Triboelectrification of toner and film in contact with surface treated carriers

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Abstract

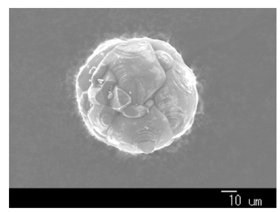
The triboelectric effect is a type of contact electrification in which certain materials become electrically charged when coming in to contact with another different material, and are then separated. As far as the electrical tribocharging is concerned, it is a fundamental physicochemical phenomenon which is applied in the electrophotographic development in two-component developers. As such, this study is carried out to understand the triboelectrification of toner and film in contact with different types of carriers. By concerning the charging tendency, it can be observed that the toner charge and film is charged respectively according to the electrostatic charge tendency of carrier.

Introduction

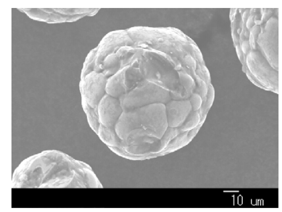
Nowadays, the modern electrostatic copying and laser printer industries provide full color reproduction capabilities as a result of many sequential improvements. There is no question that the electrophotographic (or Xerographic) printing process [1,2] which was invested by Chester Carlson, represented the most significant development in the history of applied electrostatics, as it allowed for the first time to make true dry copies of documents. As far as the Xerography is concerned, the most complex and integrated combination of electrostatic processes are involved including; photoconductivity, corona charging, triboelectrical charging [6,7], coulombic attraction, image force, adhesion force and ionic neutralization.

When the good quality of a print in this process is concerned, it is generally considered that stabilizing the distribution of charged amount of developer leads to the improvement. In other words, the good quality output depends crucially upon the stability of tribocharging of the toner. 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 [5] in which certain materials become electrically charged when coming in to contact with another different material, and are then separated. Charge is exchanged between the materials in proportion to the difference in their effective work functions. The triboelectric charging occurs when the toner is typically charged by mixing it with larger carrier beads in the two-component developers which are being widely used. With the application of coated carriers, it is also considered that they are partially useful in development of negatively charged photoreceptors as they have negative triboelectrical charging properties.

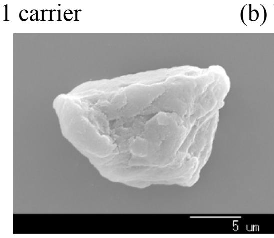
As this study is carried out to understand the triboelectrification in the developer, experiments have been done by using the toners, Ployethylene Terephthalate (PET) and carriers. The electric potential which is also called as electrostatic potential, was measured by using the Digital Low-Voltage Static meter (Model KSD-3000 by Kasuga Denki Inc.). 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, 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, the greater the resulting net change may be when two surfaces are separated after contact.



(a) N-01 carrier



(b) N-02 carrier



(C) N-01T toner

Figure 1. *SEM micrographs of minus charging ability carriers and negative toner.*

Experimental procedure

As far as the development unit is considered, toners are triboelectrically charged by mixing well with carrier beads in the two-component developers. By this rubbing, a charge of one polarity is acquired for toner and the opposite polarity on the carrier. Similarly, in this experiment, toners and PET film samples were made in contact with carriers for triboelectrically charging and the surface electric charge potential was observed. The types of toners and carriers which were used in the experiment are shown in Table 1. All these toners and carriers are recommended for standard method of measurement of Q/M by the Imaging Society of Japan. SEM micrographs of toners and carriers used in the experiment is shown in Figure 1. Aluminium evaporated PET film which has the average thickness of 50 *u*m was used. When preparing the samples for the case of toner attached on the PET film, a spray glue was used.

Table 1: Toners and carriers used in the experiment

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

*Tentative name (under developed by Technical Committee of Toner Technology in the Imaging Society of Japan).

The experiment was carried out under few steps in several cases. In the first case as for the first step, PET film is rubbed with the four types of carriers on a horizontal plane. This was done by manually as per 20 turns in each time evenly. The surface electrostatic potential was observed with the Digital Low-Voltage Static Meter which can be used for measuring a low potential static charge. In this instrument, vibration type surface potential sensor is used. The standard distance for measurement was fixed to 10 mm in every time. In the next step, toner was attached with the gum on the PET film so as the size to be 30mmX30mm. The experimental setup is as shown in Figure 3.

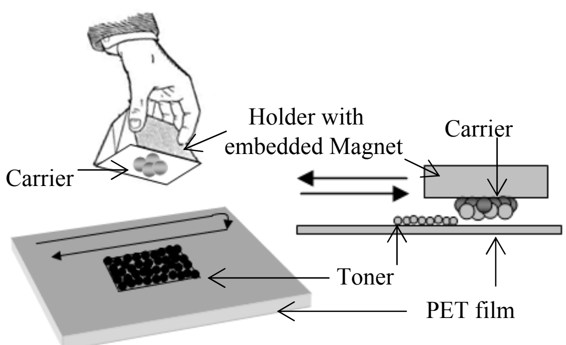


__Figure 2.__ The experimental setup for the case of rubbing toner on PET film (Not to scale).

The microscopic view of toner attached on PET film is as shown in Figure 3. Even though almost whole area is covered with toner, it could be observed that, there are exposed areas also. The magnification of the microscopic capture is 1:50. The rubbing was repeated under the same conditions as described above and followed by measuring the electric potential. The experiment was repeated for the two types of toners, where as; negative charging and positive charging toners respectively with above mentioned four types of carriers.

In the third step, samples were placed on an inclined plane with a 45 degrees of angle as per depicted in Figure 4. Then let the carriers to be contacted the PET film and toner by free fall from a height of 300 mm. Again the electric potential was measured for every case. In this step, the quantity of carrier which was subjected to free fall was varied as 5,10,15,20 and 25 grams. Same as in the previous step, the toners and carriers were changed respectively and repeated the same procedure.

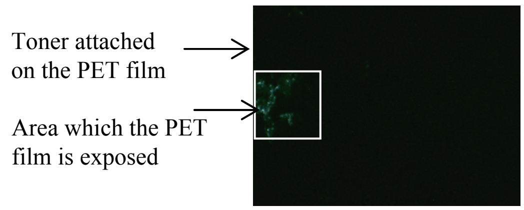


__Figure 3.__ The microscopic view of toner attached on PET film.

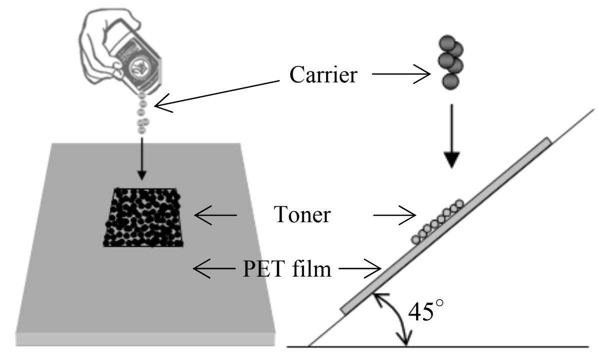


__Figure 4__. The experimental setup for the inclined case (Not to scale).

Results and Discussion

The Figure 5 depicts the specific toner charge dependence on the four types of carriers. These results have been used as the base of this experiment and these were received under private communication from the Technical Committee of Toner Technology in the Imaging Society of Japan.

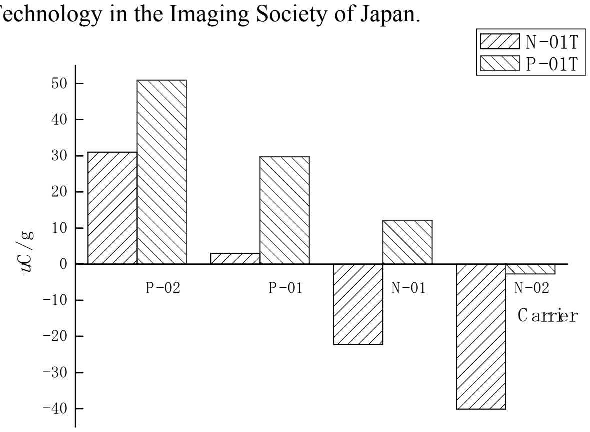


__Figure 5.__ specific toner charge dependence on the particular carriers.

The graph illustrates the charging tendencies of the carriers. The data of this graph is shown in Table 2. By setting these results as the base, the specific toner charge dependence on specific values of negative charging toner (N-01T) is plotted and is shown in Figure 6. The reference data is shown in Table 3.

Table 2: Average Specific toner charge (*u*C/g) from the Technical Committee of Toner Technology in ISJ.

Toner \ Carrier	P-02	P-01	N-02	N-01
N-01T	31.0	3.0	−22.2	−40.1
P-01T	50.9	29.7	12.1	−2.7

By concerning the Figure 6, it shows the results for the cases of rubbing with PET film, N-01T (negative toner) on PET film, P-01T (positive toner) on PET film and free fall of the carriers on PET film in the inclined plane. It is understood that the line up of charging ability (from negative to positive) is agreed with the evaluating results of the Imaging Society of Japan. In other words, N-01 carrier shows the high charging ability in minus and P-02 carrier shows the highest in positive. N-02 and P-01 lie in between them.

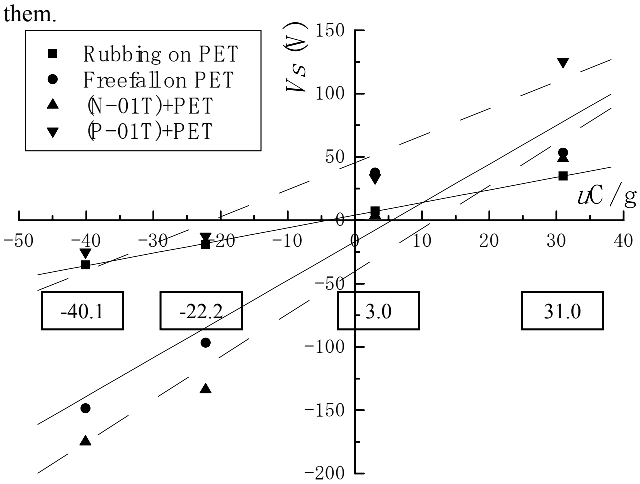


Figure 6. Static charge dependence on specific toner charge.

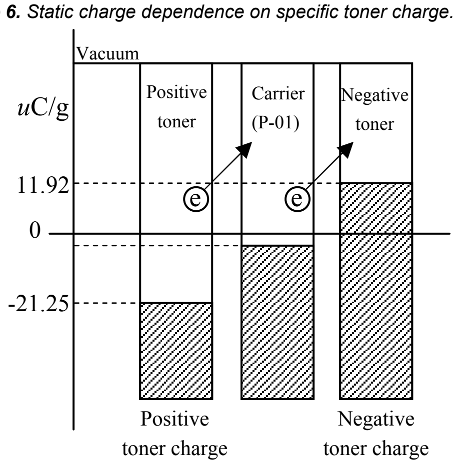


Figure 7. Model for the electron exchange between toner and carrier.

Contact electrification between different materials almost certainly involves the transfer of electrons from one to the other. On the basis of electron transfer, Figure 7 depicts the model for the electron exchange between toner and carrier. Particular *u*C/g values have extracted from Figure 6 is shown in the above model.

Table 3: Data for graph of static charge dependence on *u*C/g or voltage of particular carriers (Figure 6).

Carrier	Specific Charge (uC/g)	Surface voltage (V)			
	From Tech. Comm.-ISJ	Rubbing on PET	Freefall on PET	(N-01T) on PET	(P-01T) on PET
N-01	−40.1	−35.3	−148.5	−175.0	−25.2
N-02	−22.2	−19.3	−96.7	−134.0	−12.6
P-01	3.0	7.4	37.7	3.7	33.6
P-02	31.0	35.0	53.4	48.7	125.5

When the two cases of rubbing PET film with carriers and free fall of carriers on the PET film is compared, the high charging values could be observed when the carriers were fallen over the PET film. When the case of rubbing minus toner (N-01T) on the PET film is considered, it shows high static voltages rather than just rubbing the PET film. As far as the positive toner (P-01T) on PET film is concerned, it shows less static voltages for minus charging carriers and higher charges for plus charging carriers relative to the results of rubbing the PET film. The following Figure 8 shows the static charge dependence on quantity of carrier when the carriers were allowed for freefall.

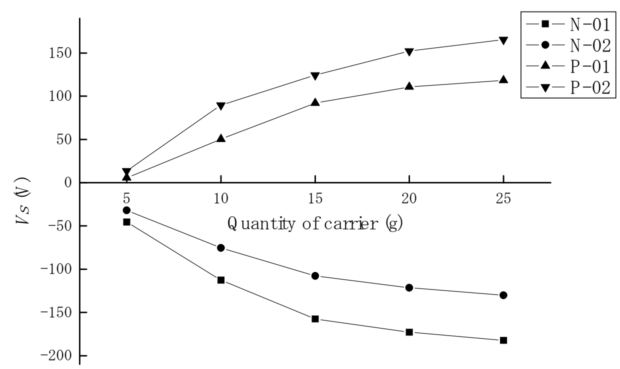


Figure 8. Static charge dependence on quantity of carrier.

By observing the graph, it is understood that the static charge increases gradually and reach to a stable situation with the increment of the quantity of carrier. In this case also, it can be clearly understood that results agree with the basement, where as charging ability of N-01 carrier is greater than N-02 carrier and on the other hand P-01 carrier is less than P-02 carrier. At the point of stabilization, it could be assumed that the electron exchange is reached to a constant.

The Figures 9 and 10 show the static charge dependence on quantity of carrier for the case where toner is attached on the PET film. Further, the carriers were allowed to free fall and the sample plane was inclined. When the Figure 9 is concerned, it shows the static charge (*Vs*) when minus charging carrier was used. And Figure 10 shows in the case of using positive charging carriers.

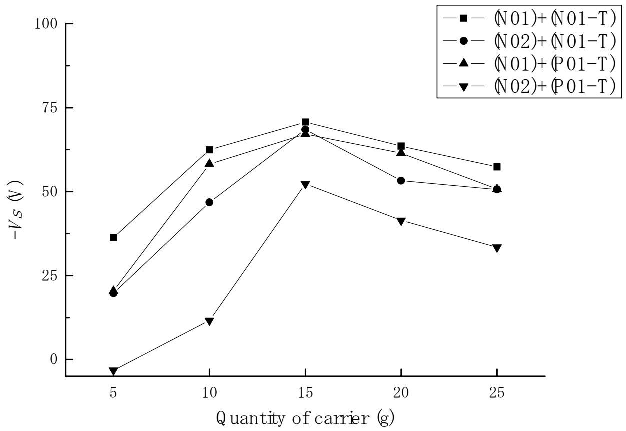


Figure 9. *Static charge dependence on quantity of carrier.*

Commonly in both cases, it can be observed that, the peak was observed when 15 grams of carrier fallen to the sample. And also it can be noticed that the *Vs* has increased gradually with the increment of quantity of carrier, reached the peak and then decreased just after the peak. This decrement of static charge after the peak is considered due to the possibility of destruction of toner and contamination of carrier as the same carrier was reused for a particular case. And also it could be assumed that these irregular results were observed as the toner was not perfectly bonded to the PET film evenly as displayed in Figure 3.

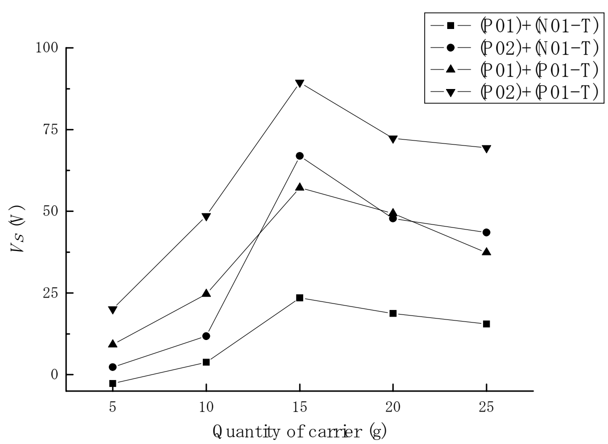


Figure 10. *Static charge dependence on quantity of carrier.*

As far as the magnitude of the Vs is considered, it can be noticed in Figure 9 that, N-02 carrier case gives the smallest while N-01 carrier gives the largest. Same as the above, by considering the Figure 10, it can be observed that P-01 carrier gives the smallest when the P-02 gives the largest. In both cases, a contradiction on ranking can be observed at the peak and afterwards for the cases of N-02, N-01 in Figure 9 and P-02, P-01 in Figure 10.

Summary

Insulating films are charged by contact or rub with standard carrier of 4 types of different charging ability by ISJ. The charge density of the films dependence on the carrier type shows good correlation with the specific charge amount of toner dependence on the carrier reported by ISJ toner technical committee. This means these types of carrier have same charging abilities to film without particle effect. It is also proposed that the charging dependence is controlled by the difference between effective work function of carrier versus toner or film. Further study will be carried out. It is suggested that these standard carrier of ISJ can be applied to estimate the charging characteristics of various material and shape.

Acknowledgement

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