Toner Charging Characteristics in the Rotation Mixing System of Toner and Carrier

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Abstract

Toner charge is very important in electrophotographic printing process. Many studies on toner charging mechanism have been carried out. However, understanding of toner charging characteristics is not yet sufficient. Toner charge distribution is measured by E-SPART (Electrical Single Particle Aerodynamic Relaxation Time) which can measure and analyze the size and the charge of respective toner. The measured toner is of a crushing type. Charging is carried out as follows: the toner is mixed with carriers in a bottle and mixed by the rotation of the bottle. Average toner charge of each channel of the toner diameter is estimated. It is found that the average toner charge is proportional to the square of toner diameter and shows a saturation as the diameter increases. The experiment of adding the toner after the toner is charged to nearly stationary is carried out. It is found that toner charge distribution becomes a new value due to charge exchange between the toner and the toner/carrier.

Introduction

Toner charging is fundamental in electrophotography and it is one of the electrostatic phenomena. The charging characteristics are influenced by many factors such as toner materials and shape, carrier materials and shape, charging methods, humidity, and so on. Many studies have been carried out on the toner charging mechanism.[1-5] Concerning the toner charge measuring method of toner charge, several methods have been proposed and are used.[6] The methods of blow off, E-SPART, and toner motion analysis in airflow with the application of electric field are the major technique. Among them, blow off method is most widely used,[1,7,8] because it has a simple measuring mechanism. E-SPART is a powerful method, because toner charge and toner size can be measured simultaneously.[9]

The distribution extent of toner charge imposes a significant effect on print quality. It is therefore important to obtain the extent of the toner charge distribution. The toner charge dependence on toner size is also important. Studies on the size dependence have been carried out. The reported power values of the toner size dependence are distributed from 2 to 3. The mechanism of size dependence has not yet been understood well.

In this paper, based on characteristic of E-SPART, the size and charge of toner are measured. From the measured results, the size dependences of toner charge, the ratios of toner charge to mass are analyzed. The change of toner charge histogram by toner charging history is measured and discussed.

Experimental

The toner used in this experiment is made by the crushing method and the average diameter is around 5-8 μm. Base material of the toner is polyester resin. The toner is adjusted for a negative charging type by CCA (Charge Control Agent) and the flow property is controlled by silica treatment. The carrier is made of steel and the diameter is around 60 – 120 μm. The developer sample is prepared on the conditions of 3, 5 and 7weight % of the toner. The developer is mixed in a rotation cylinder with a rotating speed of 120 rpm and the toner is charged by the contact with carrier.

Toner charge and size are measured using E-SPART analyzer (Hosokawa-Micron E-SPART Type 1 Improved Model). The charge and the size of individual toner are measured simultaneously using the analyzer. The toner particles are measured for 3000 counts on every mixing condition.

Results and Discussions

Photographs of the toner and carrier observed by SEM are shown in Figs. 1 and 2. It is found that the toner shape is irregular resulting from the crushing. Concerning the carrier, it is found that the surface of the carrier is wrinkled. The histogram of toner diameter is shown in Fig. 3. The diameter measured is the aerodynamic diameter obtained by E-SPART. The data are digitized and stored in the corresponding channel. It is found that the diameter is distributed from 5 to 8 μm. It is noted that the measured distribution of toner diameter is independent of toner weight %. It is suggested that the sampling of the toner from the developer in this measurement is carried out in a good condition.

As stated earlier, E-SPART can measure simultaneously the charge and the size of individual toner. The data obtained are shown in Fig. 4. It is found that the toner charge has a big distribution in every toner channel of the size and that the distribution increases as the toner size increases.

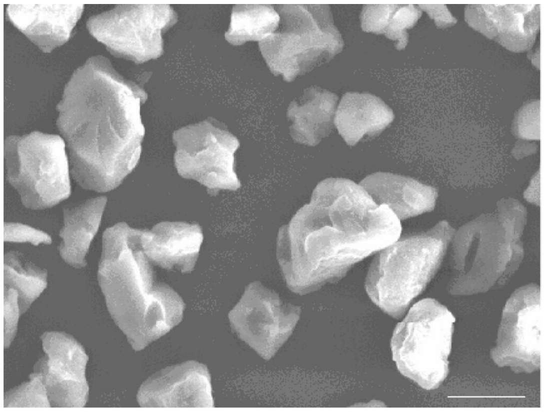

Figure 1. SEM photograph of the toner. (white bar means 10^{-5}m)

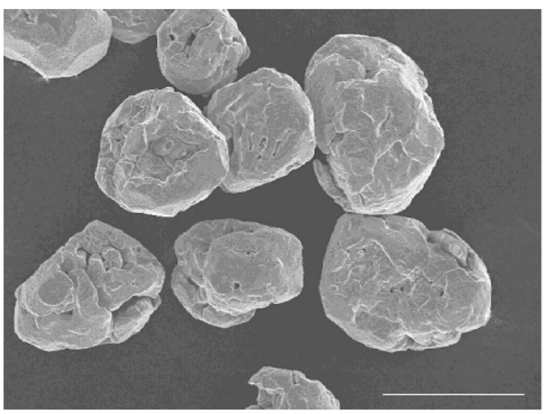

Figure 2. SEM photograph of the carrier. (white bar means 10^{-4}m)

The charge-to-mass, Q/M, is important for estimating charged particles such as toner. Toner charge is averaged for every channel of toner size in Fig. 4. The dependence of Q/M on the toner size is shown in Fig. 5. It is found that Q/M decreases as the toner diameter and toner weight % increases. To consider the toner size dependence from the other viewpoints, the relation between toner charge and toner size is plotted in Fig. 6. It is found that the toner charge increase with square of toner diameter in the range from 3 to 8 μm and then gradually shows a saturation tendency. From the square dependence of toner charge, it is considered that the toner charge is proportional to toner surface area.

Concerning the saturation, it is considered that the larger size toner has less contact possibility per area with carrier compared with the smaller toner, because the smaller toner covers the carrier closer than the larger toner.

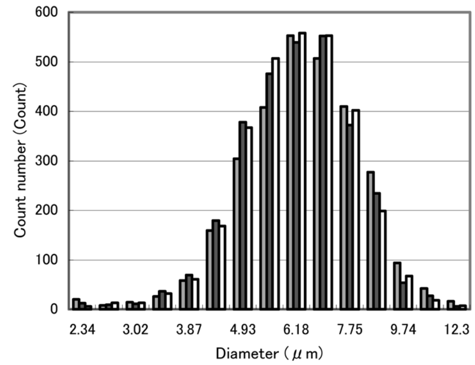

Figure 3. Toner diameter histogram measured by E-SPART; gray, black, white bars mean 3, 5, 7 weight%, respectively

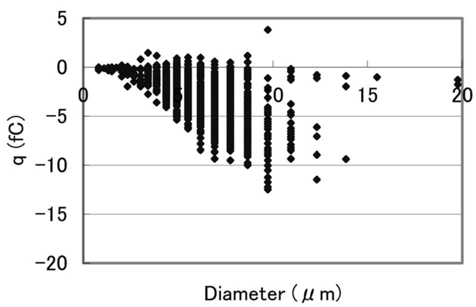

Figure 4. Two dimensional plot of the toner charge and toner size at 5 weight %.

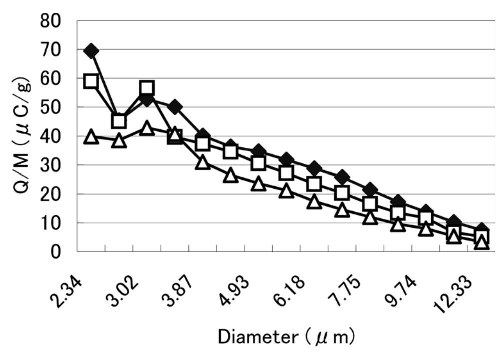

Figure 5. Charge-to-mass, Q/M, dependence on toner diameter, ◆:3 weight %, ❑:5 weight %, Δ:7 weight %.

It is therefore considered that the charge of the larger toner shows a saturation in the charge amount.

The histograms of Q/M of medium size toners are measured as: first at 3 weight % charging and measurement was carried out, then the toner of 2 weight % is added and charged. The measurement was carried out, and again toner of 2 weight % was added and same procedure was repeated. Figure 7 (a) shows the data when the toner charging is carried out for 10 minutes at 3 weight %. Figure 7 (b) is the data when the toner charging is carried out for 10 minutes after the toner is added to 5 weight % from 3 weight %. Figure 7 (c) is the data when the toner charging is carried out for 10 minutes after the toner is again added from 5 weight % to 7 weight %.

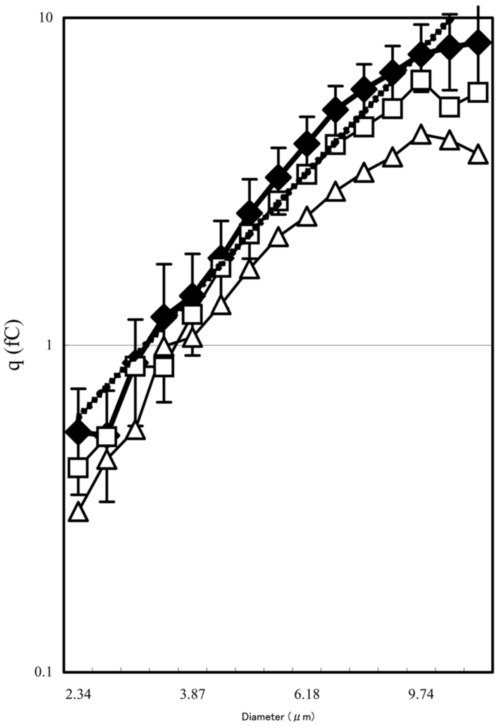

Figure 6. Toner charge q dependence on toner diameter, ◆:3 weight %, ❑:5 weight %, Δ:7 weight %.means standard deviation, dotted line is square dependence.

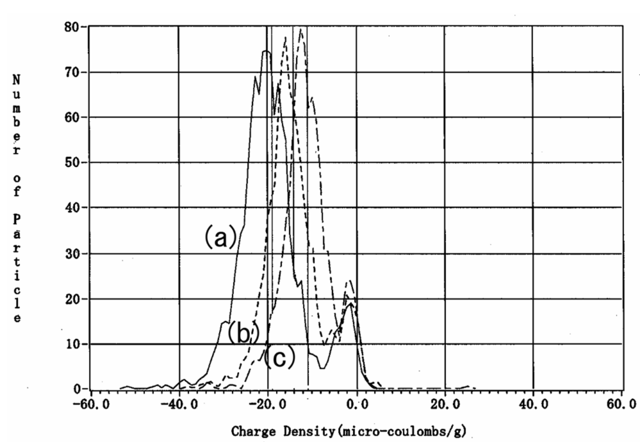

Figure 7. Histogram of specific toner charge of toner size 7 9 µm: toner weight %: (a) 3, (b) 5, (c) 7.

It is noted that the histogram of 3 weight % in the high charge toner area decreases abruptly when toner has been added. It is considered that the highly charged toner is discharged on a toner addition. It indicates that the toner charge distribution is nearly in a new equilibrium state from the evidence that the highly charged toner of 3 weight % is discharged and that the histograms of toner charge becomes almost the same histogram irrespective of the toner adding history.

Conclusions

The charge and size of individual toner is measured using E-SAPRT analyzer. It is found that the dependence of toner charge on the toner size shows a square relation and that shows a saturation when the toner size increases. This dependence is considered reasonable because the area of toner surface increases with the square relation.

From the changes in charge distribution by the charging history, it is considered that charge exchange occurs and reaches an equilibrium state during the charging period of the charging method.

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Biography

Hoshino Yasushi is professor of Nippon Institute of Technology. He gained Bs., Ms. and Dr. Degrees from The University of Tokyo, 1970, 1972 and 1984 respectively. After he gained Ms. Degree, he joined Electrical Commun-ication Laboratories of NTT and developed first LED printer, high speed laser printer (process speed 89cm/s), color laser printer by elliptical laser beam scanning, photo-induced toning technology and ion flow printing. He moved to Nippon Institute of Technology on 1994. His recent interests are toner technology, corona discharge and image processing. E-mail: **hoshino@nit.ac.jp**