Toner Charging Characteristics Dependence on Different Charging Carrier Properties

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Abstract

The charging of toner particles in contact with carrier or developing roller is the typical tribocharging method applied in the two-component development system. Control of toner charge is critical in maintaining good image quality in electrophotographic printing process. As such, understanding of triboelectric charging in the developer is important. The Technical Committee of The Imaging Society of Japan (ISJ) has introduced standard four types of carriers to estimate the specific toner charge which helps to align them in the triboelectric series according to the charging tendency. Hence, the toners which are slightly different from the surface treatment are triboelectrically charged with the standard carriers. The toner charge and the aerodynamic size of toner particles are measured simultaneously by the Electrical Single Particle Aerodynamic Relaxation Time (ESPART) analyzer to understand the charging tendency of carriers. Further, the correlation between film surface voltages charged by contact with carriers and the toner charge are discussed.

Introduction

Nowadays the two-component development system is widely used in modern electrostatic copying and laser printers. In the so-called development unit, the electrostatic force which is the dominant for moving toner particles in the electric field is induced due to the tribo-charging[2] by contacting carrier with toner. Therefore carrier plays an important role in the electrphotographic printing process[1]. As far as the good quality of a print is concerned, it is generally considered that optimizing the charge amount of toner leads to the improvement.

Triboelectric charging is the most frequently occurring phenomenon for charging materials and yet one of the least understood. The triboelectric effect is a type of contact electrification in which certain materials become electrically charged when coming in to contact with another different material, and are then separated. In practice, it is not easy to classify the contacting process for charge transfer purposes into groups, such as sliding, rolling, and impact, and thus the term "triboelectric charging"[6] is used in such a broad sense. It is considered that charge is exchanged between the materials in proportion to the difference in their work functions.

When the toners are used in the electrophotography, fluidizing agents such as Silica, Titania and Alumina are normally added in order to improve toner fluidization, toner cleaning properties and the like. Silica is frequently used surface additive and one type of Silica additive's effect is studied.

The specific triboelectric charge on toner particles is measured with the help of E-SPART (Electrical Single Particle Aerodynamic Relaxation Time) analyzer. And also the surface electrostatic potential was observed with the Digital Electrostatic Voltmeter (Trek Model 344) which is an electrostatic surface voltmeter for making non-contacting surface voltage measurements.

Experimental

Materials

As this study is carried out to understand the triboelectrification in the developer, experiments are done by using four types of toners including ISJ[4] standard toners, four types of different charging ability carriers, and films of Aluminium evaporated 25um thick polyethyleneterephthalate (PET), polytetrafluoroethylene (PTFE) and polyamide (PA). The toners other than the standard toners are categorized into two kinds according to the surface treatment of Silica where as Toner-A (with Silica) and Toner-B (without Silica). So that, it could be observed the effect of Silica on toner charge. The particular toners are triboelectrically charged by the four different charging ability carriers which have been introduced by the Technical Committee of Toner Technology in the Imaging Society of Japan.

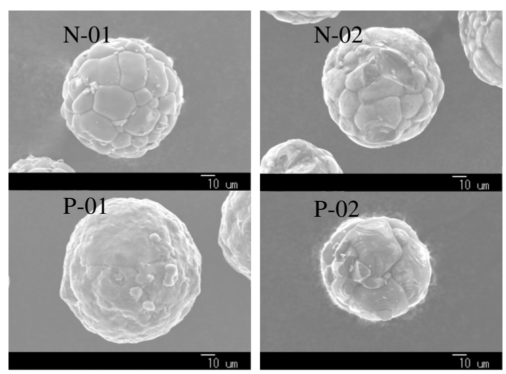


Figure 1. SEM micrographs of ISJ standard carriers.

These carriers are recommended for estimating toner charging property with standard method of measurement of Q/M by the Imaging Society of Japan. The films are used to understand the electron exchange between the carriers in the tribocharging process. Also, it would help to confirm that the carriers are aligned in the correct order in their charging tendency. By analyzing the results, charging tendency of carriers is discussed and observed that the quantitative triboelectric series in which the toners are coordinated by the Q/M value generated between the combinations of each standard carrier. Further, the electrostatic surface voltages when standard carriers come in to contact with films and toners are measured and discussed to understand the triboelectrification. As a result of consequent studies of charging mechanism of toner, it is said that, toner charge represents an equilibrium between the electric potentials at the contact area between toner and carrier and reflects the difference in their work functions of these two materials. When toner and carrier mixed in to a ratio of *m:M* become contact and then get separated, the electron exchange[3] occurs until the charge on each material get balanced. The schematic explanation for contact potential difference[7] based on Band Theory is illustrated in Figure 2.

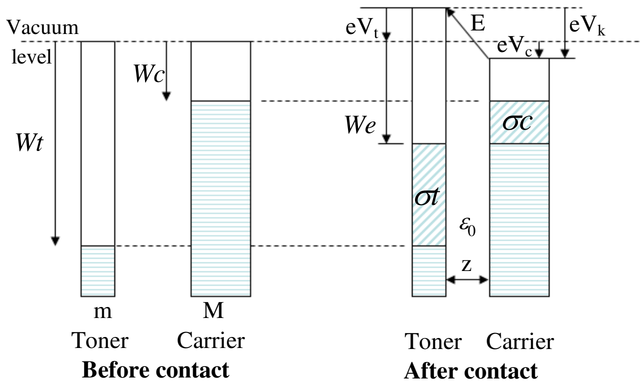


Figure 2. Model for contact potential difference between toner and carrier.

According to the model; let the work functions of toner and carrier be respectively *W*t and *W*c. The work function at the equilibrium states is considered as *W*e. Also let the absolute charge of an electron be *e*, the dielectric constant of air ε_0 and distance between toner and carrier after separation be *Z*. Concerning the model; the two materials contact each other, a flow of electrons usually exists from carrier to toner as the work function of toner is higher than the work function of carrier. A potential difference is occurs between those two materials as a result of the flow of electrons. As the model is proposed on the basis of electron energy level, the upper side refers to negative polarity and therefore; toner is negatively charged and its potential is lowered by V_c, where as carrier is positively charged and its potential is higher by V_c. The contact potential difference is V_k and consequently causes a reverse electric field E_k that prevents electron from flowing between toner and carrier further. The sum of charge densities is equivalent to zero (i.e. $\sigma t + \sigma c = 0$)and the total potential difference is equivalent to the sum of potential differences of toner and carrier (i.e.$V_k=V_t+V_c=Z.E_k$). Therefore it is understood that the charge density is proportional to the difference of work functions [i.e. $\sigma \propto (Wt - Wc)$]. Contact charging and electromechanics of particles have been studied for many years; however, it is difficult to understand the charging mechanism as there are many factors, such as chemical, physical, and electrical properties and environmental conditions, which affect the process.

Procedure

The experimental procedure is divided into two sections according to the observation method where as E-SPART analyzing and free fall.

Table 1: Toners and carriers used in the experiment

Toner/Carrier	Charging tendency against toner	Remarks
Toner:		
N-01T	(−)	
P-01T	(+)	
Toner-A (with Silica)		
Toner-B (Without Silica)		
Carrier:		
N-01	(−)	According to the
N-02	(−)	charging ability
P-01	(+)	N-01 > N-02
P-02	(+)	P-01 < P-02

E-SPART analyzing

The developer samples were prepared for the 5wt% of toner concentration by mixing the particular toners and carriers. Soon after preparing the samples, they were kept under control conditions where as 20℃ of temperature and relative humidity of 60% for 24 hours duration for stabilization. Just before analyzing the samples, the toner was triboelectrically charged by shaking with hand for 200 times at the same speed and turn. This was followed to be same in the method of tribocharging with the Technical Committee for Toner Technology in Imaging Society of Japan. Each sample was analyzed till 3000 count by E-SPART analyzer. During this course, situate the feed funnel and gas blow nozzle as illustrated below.

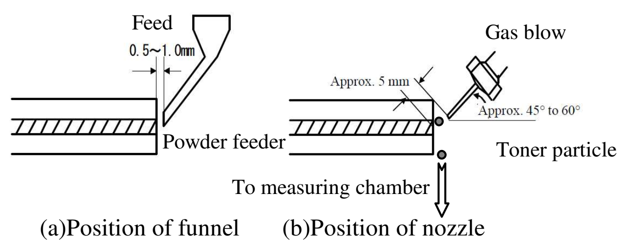


Figure 3. Measurement setup for ESPART analyzer.

Free fall

In this method carriers were allowed to free fall on the toners attached on the PET film and the surface electrostatic voltage was observed. The samples were prepared by adhering toners to the Aluminium evaporated PET film to an area of 10mm x 10mm with the help of spray glue as illustrated in Figure 4. Even though almost whole area is covered with toner, it could be observed that, there are exposed areas too.

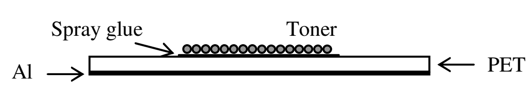
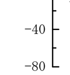


Figure 4. The toner attached on PET film (Not to scale).

The sample was placed on an inclined plane as shown in Figure 5 and then allowed 10grams of carriers to be fallen freely on the attached toners. The surface electrostatic potential was observed



with the Digital Electrostatic Voltmeter (Trek Model 344) which is a precision electrostatic voltmeter for making non-contacting surface voltage measurements. In this instrument, vibration type surface potential sensor is used. The standard distance for measurement was fixed to 10 mm in every time. The carriers were collected to a container placed at the bottom and reused the same. Repeated the same procedure for 10 times. The surface electrostatic potential was noted down. At first, the height of free fall was fixed to 20 mm and then it was changed to 40mm and 80mm. Repeated the same procedure for the all combinations of two types of toners and four types of carriers.

The films (PET, PTFE, PA) were also allowed to make in contact on the inclined plane with particular four types of carriers.

The samples were prepared as depicted in Figure 4. The amount of carrier remained unchanged and the height of free fall was fixed. Also to understand the electron exchange and charging tendency of the films[5]; three samples as in Figure 9 was rubbed each two at a time.

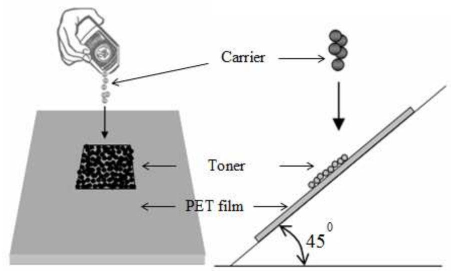


Figure 5. The experimental setup for free fall on the inclined plane, (Not to scale).

The Figure 6 illustrates the specific toner charge dependence on the four types of carriers which was received under private communication from the Technical committee of Toner Technology in the Imaging Society of Japan. N-01T and P-01T are two specific standard toners (negative and positive) introduced by the Imaging Society of Japan for measuring the toner charge.

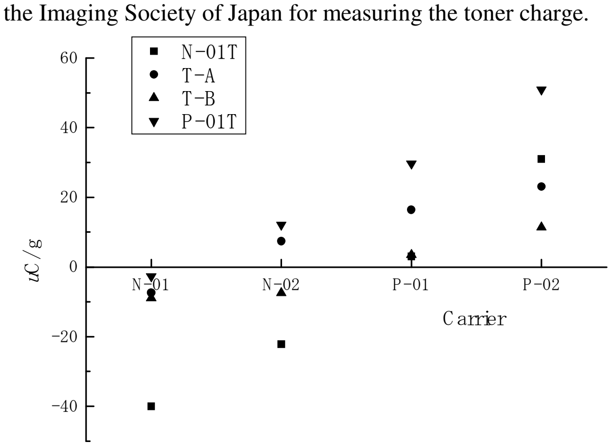


Figure 6. specific toner charge dependence on the standard carriers for standard toners.

Concerning the Figure 6, it is understood that the standard carriers show excellent alignment in charging tendency from negative to positive. Also, it is noticed that toner-A which consists of Silica show lower toner charges rather than toner-B (without Silica) in the case of negative charging carriers and in the case of positive charging carriers vice versa.

Figure 7 shows the surface electrostatic potential dependence on standard carriers with toner-A & B attached on film for the free fall heights of 20mm, 40mm and 80mm respectively.

Concerning the graphs in Figure7, it is observed that the results are agreed to the correlation which confirms by the Figure 6. Also it can be noticed that, the surface electrostatic potential is increased when the height of free fall is increased to 40mm and then again decreased when the height is further increased to 80mm. It is assumed that, the carriers get in contact with the toner surface well when the height is 40mm rather than 20mm. But in more higher case (i.e. 80mm), it is assumed that the toner are not rubbed thoroughly with the toner surface. There may be possibilities that they are jumping over the surface instead of sliding and rolling smoothly and consequently lack of electron exchange between the toner and carrier has occurred.

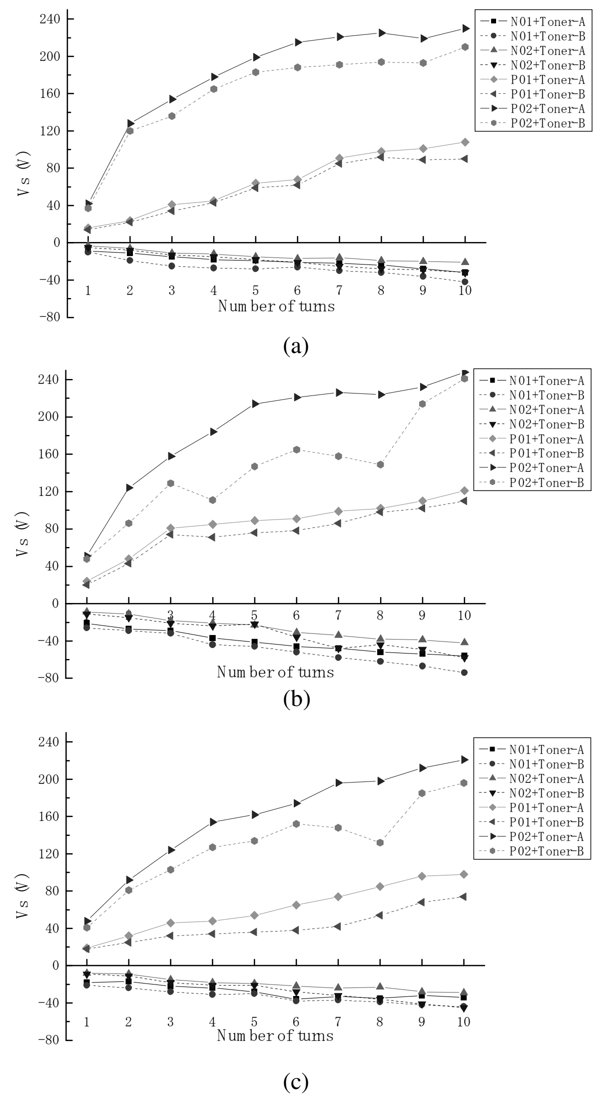


Figure 7. Surface electrostatic potential dependence on number of turns for; (a)20mm, (b)40mm and (c)80mm height free fall.

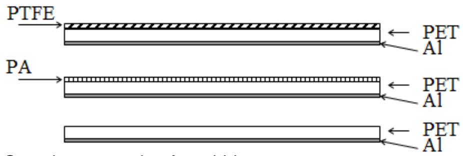


Figure 8. Sample preparation for rubbing.

A well known triboelectric series is fixed to align the dielectric materials in the order of charging tendency. It could confirm that the PTFE is considered to develop strong negative charges upon tribocharging. Also PA showed the strong positive charging tendency meanwhile PET lies in between those.

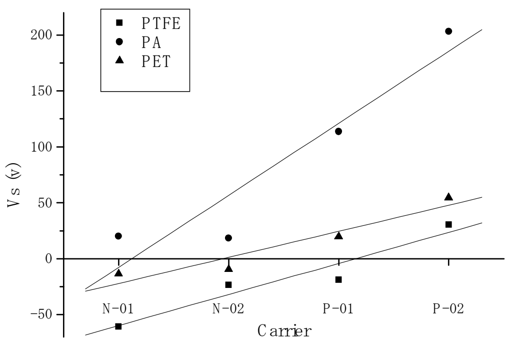


Figure 9. Surface electrostatic potential on films dependence on standard carriers.

It is considered that contact electrification between different materials almost certainly involves the transfer of electrons from one to the other. When considering the Figure 6, it can be noticed that the zero point charges are in a correlation.

On the basis of electron transfer, Figure 10 depicts the model for the electron exchange between toner and carriers for the particular case. When those materials contact each other, a flow of electrons usually exists from one material to the other as the work functions are at different levels. A potential difference occurs between those two materials as a result of the flow of electrons. This is based on the Band Theory and it is considered that the difference of each work function of the toner and carrier could become equal to the contact potential difference of those two particles.

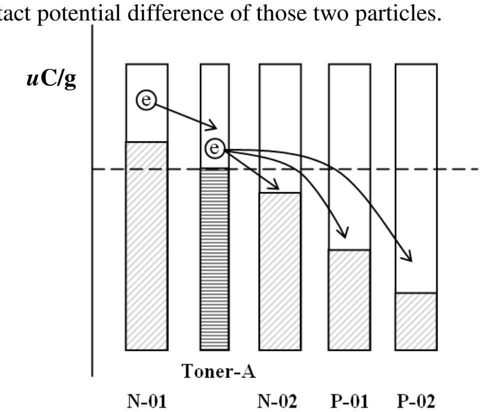


Figure 10. Model for the electron exchange between toner and carriers.

Summary

Four types of toners including the standard toners of ISJ, were triboelectrically charged by standard carriers to understand the charging ability and the effect of particular external additive. Insulating films are charged in contact with standard carrier of four types of different charging ability which were introduced by ISJ. It could be understood that the specific toner charge dependence on four types of carriers in correlation with the surface potential by free fall contact with four types of carriers. And also, on this toner system of with Silica and without Silica, toner charge shifts to positive side by addition of Silica in all four types of carriers.

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