Color Imaging Technology with Amorphous Silcon Drum[1]

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Abstract

The electrophotographic full color mutifunction printer (MFP) imageRUNNER™ C6800 is equipped with an amorphous silicon (a-Si) photoconductive drum.The concept of the MFP is "a color MFP to replace B/W MFPs in the office."To realize the concept, we selected the a-Si drum, which has many merits: high surface hardness, linear E-V characteristics, few degradation by primary charging or light exposure, and high permittivity.

And as a developing system suitable for the a-Si drum, we combined magnetic one-component jumping development for black and two-component development for Y, M and C.

The color development system features high resistive and low magnetized carrier particle and low compression to the developing agent.

Overview and Concept of the Product with the Technology

Overview

The electrophotographic full color MFP imageRUNNER™ C6800, introduced into market by Canon in 2004, is one of its full color MFP line-ups for office use along with the imageRUNNER™ C3200/C3200N introduced in 2002, the imageRUNNER™ C3100 introduced in 2004.

1.1.1 Major Specifications

Productivity:
Multicopy speed (Letter):
68ppm (B/W)/ 15.5ppm (full color)
First Copyout Time(FCOT):
5.3sec(B/W)/12.2sec (full color)
Resolution:
Scanning: 600dpi×600dpi
Printing: Up to 2400 dpi equivalent x 600 dpi (interpolated)
Durability:
Yield for a-Si drum:3M impressions
Life of developing units:
1M images (B/W)/0.5M images (full color)

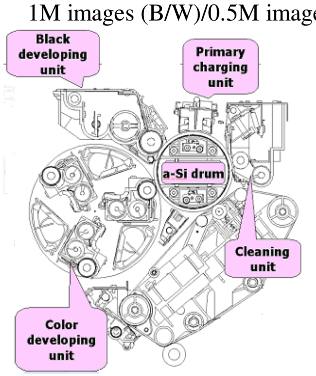

Fig.1 Cross section of imageRUNNER™ C6800 marking engine

1.1.2 Marking Engine

Its cross section is shown in Fig.1.
The a-Si drum is surrounded by a black developing unit, color developing units, a cleaning unit, etc.

1.1.3 Features

A-Si drum
Hybrid engine for a-Si drum
Compactness rivaling to B/W products
Large black toner bottle（yield 40K images) (not shown in Fig.1)

Concept

"A color MFP to replace B/W MFPs in the office"
More concretely,
1 To maintain the merit as a B/W MFP, low operation cost, long-range stability and high productivity
2 To add function as a full color MFP
To realize the concept, we have selected the a-Si drum.

Characteristics of A-Si Drum[2]

Canon has adopted a-Si drums for all the B/W MFPs and copiers with the speed of over 50ppm since its world's first success in the commercialization of the drum in 1984. But the imageRUNNER™ C6800 is the fist full color product for Canon to be equipped with the drum.

Fig.2 shows the cross section of the a-Si drum which features high surface hardness, linear E-V characteristics, few degradation by primary charging or light exposure, and high permittivity.

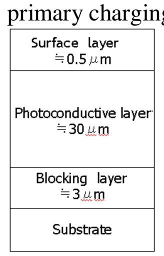

Fig.2 *Cross section of a-Si drum*

These merits are not available with organic photoconductive (OPC) drums which have been widely used for a long time.
These merits will be hereinafter reported in detail.

High Surface Hardness

This is due to a three-dimensional atomic bonding structure. Vickers hardness is 1500-2000.

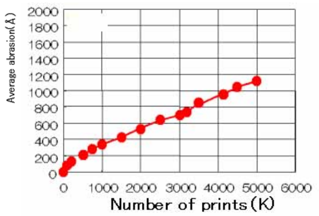

Fig.3 *Transition of accumulated abrasion of a-Si drum*

Fig.3 shows the transition of accumulated abrasion of the a-Si drum. The accumulated abrasion is only 1 μ m after 5M prints, which proves the high surface hardness.

2.2 Linear E-V Characteristics

Fig.4 and Fig.5 respectively shows the E-V characteristics of the a-Si drum and of the OPC drum. The horizontal axes correspond to the amount of exposure E (the maximum value is set to 255). The vertical axes correspond to drum potential V.

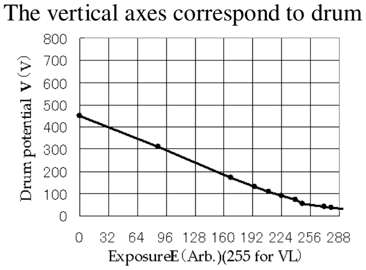

Fig.4 *E-V characteristics of a-Si drum*

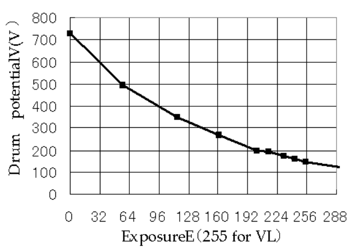

Fig.5 *E-V characteristics of OPC drum*

It can be understood that the linear E-V characteristics of the a-Si drum result in gradation for the entire image density range.

Fig.6 shows the stability of E-V characteristics of the a-Si drum. The horizontal axis corresponds to the amount of exposure.

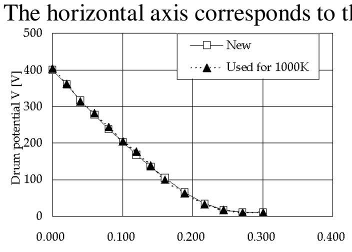

Fig.6 *Stability of E-V characteristics of a-Si drum*

Because photoconductive drums are destined to be primary-charged and light-exposed, most of them become degraded after many prints (especially in case of the OPC drum). It can be understood that the E-V characteristics of the a-Si drum are stable and that the excellent gradation before the use is maintained.

2.3 High permittivity

Fig.7 shows the simulated toner image on drums.

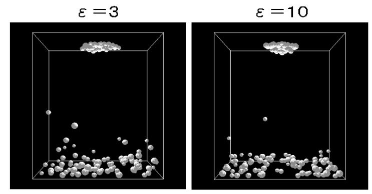

Fig.7 *Toner image on drum (Simulated)*

The upper face corresponds to a drum and the lower to a developing roller. The permittivity ε =3 is for the OPC and ε =10 for the a-Si. It can be understood that the higher the ε , the more faithful the toner image [3],[4] .Fig.8 shows experimented toner images on drums. It can be understood that with the a-Si drum, the developed image is more faithful to a latent image and is less scattered.These results match very well with the simulation.

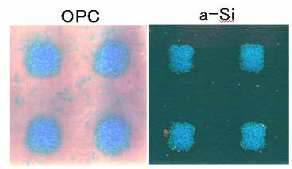

Fig.8 *Toner image on drum (Experimental)*

The components of the stable and high-quality imaging system, taking advantage of the above-mentioned characteristics of the a-Si drum, will be hereinafter reported in detail.

Components

3.1 Developing system

A "hybrid developing system", which is a combination of magnetic one-component jumping development for black and of two-component development for Y, M and C, has been adopted to reduce operation cost and to stabilize the image quality of B/W prints.

3.1.1 Black developing system

Magnetic one-component toner is employed, containing no carrier particle (Fig.9).

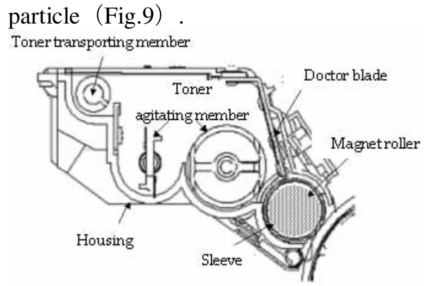

Fig.9 *Cross section of black developing unit*

The sleeve is treated with resin coating.

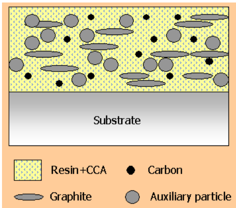

Fig.10 *Cross section of black developing sleeve*

The coating has been widely used for the jumping development technology at Canon. Fig.10 shows the cross section of the sleeve. Its substrate is made of aluminum alloy to prevent deformation by the heat from a drum built-in heater. The coating regulates the quantity and the triboelectric charge of the toner on the sleeve. The coating is so abrasion-resistant (0.14umRa of roughness change / 3.3um of abrasion, after 1M prints) that the quantity and the charge of the toner on the sleeve and on the drum are stable. Thus, the developing unit does not need to be replaced for over 1M prints. Not only the developing unit but the developing agent does not need to be replaced, enabling the reduced operation cost.
Moreover, toner concentration control is not necessary, enabling the reduced operation cost and stable image quality.

Newly-developed toner with small particle size（7um on the basis of weight）has been adopted for improved image quality and reduced toner consumption. Character images on paper are shown in Fig.11. It can be understood that the image quality is improved with the newly developed toner, compared to the conventional large particle sized toner.

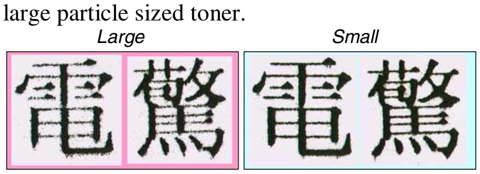

Fig.11 *Comparison of character image quality on paper between different toner particle sizes*

The reduced toner consumption by about 20% results in the reduced operation cost.

3.1.2 Color development system

Two-component developing agent is employed, containing non-magnetic toner and magnetic carrier (Fig.12) .

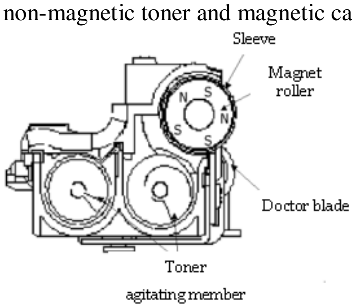

Fig.12 *Cross section of color developing unit*

There are three color developing units: Yellow, Magenta and Cyan. Each unit is selectively placed to oppose the drum, to develop each color toner.

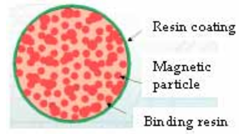

Fig.13 *Cross section of carrier particle*

As a carrier particle, we selected one with high resistivity（about 10^5 times as high as conventional one）and with low magnetization（about 0.6 times of conventional one）（Fig.13）.

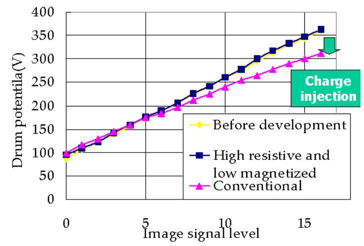

Fig.14 *Comparison of charge injection between different types of carriers*

Fig.14 shows the relation between image signal level and drum potential V.It can be understood that the high resistive carrier reduces the charge injection to the a-Si drum, preventing the lowered image resolution by scavenging by magnetic brushes.

Fig.15 and Fig.16 respectively shows the comparison of fog and of carrier attachment between different carrier resistivities. The horizontal axes correspond to fog-removing potential difference Vfr, the vertical axis of Fig.15 to fog on the drum and the vertical axis of Fig.16 to the index for carrier attachment to the drum.

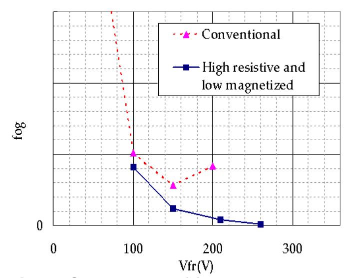

Fig.15 *Comparison of fog on drum between different types of carriers*

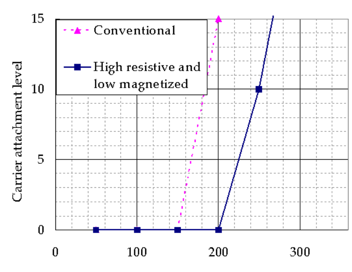

Fig.16 *Comparison of carrier attachment on drum between different types of carriers*

It can be understood that the high resistive carrier (blue lines) has a larger latitude of Vfr against the fog and against the carrier attachment level.

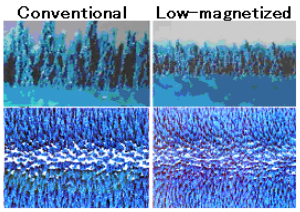

Fig.17 *Comparison of magnetic brush appearances between different types of carriers*

The upper half of Fig.17 shows the magnetic brushes on the sleeve seen form side. The lower half shows the brushes seen from above. Low magnetized carriers form short brushes, reducing image coarseness.

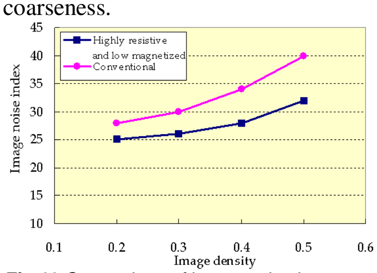

Fig.18 *Comparison of image noise between different types of carriers*

Fig.18 shows a comparison of image noise between different types of carriers [5].The smaller image noise index on the vertical axis is more favorable. The horizontal axis corresponds to image density. It can be understood that high resistivity and low magnetization improve the resolution and the image noise. The image noise index is calculated by scanning an printed image and considering the human visual characteristics. Fig.19 shows the comparison of toner compression in the transition of the triboelectric charge of the color toner. Because the color developing units have been designed to reduce the compression to the developing agent, it becomes less degraded, the triboelectric charge of the toner and image quality are stable.

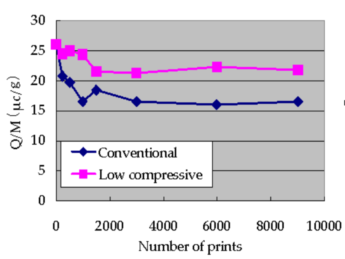

Fig.19 *Comparison of toner compression in transition of triboelectric charge of color toner*

We have introduced blank sections in the wave shape of a color developing bias voltage, (Fig.20) .

The bias consists of an oscillating section and a "blank" section. The oscillating section consists of rectangular waves and the "blank section" consists of DC component only.

The BP bias has been widely used for the two component developing system at Canon.

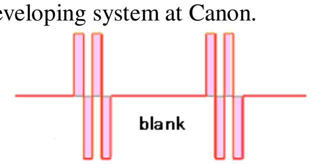

Fig.20 *Wave shape of color developing bias volotage*

Fig.21 shows toner particle size distribution before and after the development. The horizontal axes correspond to the toner particle size on the basis of weight, the vertical axes to the percentage of the toner particles included in each particle size zone.

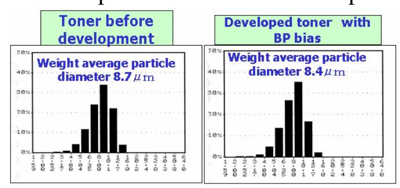

Fig.21 *Toner particle size distribution before and after development*

It can be understood that a sufficient quantity of toner is supplied to latent image and that almost all the toner particles are developed due to rearrangement effect by the BP bias.

3.2 Cleaning system

A rubber blade and a magnet roller, conventionally equipped on B/W MFPs, have been employed, because the function of the cleaning system is the same with that of the B/W MFPs in that the system cleans the magnetic black toner on the a-Si drum (Fig.22) . The combination of the rubber blade and the magnet roller is characterized in that the black toner held on the roller is applied on the drum and forms a blocking layer on the edge of the blade.

A potential drawback of the combination is defective cleaning when color image output becomes dominant.

The defective cleaning occurs as follows:

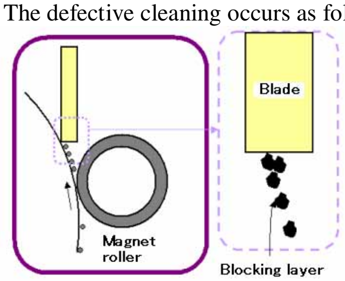

Fig.22 *Cleaning with blade and magnet roller*

the non-magnetic color toner becomes dominant on the magnet roller→the color toner becomes dominant also on the drum→the blocking layer formed on the blade edge decreases→the defective cleaning occurs

To overcome the drawback, the concentration of the color toner on the magnet roller is controlled according to the image signal, by supplying the magnetic black toner.

Conclusion

By employing the a-Si drum and, the developing and cleaning systems taking advantage of the drum, the full color MFP imageRUNNER^{TM} C6800 has realized its concept "a full color MFP to replace B/W MFPs in the office."

More specifically, the MFP has realized low operation cost, stability and high productivity (multicopy speed and FCOT), receiving high reputation in market along with its sister models.

We will keep commercializing technologies featuring the a-Si drum, which is a core competence of Canon.

References

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Author Biography

Hideki Fujita is a senior engineer at Office Imaging Products Device Development Center, Canon, Inc. He obtained his Bachelors degree in engineering from the University of Tokyo and joined the company in 1989. He has been mainly involved in magnetic one-component development technology for electrophotographic copiers and printers, including the imageRUNNER™ C6800.