Factors Affecting Tribocharging Characteristics of Toners

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Abstract

Factors affecting tribocharging characteristics of toners were investigated by measuring charge to mass ratio (Q/M) and thermally stimulated current (TSC) spectra. First, the charging characteristics of toners were examined. The toners were chemically treated by methanol vapor or acetone vapor to modify the charging characteristics. The influence of heat treatments on the charging characteristics of toners were also investigated. Charge to mass ratio, ionization potentials, apparent resistivity and TSC spectra after corona charging were measured on untreated and treated toners. The density and depth of charging traps in toner particle were examined by measuring the TSC spectra of the toners. Change in ionization potentials, apparent resistivity and TSC spectra associated with the chemical or heat treatments depended on the kinds of toner. The influences of ionization potential and apparent resistivity on tribocharging characteristics of toners are discussed. The charge to mass ratio of toners increased with an increase in TSC peak height. The tribocharging polarity depended on the ionization potentials. Next, charge traps in toner particle were examined by measuring TSC. Toners with or without charge control agent (CCA) were used in the study. It was confirmed through the TSC measrurements that the TSC peak height of the toners with CCA was larger than that of the toners without CCA.

1. Introduction

It is well known that the tribocharging characteristics of a toner play an important role in the electrophotographic processes.[1] In these processes, the behavior of the toners is controlled by electrostatic force. So, it is desirable that all the toner particles are charged normal polarity to control the behavior of toners. Usually, however, generation of a few fractions of toner particles charged opposite polarity, called wrong sign toner, is not unavoidable in real electrophotographic systems.[2,3]

Since the tribocharging of toner is a complicated phenomenon, which is affected by many factors, such as particle size, resistivity, process condition, environmental condition, etc., the generation mechanism of wrong sign toner has not perfectly been clarified yet. It is necessary to clarify the factors affecting tribocharging characteristics of toners to remove the wrong sign toner and to brush up the electrophotographic process.

Recently, some of the experimental results on tribocharging of electrophotographic developers can be explained by the ionization potentials of toner and carrier or doctor blade.[4,5] We studied tribocharging characteristics of toner particles through tribocharging between toner and carrier. The influence of chemical treatments and heat treatment of toners on their charging characteristics was investigated. Further, charge traps in toner particle were studied by measuring TSC (Thermally Stimulated Current) spectra in toner particle layers.[6-8]

2. Experimental

2.1 Sample Preparation

Four kinds of toner (Table 1) and two kinds of carrier (Table 2) were used in this study. The toner was tribocharged by using a carrier. The influence of methanol vapor treatment, acetone vapor treatment and heat treatment on the charging characteristics of toners was investigated.

Methanol vapor treatment and acetone vapor treatment was curried out by leaving toner and solvent (methanol or acetone) in a desiccator for 24 hours. Toner of 2 g and solvent (methanol or acetone) of 20 g were used in this treatment. Heat treatment of four kinds of toner was performed in an oven (DN-44, Yamato Scientific Co., Ltd.) at various temperatures for five minutes, and it was repeated five times.

2.2 Measurements

The changes in toners associated with the chemical treatment were examined in detail in order to clarify the factors which determined the charging characteristics of toners. For that purpose, basic characteristics, such as charge to mass ratio, apparent resistivity, ionization potential were evaluated for the chemically treated toners. In addition, TSC measurements were carried out on the chemically treated toners.

Table 1. Fundamental Characteristics of Toners Used in this Study

Toner	D_{mean} [μm]	ρ [Ωcm]	Ionization Potentials [eV]	Resin	Note
A	8.52	$3.06*10^{11}$	4.16	Styrene-acrylic	Polymerization, Positive
B	8.52	$1.15*10^{11}$	5.74	Styrene-acrylic	Resin+CCA
C	9.39	$2.27*10^{11}$	4.15	Polyester	Pulverization, Positive
D	8.98	$2.32*10^{11}$	5.38	Styrene-acrylic	Resin+CB+CCA

CB: Carbon Black

Table 2. Fundamental Characteristics of Carriers Used in this Study

Carrier	D_{mean} [μm]	ρ [Ωcm]	Ionization potential [eV]
A	42.17	$3.27*10^{6}$	4.22
B	71.62	$3.78*10^{1}$	4.74

The charge to mass ratio was measured as a function of agitation time by the suction type blow-off method. A dual-component developer was prepared by using a toner and a carrier, the toner concentration of which was 5 wt%. An appropriate amount of the developer was charged into a polystyrene tube and was rotated at the rate of 209 rpm for various time. The apparent resistivity was measured by a dielectric constant auto-measuring unit (TR-1100, Ando-Denki Co., Ltd). The ionization potentials were measured by observing electron emission from the toner particles associated with UV-light irradiation.

Thermally stimulated current (TSC) measurements were carried out with a home-made equipment by the following procedure. Suitable amount of the sample powder was put into a well-shaped (0.5 mm depth and 32 mm diameter) aluminum sample holder. Then, this powder layer was corona charged in the ambient air. The corona voltage was -5 kV. Open-circuit TSC spectra of samples were observed by a collecting electrode placed about 2 mm above the upper surface of the sample powder layer on the aluminum substrate. The heating rate was 3°C/min and the measurement ranged from room temperature to about 160°C. For the TSC measurement, the aluminum sample holder was used as an grounded electrode.

3. Experimental Results and Discussions

3.1 Influence of Chemical Treatments

3.1.1 Charge to Mass Ratio

The results of the charge to mass ratio of toners before and after the chemical treatment are shown in Tables 3 and 4.

The increase in charge to mass ratio in toner B and the decrease in toner D associated with the acetone treatment were confirmed.

Table 3. Influence of Chemical Treatments on Q/M of Toners

Toner	Q/M [μC/g] (with Carrier A)		
	untreated	methanol	acetone
A	33.45	17.85	31.96
B	-49.23	-47.58	-68.71
C	22.28	19.49	16.22
D	-34.29	-20.84	-30.17

Table 4. Influence of Chemical Treatments on Q/M of Toners.

Toner	Q/M [μC/g] (with Carrier A)		
	untreated	methanol	acetone
A	33.45	17.85	31.96
B	-49.23	-47.58	-68.71
C	22.28	19.49	16.22
D	-34.29	-20.84	-30.17

3.1.2 Apparent Resistivity

The apparent resistivities of chemically treated or untreated toners are shown in Table 5. The ratios of apparent resistivity of methanol or aceton-treated to that of untreated toners are given in the table. A significant decrease was found in the methanol-treated toner B and toner D as shown in Table 5. The apparent resistivity decreased considerably in the negatively charging toners associated with the methanol treatment.

3.1.3 Ionization Potentials

The ionization potentials of chemically treated toners are shown in Table 6. Change in ionization potentials associated with chemical treatments depended on the kinds of toner. The charge to mass ratio of chemically treated or untreated toners as a function of ionization potential difference (carrier – toner) is shown in Fig. 1. As described in Table 2, the ionization potentials of the carrier A and B are 4.22 and 4.74 eV respectively. If the ionization potential of toners is smaller than that of the carrier, charging polarity of the toner tents to be positive. On the contrary, if the ionization potential of toner is larger than that of carrier, charging polarity of the toner tends to be negative. Relationship between charge to mass ratio and ionization potential difference is approximately linear having no relevance to chemical composition of toners and with or without chemical treatment. Therefore, it is clarified that the tribocharging polarity and the charge to mass ratio of the toner depend on its ionization potential.

Table 5. Influence of Chemical Treatments on Apparent Resistivity of Toners.

Toner	Polarity	Apparent resistivity [Ωcm]		
		Untreated	methanol untreated	acetone untreated
A	Positive	$3.06*10^{11}$	0.97	0.75
B	Negative	$1.15*10^{11}$	0.17	1.2
C	Positive	$2.27*10^{11}$	0.81	0.61
D	Negative	$2.32*10^{11}$	0.13	0.76

Table 6. Influence of Chemical Treatments on Ionization Potential of Toners.

Toner	Ionization potential [eV]	
	methanol	acetone
A	4.19	4.32
B	5.51	5.60
C	4.17	4.22
D	4.72	5.26

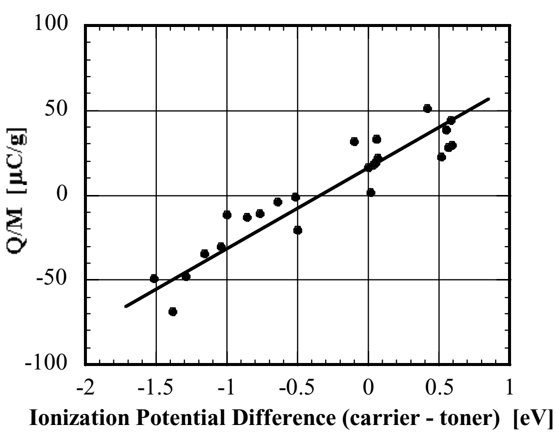

Figure 1. Charge to mass ratio as a function of ionization potential difference (carrier - toner).

3.2 Influence of Heat Treatments

3.2.1 Charge to Mass Ratio

The charge to mass ratio of heat treated toners as a function of charging time is shown in Figs. 2-5. The charge to mass ratio of the heat-treated toners decreased with an increase in heat treatment temperature. Since the crystallization of toners is promoted by the heat treatment, the charge to mass ratio of toners is considered to correlate with structural defects in the toner. These results suggest that the charging sites are structural defects and/or amorphous region in the toner particle.

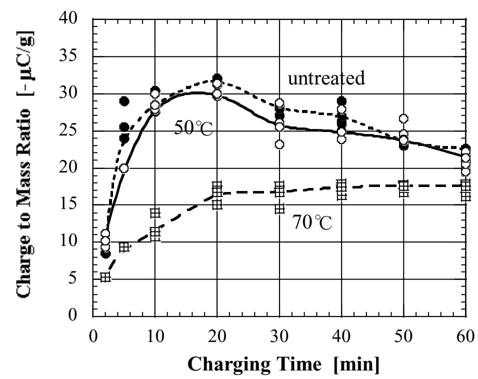

Figure 2. Charge to mass ratio of toner A as a function of charging time.

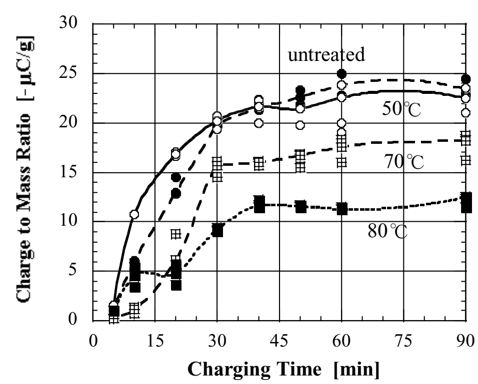

Figure 3. Charge to mass ratio of toner B as a function of charging time.

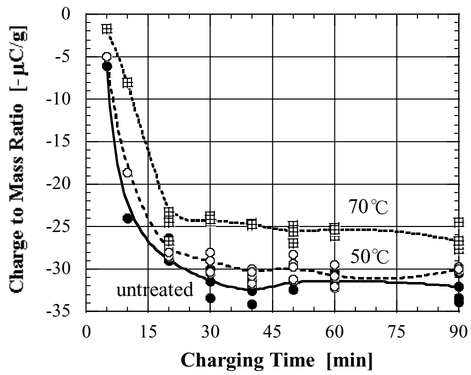

Figure 4. Charge to mass ratio of toner C as a function of charging time.

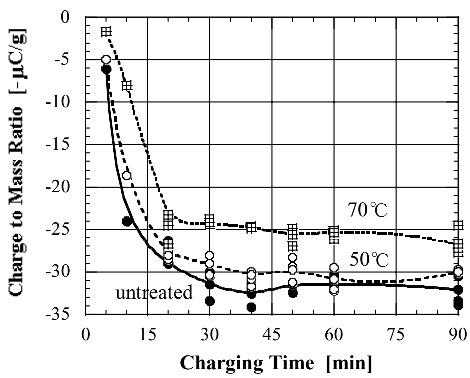

Figure 5. Charge to mass ratio of toner D as a function of charging time.

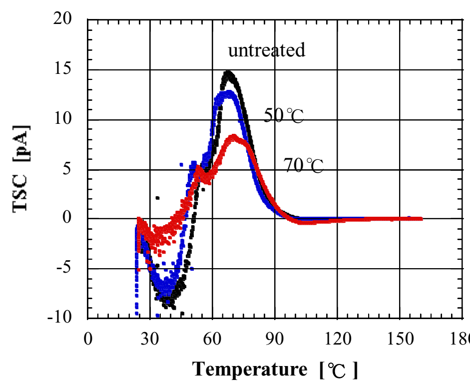

Figure 6. TSC spectra of toner A corona-charged at -5 kV.

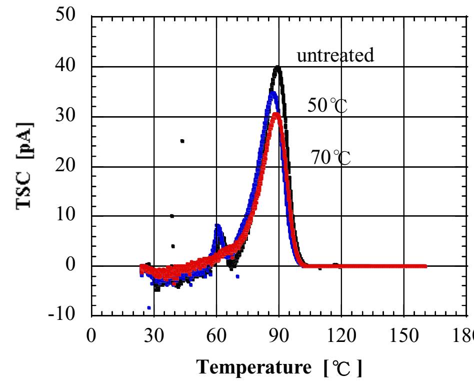

Figure 7. TSC spectra of toner B corona-charged at -5 kV.

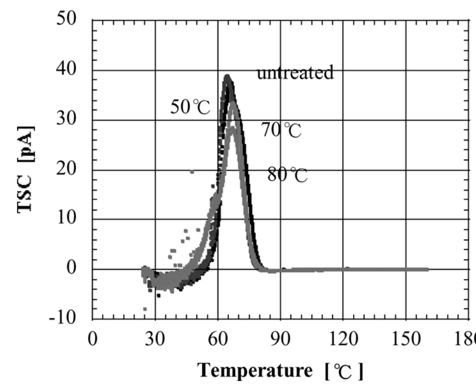

Figure 8. TSC spectra of toner C corona-charged at -5 kV.

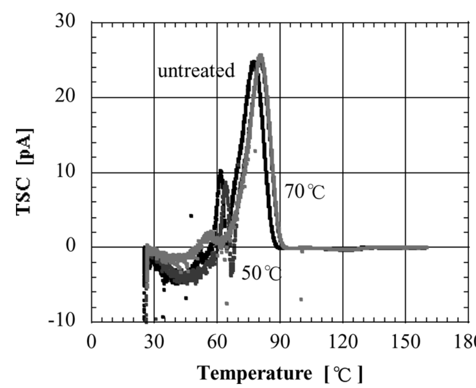

Figure 9. TSC spectra of toner D corona-charged at -5 kV.

3.2.2 Thermally Stimulated Current

TSC spectra of heat-treated toners are shown in Figs. 6-9. The peak height of TSC spectra decreased with an increase in heat-treatment temperature of toners. The higher the heat treatment temperature, the lower the charge to mass ratio of heat- treated toner. These results indicate that the density of charge traps of in a toner decreased by the heat treatment. Further, the charge to mass ratio of a toner seems to be related to the charging traps, which can be assigned to the structural defects of a toner.

3.3 Charge Traps in Toner With or Without CCA

In order to examine the influence of charge control agent (CCA) on the tribocharging characteristics of toners, another four different toners were used in this study. The fundamental characteristics of toners used in this experiment are shown in Table 7. Charge to mass ratios of toners tribocharged with the carriers are shown in Table 8. The apparent resistivity and the diameter of the four kinds of toner were almost same. As described in Table 8, however, charge to mass ratio was different with each other in the four kinds of toner. Charge to mass ratio of the toners with CCA was larger than those without CCA.

Table 7. Fundamental Characteristics of Toners Used in This Study.

Components	D_{mean} [μm]	ρ [Ωcm]	Ionization Potential [eV]
R	10	$2.44*10^{11}$	4.51
R+CB (92/8)	10	$1.79*10^{11}$	4.46
R+CCA (98/2)	10	$2.25*10^{11}$	5.74
R+CB+CCA (92/8/2)	10	$1.85*10^{11}$	4.81

R: styrene-acrylic, CB: carbon black

Table 8. Charge to Mass Ratio of Toners Used in This Study.

Toner	Charge to mass ratio [μC/g]	
	with carrier A	with carrier B
R	-4.53	-1.32
R+CB (92/8)	-2.78	3.42
R+CCA (98/2)	-49.23	-11.81
R+CB+CCA (92/8/2)	-25.64	-4.54

Thermally stimulated current measurements were also carried out on these toners. The results are shown in Figs. 10-13. The peak height of TSC spectra is larger in the toners with CCA than in those without CCA. The density of charge traps in the toner may increase by incorporation of a CCA to toner, or the density of charging traps is almost independent of CCA, but the charge is easily to transfer between carrier and toner through CCA. In other words, the toner charging originates from the charge trapped in CCA or trapped in toner traps through CCA.

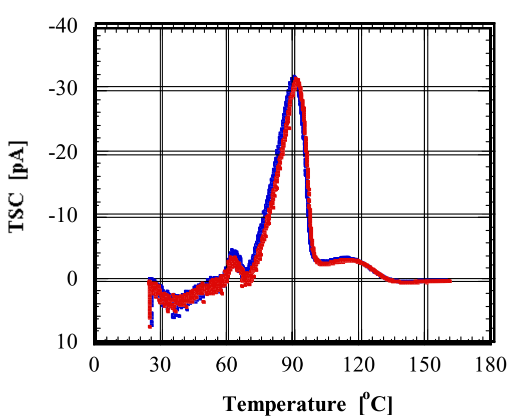

Figure 10. TSC spectra of toners (R) corona-charged at +5 kV.

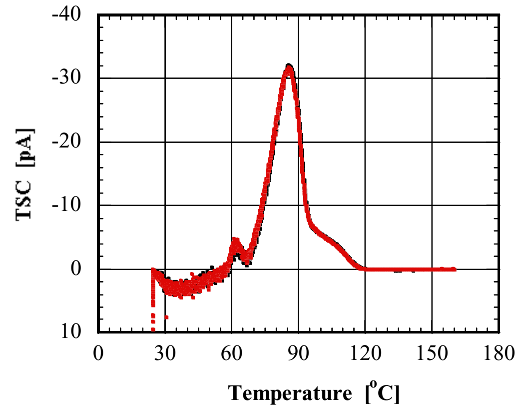

Figure 11. TSC spectra of toners (R+CB) corona-charged at +5 kV.

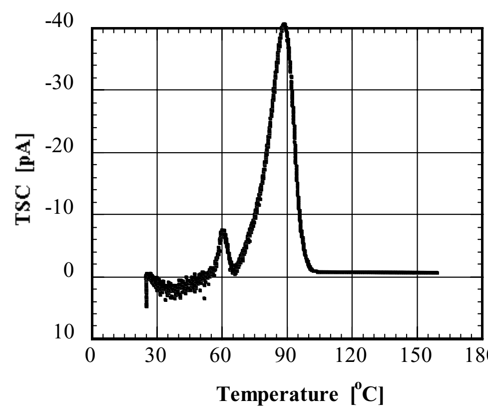

Figure 12. TSC spectra of toners (R+CCA) corona-charged at +5 kV.

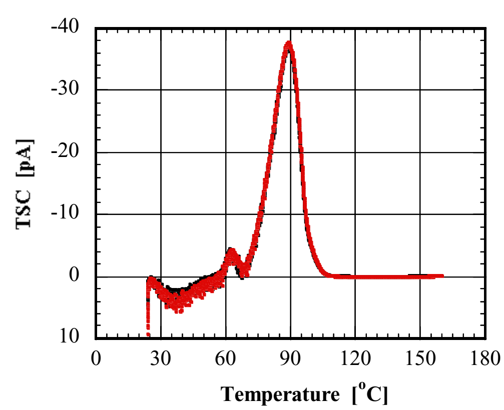

Figure 13. TSC spectra of toner (R+CB+CCA) corona-charged at +5 kV.

4. Conclusions

Factors affecting tribocharging characteristics were investigated in this study. The following results were obtained.

1. The tribocharging polarity and the charge to mass ratio depended on the ionization potentials.
2. The charge to mass ratio of toners increased associated with an increase in the TSC peak height.
3. The charge to mass ratio of toners may have a relationship to structural defects of toner.

Acknowledgement

This work is supported in part by Grant-in-Aid for Scientific Research (C) from The Ministry of Education, Science, Sports and Culture.

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Biography

Kenichi Kutsukake received his B.S. degree in Engineering from the Ibaraki University in 2003. He is now a student of the graduate school of science and engineering of Ibaraki University. He has been working on tribocharging of toners, and currently studying charge traps in toners by thermally stimulated current measurements. He is a member of The Society of Electrophotography of Japan and Institute of Electrostatics Japan.