printers and copiers assemble their devices in Asia, including China. The production of OPCs and their peripherals in China thus offers a great deal of convenience.

4.1 Organic Photoconductors (OPCs)

The demands of Fuji Electric's customers are growing increasingly diverse. Fuji Electric has created an organization to respond to these demands. It develops OPC products matching the wavelengths of printer and copier light sources, in order to deliver crisp and clear images.

Table 1 shows the company's product series.

(1) Printer OPCs (Type 8)

Type-8 products were developed as OPCs for general printers. This type includes a lineup that can support a wide range of potential responses and sensitivities, from low-speed to high-speed devices. In particular, the company continues to develop technologies relating to organic materials (e.g. charge-generating materials and charge-transporting materials). These include a wealth of technologies for designing materials, including technologies for molecular design using computers, dispersion technologies for converting materials into coating liquids, and coating technologies for finishing OPCs. This type is able to meet a wide range of customer demands, including the high resolution and color-image reproduction demanded of color printers. The company won the Best Poster Award of the Imaging Society of Japan for its research into the mechanism of latent-image formation of OPCs, and for revealing the relationship between photoconductor characteristics and resolution[4),5)]. The aim of this research was to improve resolution, through support for color imaging and photo-image quality.

The company aimed to reduce toner usage, in order to make an OPC suited to energy-efficient electrophotographic devices. Focusing on photoconductors and toner adhering strength, Fuji Electric has proposed various physical models taking into account both the photoconductor and the toner[6),7)].

The company has also improved the dimensional precision of drums by developing outstanding rotational stability. This is achieved by advancing technologies for processing element tubes, and designing high-precision drive gears.

(2) Copier OPCs (Type 9 & Type 10)

Two series of photoconductors are developed: Type-9 products for analog copiers and Type-10 for digital copiers.

These lines of products satisfy the particular demands of copiers: high responsiveness, high durability, and gradations. Fuji Electric also continues to improve these characteristics through the design and development of new materials. Digital copiers in particular have strong demands for long lifetime and potential stablity. The company has thus created high-functionality OPCs via technologies for molecular design of OPC binder materials and additive technologies for potential stablity, in order to meet these demands.

(3) Positive Charge OPCs (Type 11 & Type 12)

As Fuji Electric expands its lineup of OPC products suited to negative electric charge, it has also been developing positive-charge OPCs. Positive OPCs have high possibility to improve image quality easily, and produce less ozone, which is better for the environment. The development of electron-transport materials with high mobility is essential for creating these OPCs. Fuji Electric succeeded at synthesizing unique materials, and released a product using them in 1999. As is well known, positive-charge OPCs generate low levels of ozone even when using an electric-charge process via corona discharge. They can also improve resolution, because light is absorbed and electric charge generated on the surface.

Then in 2009, Fuji Electric became the first in the industry to develop a multilayer positive-charge OPC as an energy-efficient laser light source. This has higher sensitivity, responsiveness, and environmental stability than single-layer OPCs, and moving forward will be able to make a contribution as an OPC friendly to the global environment. The company is taking advantage of these features to expand them to use in

monochrome printers, color printers, and on-demand printers, as their application expands to high-speed devices as well.

4.2 Peripheral Products

Fuji Electric has developed electrophotographic process technologies over many years. Based on these technologies, the company develops and designs development sleeves and other peripheral products using process simulators that combine the electric-charge module, development module, and cleaning module. Development sleeves using development modules are also used in both monochrome printers and color printers, via more advanced OPC element-tube processing technologies, and more advanced minute surface-processing technologies and thin-film coating technologies.

5. Postscript

Electrophotographic technologies are increasing in adoption; the growth of the Internet has caused a dramatic increase in the adoption of digital and color devices. The functionality expected of OPCs includes crisper images and better durability; energy-efficient OPCs are also becoming increasingly friendly to the global environment.

Fuji Electric is committed to meeting these market needs with more advanced technologies for designing materials, creating products, and production. It is developing products that are attractive to its customers. Fuji Electric will continue to leverage the combined strength of the Fuji Electric Group to improve its technical capabilities, meet the needs of its customers, and offer highly capable products and services with the highest level of quality in the industry.

References

(1) Hirakura, Koji. Environmental Strategy of Japanese Digital Printing Industry. IS&T's NIP25 International Conference on Digital Printing Technologies. 2009, p.5.

(2) Inter Watch. Worldwide Market Trends of Color & Monochrome Printers and MFC (All Types) by Model; Consumables Market; and Future Analysis. 2010.

(3) Data Supply. Photoconductor Market Outlook. 2010 Photoconductor Market Overview.

(4) Aizawa, K. et al. A Study of 1-dot Latent Image Potential. IS&T's NIP17 International Conference on Digital Printing Technologies. 2001, pp.572-575.

(5) Aizawa, K. et al. A Study of Electrostatic Analysis Technologies. The Imaging Society of Japan. Imaging Conference JAPAN 2008 Fall Meeting. 2008, pp.33-36.

(6) Aizawa, K. et al. A Study of Latent Image Analysis Technologies Using Electrostatic Force Microscopy. The Imaging Society of Japan. Imaging Conference JAPAN 2009 Fall Meeting. 2009, pp.29-32.

(7) Hitomi, M. et al. Organic Photoconductors, Technologies for Evaluating Adhesion of Toner, and Impact of Charge Transport Layer on Toner Adhesion. The Imaging Society of Japan. Imaging Conference JAPAN 2007 Fall Meeting. 2007, pp.35-38.