Toner Printing Technology

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Abstract

Toner printing technologies represented by electrophotography have big advantages in electronic printing. Toner is controlled by electrostatic force and forms images on paper. So, high speed and plain paper printing are realized. The electrophotography has six processes of charging, exposure, developing, transfer, fixing, and cleaning. Charging and exposure are unified into one process to form latent electrostatic image and electrostatic printing is developed. To realize simpler printing mechanism, TonerJet® and TCB (Toner Cloud Beam) are also proposed. Electrophotography is reviewed from the fundamental viewpoint. Other toner technologies are also reviewed.

Introduction

Non-impact printing technologies progress very rapidly in recent three decades. Electrophotography, inkjet and thermal printing are main stream of non-impact printing technologies[1,2].

Electrophotography has characteristics of high speed, high quality and plain paper printing, so widely used in office. Electrophotographic technology has advanced very much. In these advances, contribution of physics and chemistry is very big. Idea of printing mechanism is also important.

So, in this article, printing mechanism of toner printing technology is reviewed. It is referred from the aspect of physics and chemistry.

Printing mechanism by toner

Electrophotography[3]

The technology was invented by C. F. Carson in 1938. Copying is carried out in dry process by controlling charged toner particle with electrostatic force. The force is generated by electrostatic image on photoreceptor. After the invention, numerous improvements and refinements have been carried out and electrophotography has become very refined technology. The printing mechanism of electrophotography is shown in Fig. 1. Its process accomplished by 6 processes: charging, exposure, developing, transfer, fixing and cleaning. The printing process is fundamentally not changed since its invention.

Electrophotography consists of many components and materials. It also utilizes many phenomena and mechanism. From the viewpoints of physics and chemistry, photoconductive phenomena, electrostatic phenomena, and corona discharge and so on are important. Photoconductivity is the base of photoconductor drum. The drum has the characteristics of charge retention in the dark and charge decay in the light. Charge generation by photo and charge transport is fundamentals. Concerning these phenomena, many studies are carried out and our understanding of these phenomena and materials advanced well. These knowledge are applied to the developing of organic electro luminescent display and organic solar cell.

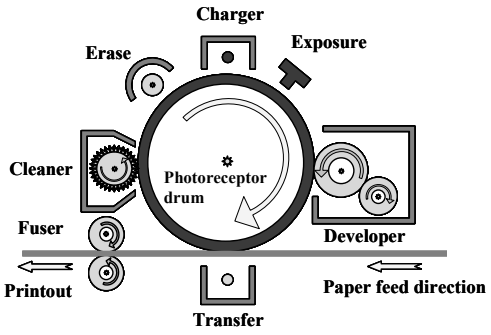

Figure 1. Schematic diagram of electrophotographic printing process.

Electrostatic Printing

Concerning the electrostatic printing, several methods are known. First one is using coated paper. Multi-stylus pin electrode is used for electrostatic latent image formation on the coated paper. Then the latent image is developed by toner. This method is very simple, so it is used in early stage of facsimile. This method was applied to wide format color printing.

Plain paper printing was developed as a next step as shown in Fig. 2. The mechanism can directly form electrostatic image on dielectric drum by multi-stylus pin electrode. Then the image is developed by toner and the toner image is transferred to paper. The toner image on the paper is fixed by heat roller. The method has characteristics of un-necessity of photoconductive drum. Electrostatic image is formed by one process. Instead of multi-stylus pin electrode, corona ion control method[4] and ion projection method are developed. The methods are shown in Fig. 3 and 4. Corona ion flow is controlled by aperture electrodes and electrostatic image is formed on dielectric drum. This method has characteristics of continuous-tone printing. Ion projection method generates discharge where it is needed and generated charge is projected to dielectric drum. This method is suitable for high speed printing and high speed printer is developed.

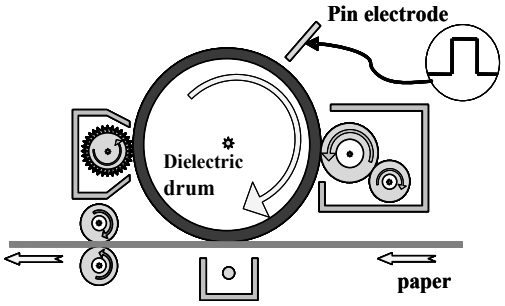

Figure 2. Electrostatic plain paper printing by multi-stylus pin head.

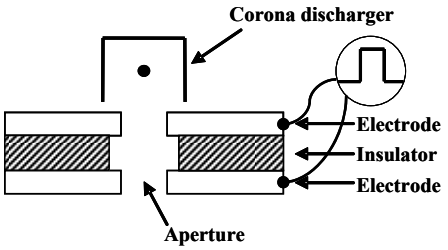

Figure 3. Ion flow control mechanism.

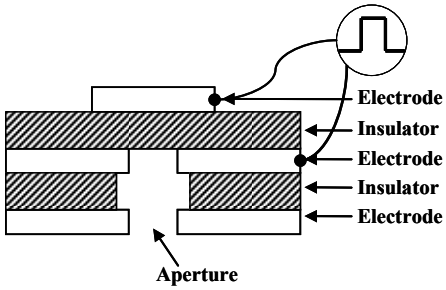

Figure 4. Ion projection mechanism.

TonerJet®

This method is excellent concept that toner image is directly formed on paper[5]. Fig. 5 shows the printing mechanism. Charged insulating toner layer is formed on developing roller and the toner is pulled from the roller by electric field generated between aperture electrodes and developer sleeve, and toner jumps to paper. The printing mechanism has characteristics of conciseness and compactness. Compact printer is realized by its technology and also color printing mechanism was developed.

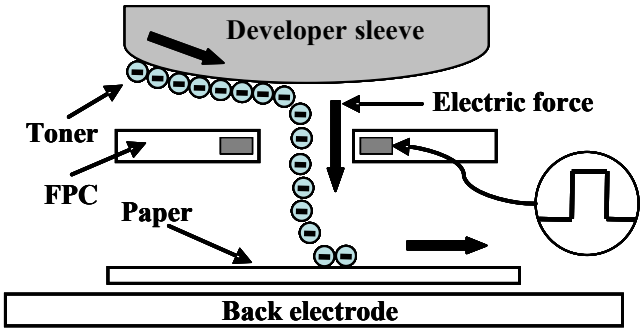

Figure 5. Printing mechanism of Tonerjet®.

Toner cloud beam[6-12]

Conductive toner has been tried to apply to printing and toner image was developed on dielectric medium. It is known that conductive toner jumps up and down between voltage-applied electrodes. It is found that the conductive toner is confined like a cloud around the dented electrode as shown in Fig. 6. It is proposed that the cloud toner is extracted to paper by controlling the voltage between two aperture electrodes. The printing mechanism by TCB (Toner Cloud Beam) printing is shown in Fig. 7. The dot formed by TCB is shown in Fig. 8.

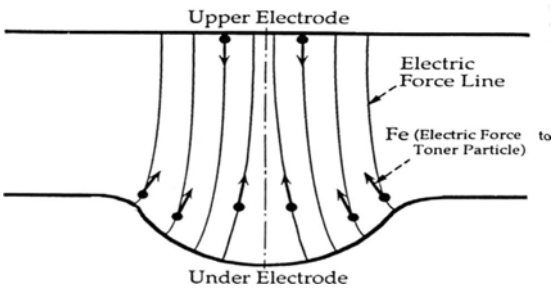

Figure 6. Toner confinement by dented electrode.

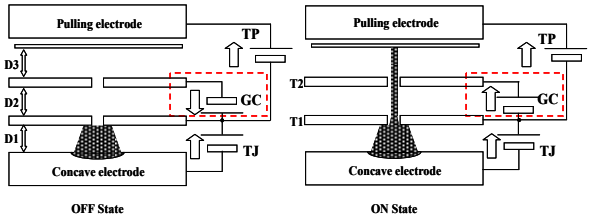

Figure 7. Toner cloud beam control by a pair of aperture electrodes.

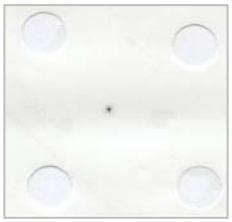

Figure 8. Example of dot generated by TCB.

Others

Toner image is formed on photoreceptor drum where light image is irradiated form the back of photoconductive layer. It is called PITE (Photo Induced Toner Electrophotography)[13]. In this method, light scanning unit is inside photoreceptor drum, so there is possibility of realizing simple and compact printing mechanism. As other toner printing technology, there is magnetography. Magnetic image is formed on magnetic drum and magnetic toner is attracted from the magnetic image and toner image is formed on the drum. This method has characteristics of use of magnetic force instead of electrostatic force.

Charging mechanism of toner

Toner charge is important in electrophotographic printing and also other toner printing. The studies on toner have been carried out from various viewpoints. Many studies on toner charging mechanism are carried out. The charging mechanisms are reviewed on two cases of insulator toner and conductive toner.

Insulator toner

Toner is charged by contact or rubbing with other materials such as carrier. Charging phenomena by contact with two materials is known as tribo-electric series. Many requirements are imposed on toner. The requirements are charge amount, charge

distribution, charging time, temperature/humidity dependence, attaching force, preservation characteristics and so on. Toner is composed of many materials of resin, pigments, CCA(Charge Control Agent), wax and external additives. The schematic explanation of toner structure is shown in Fig. 9.

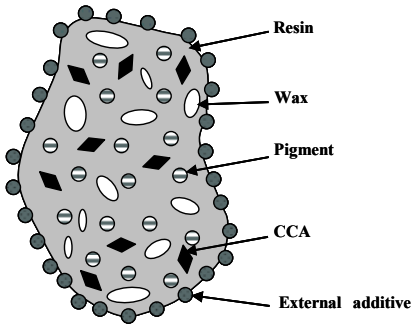

Figure 9. Toner Model.

Many studies on charging mechanism of toner have been carried out. The mechanism is very complex and it is considered that satisfactory understanding is not obtained yet. Kondo proposed the theory that toner charge become equilibrium between electric field at contact area of toner and carrier and the difference of charging strength of them. Contact charging model is proposed as shown in Fig.10 and the theory is applied to many experimental results. Shein summarized toner charging theory[14]. Okada recently reexamined the toner charging theory[15].

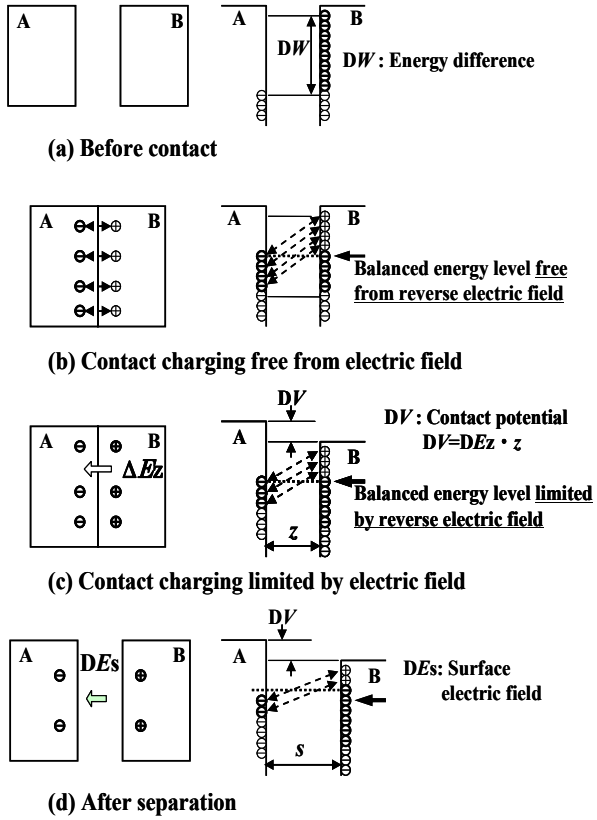

Figure 10. Contact charging model.

The mixing system of toner and carrier is interesting charging system for two kind of powder mixing system. The charging characteristics are understood by the contact phenomena and also the effect of powder mixing.

Typical toner made by pulverized method is shown in Fig. 11. Toner shape has variety from the irregular shape as shown in Fig.11 to spherical shape toner. The measured example of specific toner charge distribution is shown in Fig.12. Usually toner charge has distribution and the reason of the distribution is not yet understood well.

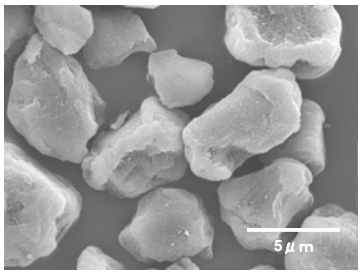

Figure 11. Shape of typical pulverized toner.

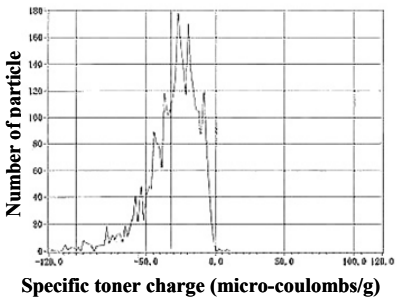

Figure 12. Example of toner specific charge distribution.

Conductive toner

When toner is conductive, toner charging is carried out by conduction of charge at the contact with other conductive material. The schematics explanations are shown in Fig. 13. When the toner is insulator, the toner charge is un-changed by electric field application, on the other hand, when the contact of conductive toner and electrode is electrically ideal, the potential of them becomes same and the toner is charged by the application of electric field[16]. In some cases, contact potential and non-linear conductivity between toner and electrode can not be neglected.

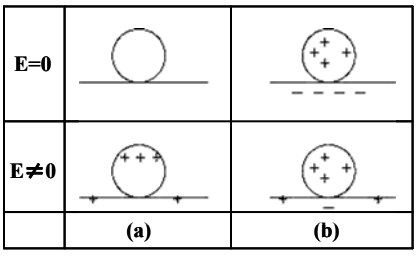

Figure 13. Illustration of toner charge dependence on external electric field, (a) conductive toner, and (b) insulator toner.

Summaries

Toner printing technology is important in non-impact printing and is progressing in various aspects such as mechanism, material, components, designing and so on. Fundamental understanding from the physics and chemistry is necessary for the progress. At present, more understanding is expected. Toner printing technology will provide interesting theme to physics and chemistry.

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Author Biography

Yasushi Hoshino is professor of Nippon Institute of Technology. He gained B.S, M.S and Ph.D. from the University of Tokyo, 1979, 1972, and 1984 respectively. After he gained M.S Degree, he joined Electrical Communication Laboratories of NIT and joined the developing of first LED printer, high speed laser printer, color-laser printer by using ultra elliptical laser beam scanning, photo-induced toning technology and ion flow printing. He moved to Nippon Institute of Technology on 1994. His recent interest is toner technology, corona discharge and image processing. IS&T fellow