Powder and Film Charging Characteristic Estimation by the Standard Carrier of Imaging Society Japan

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Abstract

Two-component developers which consist of toners and carriers are widely used in modern electrostatic copying machines and laser printers which utilize electrophotographic printing process. Toner charge is essential in electrophotography. The toners are triboelectrically charged by the carriers when they come in to contact. Although there are several factors which come to effect in quality in electrophotography, control of adhesion of triboelectrically charged toner particles is crucial. As such the estimation of toner electrostatic properties is very important. ISJ (The Imaging Society Japan) has proposed the standard carriers with different charging abilities for estimating toner charging property as a standard method of measurement. The electrostatic surface potentials, when the films come in to contact with standard carriers are discussed. Further, Tungsten is used for film charging to understand the charging property. The contact is carried out as carriers and Tungsten beads are rolling on the film. It is confirmed that the standard carriers proposed by the committee of ISJ show same tendency in the film charging estimation as against standard toner. It is proposed that the standard carriers are useful to estimate the charging properties of various shape material.

Introduction

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. The toners are triboelectrically charged by the carriers when they come in to contact in the development system in electrophotography[1]. Triboelectric charging[2] 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” is used in such a broad sense. When the theoretical background on triboelectric generation is considered, it could be understood that there are several mechanisms that contribute to the resulting charge that is generated by the triboelectric process. There appear to be four major factors that have the greatest influence on the triboelectric charging process and they are; surface contact effects, electronic properties of surface such as work function, charge back flow and so on. Surface contact effects include the surface roughness, contact forces and frictional heating (caused by rubbing), all of which influence the amount of surface area that is in contact with the other material during tribocharging. The greater the surface contact ratio of surface area, the greater the resulting net change may be when two surfaces are separated after contact. It is considered that charge is exchanged between the materials in proportion to the difference in their work functions. Therefore, in this present study, powder (which is referred to toner) and film charging characteristic estimation[3] by the standard carrier of ISJ (Imaging Society of Japan) and Tungsten beads is carried out.

The Technical Committee of Toner Technology in the Imaging Society of Japan has proposed four types of standard carriers with different charging abilities, where as; highly positive, medium positive, medium negative and highly negative. These charging abilities are determined with the help of toner charge measurements of two types of standard toners by committee members. The films were used to understand the electron exchange between the carriers/Tungsten in the tribocharging process[4,5]. It would help to confirm that the carriers are aligned in the correct order in their charging tendency. Also the work functions of carriers are estimated from the surface voltage by Tungsten against films.

The specific triboelectric charge on toner particles is measured with the help of E-SPART (Electrical Single Particle Aerodynamic Relaxation Time) analyzer. 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

Four types of standard carriers (see Figure 1) with different charging abilities, Tungsten beads and three types of toners were used in the experiment. Among the toners, two kinds were standard toners introduced by ISJ[4] and the other was a kind of which generally used in commercial printers. The toners and carriers used in the experiment are shown in Table 1. Films of Aluminium evaporated 75um thick PET (polyethyleneterephthalate), PTFE (polytetrafluoroethylene, 90um) and PA (polyamide, 50um) were used. Since the

Table 1: Toners and carriers used in the experiment

Toner/Carrier	Charging tendency against toner	Remarks
Toner:		
N-01T	(−)	
P-01T	(+)	
Toner-A		
Carrier:		
N-01	(−)	According to the
N-02	(−)	charging ability
P-01	(+)	N-01 > N-02
P-02	(+)	P-01 < P-02

thicknesses of films are slightly different, there may be discrepancies in observed surface electrostatic potentials.The Technical Committee of Toner Technology in ISJ has introduced standard carriers, as it is necessary to position the charging ability of substances. And also standard toners have introduced as it is required to examine the charging ability of standard carriers. By using these standard carriers and toners, it is possible to compare toner charge of every kind of toners as a standard gauge on characteristics and also to evaluate the charge distribution in a standard gauge. As we discuss in this report, it is possible to evaluate the charging characteristics[6,7] of surfaces of toner and films.

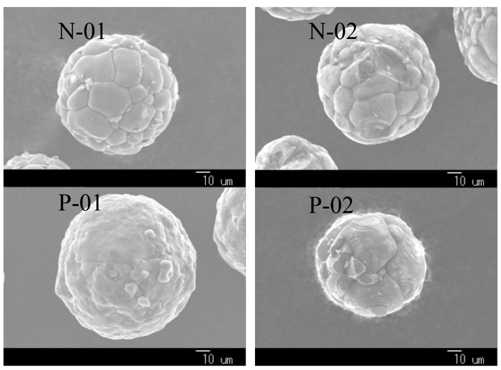

Figure 1. *SEM micrographs of ISJ standard carriers.*

Procedure

The experimental procedure is described under two sections according to the observation method, where as; ESPART (Electrical Single Particle Aerodynamic Relaxation Time) analyzing and film charging by a rotating instrument followed by observing the surface potential by electrostatic voltmeter.

ESPART analyzing

Firstly, specific toner charge (Q/M) was measured by ESPART analyzer for toner-A against standard carriers. 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 of Toner Technology in Imaging Society of Japan. Each sample was analyzed till 3000 count by E-SPART analyzer.

Surface potential measuring

At first, a square shape (100 mm x 100 mm) PET film is rolled and placed in a cardboard barrel (30 mm dia. and 100 mm long). Then, end-cap one side and 10 grams of standard carrier was inserted. Closed the other end and placed on the rotating instrument. A simple handmade instrument was used to unify the triboelectrification throughout the experiment and the schematic illustration of the rotating instrument is shown in Figure 2.

This proposed method seemed comparatively a good method of triboelectrical charging. The film was triboelectrically charged for 10 minutes at the rotating speed of 120 rpm. The speed was checked with trial an error method by varying the speed of rpm. It was observed that the optimum speed is 120 rpm. Also the surface potentials were examined with the increasing time of rotation up to 20 minutes. However the representative results for 10 minutes of rotating is discussed and representative data for positive charging carriers up to 10 minutes rotation is shown in Figure 4. The charged PET film was taken out and measured the surface potential with the help of Digital Electrostatic Voltmeter. The surface potentials at several places were measured and averaged the value. This procedure was repeated for PTFE and PA films too against standard carriers and Tungsten as well. The room temperature and Relative Humidity were observed and were recorded as 24.5 ± 1.8℃, 57.3 ± 6.2% respectively. A well known triboelectric series is fixed to align the dielectric materials in the order of charging tendency. Therefore, as for the second step, PET, PTFE and PA films were rubbed each two at a time and observed the surface potentials to confirm their position in the triboelectric series. The film samples were prepared as shown in Figure 3.

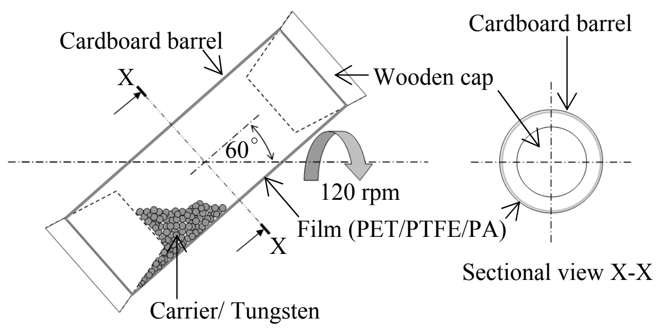

Figure 2. The schematic illustration of tribocharging method (Not to scale).

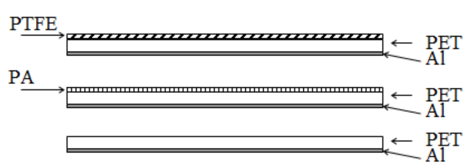

Figure 3. *Film samples preparation for rubbing (Not to scale).*

Results and Discussions

Figure 4 representatively depicts the surface electrostatic potentials on rotation time (duration of triboelectrification) for positive charging standard carriers against PET film. It can be observed that the surface potential is increased gradually with the rotation time. Also, according to the charging ability, P-02 carriers give higher values as they have introduced.

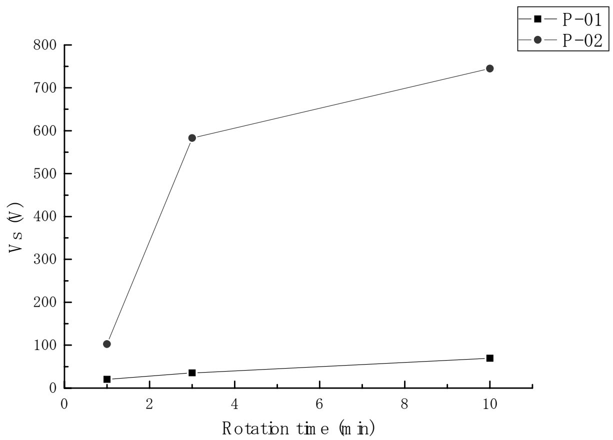

Figure 4. Dependence of surface electrostatic potentials of PET film on rotation time for positive charging standard carriers.

The Figure 5 illustrates the specific toner charge dependence on the four types of carriers. The Q/M values for standard toners (N-01T and P-01T) were received from The Technical committee of Toner Technology in the Imaging Society of Japan under private communication.

By observing Figure 5, it is understood that the standard carriers show excellent alignment in charging tendency from negative to positive as they have introduced by ISJ. Also Q/M for toner-A depicts the correlation with standard carriers in charging tendency, even though it doesn't show parallel translation to standard toners.

Therefore, it can be admitted that, the introduced standard carriers can be used in standard method of measurement for any type of toner.

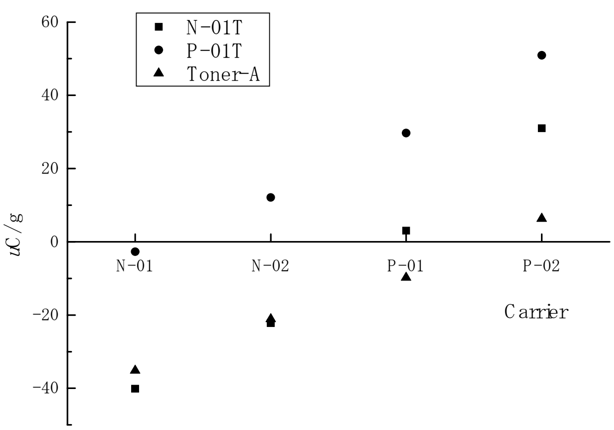

Figure 5. Specific toner charge dependence on standard carriers.

The Figure 6 illustrates the dependence of surface electrostatic potentials on toner specific charge for N-01T standard toner with standard carriers. The particular data have been extracted from Figure 5. For an instance; referring to Figure 5, it can be observed that the Q/M for N-01T with N-01 carrier is -40.1*u*C/g. Likewise, the other data too were extracted and put the base for x-axis in Figure 6. By concerning the Figure 6, it can be observed that the surface electrostatic potentials on films have shown increments against standard carriers when they are aligned from highly negative (N-02) to highly positive (P-02). These results are in correlation with the results shown in Figure 5.

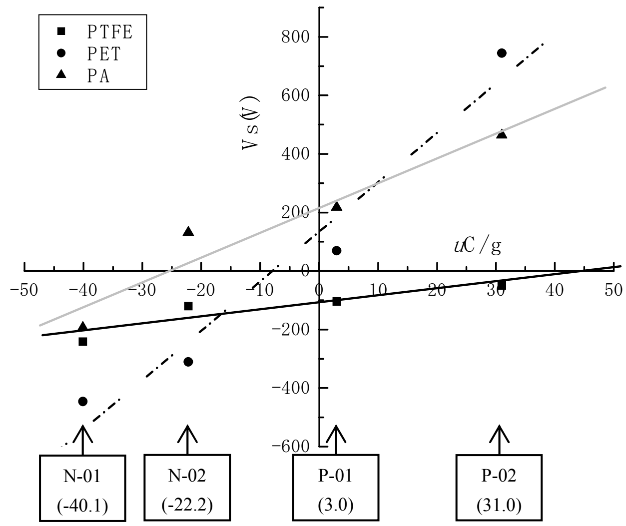

Figure 6. Dependence of surface electrostatic potentials of films on Q/M for N-01T standard toner with standard carriers.

Therefore, it can be confirmed that the standard carriers possess the ability of charging the opposition (toner/film) from negative to positive in the order of N-01, N-02, P-01 and P-02. When the zero point surface potentials are considered, it can be observed that the PA, PET and PTFE films got aligned according to their positions in triboelectric series. The alignment of films remains unchanged with positive charging carriers. However, it shows different results for negative charging carriers. *i.e.* the surface potentials on PET films show higher values rather than expected on PTFE films.

Table 2: Surface voltages on films when rubbed

Surface Potential value / Rubbed film	PTFE (V)	PET (V)	PA (V)
PTFE		5.0 x10^1	1.6 x10^2
PET	-1.0 x10^2		5.9 x10^1
PA	-4.3 x10^2	0.9 x10^1	

Table 2 shows the results of surface electrostatic potentials when films were rubbed each two at a time. It can be understood that the PTFE films are high negatively charged and PA is high positively charged. For an instance, when PTFE and PA films are rubbed, the observed surface voltages were -4.3x10^{2}V and 1.6x10^{2}V respectively (see Table 2). PET film lies in between PTFE and PA. In the well-known triboelectric series, where materials are empirically ordered according to their tendency to acquire a positive or negative charge upon contact; typically PTFE is supposed to develop strong negative charges and PA is supposed to develop strong positive charges. It could confirm that the above results too agree with the well-known triboelectric series. Figure 7 illustrates the empirical order of PTFE, PET and PA films according to their charged tendency.

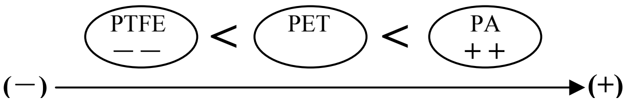

Figure 7*. Empirical order of PTFE, PET and PA films according to their charged tendency.*

Tungsten beads too, were used to examine the surface electrostatic potentials against films as they show comparatively low variation in work function. According to the results, it could be noticed that the Tungsten beads possess the charging ability which is roughly between the charging ability of N-01 and N-02 carriers.

Charging mechanism based on work functions

According to the studies on triboelectric charging, there are convincing evidences for both electron and ion exchange mechanisms, and yet least understood. The work function[8,9] and surface state theory are taken in to consider for understanding the charging mechanism when electron transfer is accounting. Therefore, in this report, electron exchange and work function is considered as the base to this study. When toner charging mechanism in electrophotography is taken in to consider, it is said that, toner charge represents equilibrium between the electric potentials at the contact area between toner and carrier and reflects the difference in their work functions due to the flow of electrons. To realize this mechanism, typical dielectric films (PTFE, PET, PA) were used. According to the previous studies[10] observed values of work function have presented as 4.26eV (PTFE), 4.25eV (PET) and 4.08eV (PA). Films were charged by standard carriers and Tungsten beads which have less variation in work function as a representative method of understanding the toner charging mechanism. A quantitative understanding is required and further studies shall be carried out.

Summary

To characterize toner charging property, four type carriers are proposed by The Technical Committee of Toner Technology of Imaging Society of Japan as standard carrier. The carriers have possibilities of estimating charging properties of various shapes in addition to toner particle. Typical insulating films of PTFE, PET and PA are charged by the four type standard carriers of Imaging Society of Japan. From the surface voltage of the film dependence on the carriers, the crossing points of the voltage dependence line is obtained and the charging abilities of the films are estimated. It is also obtained that the charging abilities coincide with the surface voltage obtained by contacting each film with other in order. It is considered that the standard carriers of Imaging Society of Japan are useful to estimate the charging properties of insulating film besides toner powder. The next step is to quantify these relations between carries, powders and films. These films are charged by Tungsten which has relatively little variation of work function and the surface voltages are measured. The result of the surface voltages is the voltages between N-01 and N-02. It is proposed that the carrier N-01 has negative charging property and N-02 has positive charging property compared with Tungsten.

Acknowledgement

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