Study of Tribo-Charging Characteristics between Toner and Carrier

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Abstract

To understand tribo-charging characteristic of toner and carrier, the mixing time dependence of the toner charge at various toner concentration was investigated. A new blow-off tribo-charge measurement apparatus was used to btain more precise data. As a result, the decay of the toner charge was observed in most cases.

A new model was proposed based on the assumption that recombination of the charges between external additive and carrier caused the decay, and the model was estimated by numerical analysis. Because the fitting curves derived from this model were in good agreement with the experimental values, it was clarified that the assumption was appropriate.

Introduction

Electrophotographic processes can be divided roughly into mono-component development and two-component development. The two component development process is applied widely for high-speed copiers and printers and is still the main stream technology in this field. Therefore, understanding the tribo-charging mecha-nism[1,2] between toner and carrier is important and the charge should be measured more accurately.

Although blow-off tribo-charge measurement pparatus is generally used for measuring toner charge, recharge between toner and carrier in Faraday-cage causes an error. We developed a new blow-off apparatus [3] which removed the error, and the relationship between the toner charge and the mixing time was investigated. We also investigated the toner concentration dependence of the toner charge. Charging curves obtained from our experiment showed the decay of the tribo-charge. It has been suggested in some previous reports that external additives affect the tribo-charging behavior of two-component developers greatly.[4-6] Considering these results, we proposed a new model. Since our model includes the charge recombination between external additive and carrier, the obtained fitting curves agree well with experimental values.

In this study, two kinds of negative charge control agents (CCA) were used for the toner and the content was fixed. A negative fumed silica (SiO_2) was used as an external additive, and the amount of addition in relation to the toner was fixed.

Experimental

Materials

A general polyester resin which has a low acid value (AV, approx. 5.0mgKOH/g polymer) and branched chains was selected in this study. Two kinds of negative CCA (CCA1,CCA2) were employed, and both of them were colorless salt type. A negative fumed silica (SiO_2) whose primary diameter is 16nm was selected as an external additive. All toners were composed of polyester, CCA and pigment (phthalocyanine was selected). All of them were compounded in a kneader and crushed to powder of 8μm diameter. The fumed silica was added to the powder in 1wt%. A polymer-coated ferrite carrier of 50μm diameter was used.

Measurements

We used the new blow-off apparatus. Figure 1 shows the schematic diagram of the new blow-off cage. We prepared the developers whose toner concentrations were 1wt%, 3wt%, 5wt%, 10wt% and 15wt%, respectively. The 50g of the developer was put into a 20ml polyethylene vessel. The vessel was rolled on a roll mill. The 100mg of the developer was put into a Faraday-cage. When charged toner was removed by blow and suction of air, the opposite polarity charge to the toner was left on the carrier in the cage. The net charge on the cage was measured with an electrometer. All measurements was carried out at 18-20 °C and 50-60 %RH.

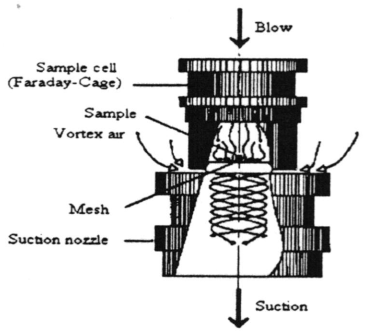

Figure 1. Schematic diagram of the new blow-off cage.

Results and Analysis

Tribo-Charging Characteristic between Toner and Carrier

Figures 2 and 3 show the typical relationship between the toner charge and the mixing time with toner A and B, respectively. The toner charge means total charge exchanged between the toner and the carrier in the 100 mg of the developer. As shown in Figs. 2 and 3, the toner concentration dependence of the toner charge is different for toner A (applied CCA 1) and B (applied CCA 2). However, in both cases, the toner charge decreases gradually after becoming the maximum, and it takes longer to reach the maximum charge with increasing toner concentration.

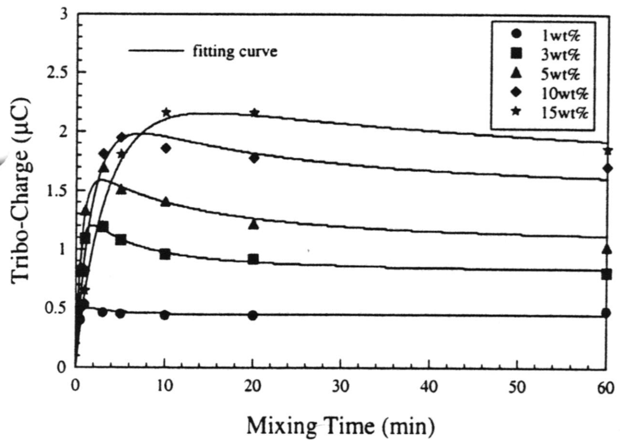

Figure 2. Relationship between the toner charge and the mixing time with toner A (applied CCA 1) at various toner concentration.

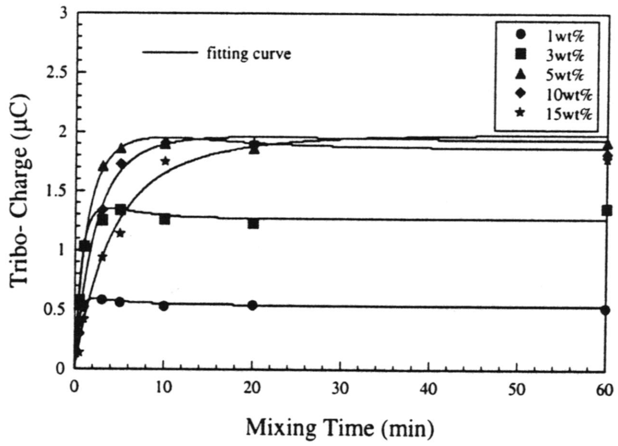

Figure 3. Relationship between the toner charge and the mixing time with toner B (applied CCA 2) at various toner concentration.

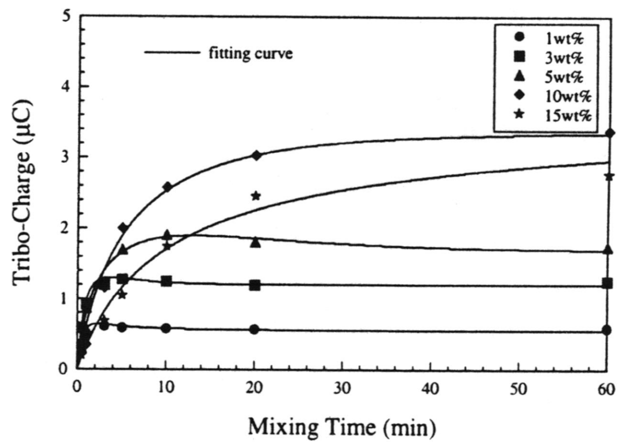

Figure 4. Relationship between the toner charge and the mixing time with toner C (CCA free) at various toner concentration.

Figure 4 shows the relationship between the toner charge and the mixing time with toner C which is CCA free. In the case of toner C, the time required to reach the maximum charge is longer than that for toner A or B. The amount of the saturated charge of toner C is larger than that of toner A or B at each toner concentration. In addition, the time to reach the maximum charge also lengthens with increasing toner concentration. These results indicate that one of the functions of the CCA is to activate the toner charge quickly.

Model and Theory

To understand the tribo-charging process of the toner and the carrier, we made a new model and fitted the experimental data. Since the decay of the toner charge was observed with the CCA free toner (toner C) in low toner concentration region, the decay tendency will be independent of the CCA. Moreover, according to some experimental results reported [4-6], the tendency was not observed with external additive free toner. Hence, we assumed that the external additive mainly influences this phenomenon, and recombination of the charge between the external additive and the carrier occurs during mixing. Considering the number of the effective charging sites between the toner and the carrier and between the external additive and the carrier, respectively, the tribo-charging rate equation of the toner is described as follows:

$$d(T)/dt = \alpha(T_0 - T)(C_{0T} - C_T) \qquad (1)$$

where T and C_T are the number of the tribo-charged sites of the toner and the carrier, respectively, T_0 and C_{0T} are the number of the effective tribo-charging sites of the toner and the carrier, respectively, and α is the charging rate constant for the toner and the carrier. T means the number of the tribo-charged sites of the toner without the external additive. Since the exchange of the charge depends on the difference of the energy level, we distinguished the effective tribo-charging sites of the carrier against the toner and that of the carrier against the external additive. In the case of discharging process, we did not distinguish the tribo-charged sites of the carrier with the toner and that of the carrier with the external additive, because the discharge is brought about by recombination results from coulomb attractive force. Hence, the tribo-charging rate equation of the external additive is described as follow,

$$d(E)/dt = \beta(E_0 - E)(C_{0E} - C_E) - kE(C_E + C_T) \quad (2)$$

where E and C_E are the number of the tribo-charged sites of the external additive and the carrier, respectively, E_0 and C_{0E} are the number of effective tribo-charging sites of the external additive and the carrier, respectively, β is the charging rate constant for the external additive and the carrier, and k is the discharging rate constant for the external additive and the carrier. The tribo-charging rate equations of the carrier is given by,

$$d(C_{total})/dt = \{\alpha(T_0 - T)(C_{0T} - C_T) + \beta(E_0 - E)(C_{0E} - C_E)\} - kEC_{total} \qquad (3)$$

where C_{total} (= $C_E + C_T$) is total carrier charge. This model is illustrated in Fig. 5.

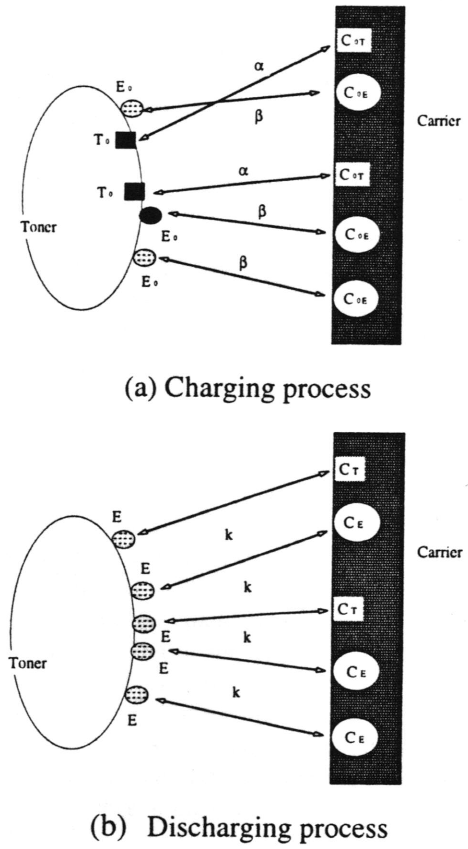

Figure 5. Charging and discharging process of the model.

Parameters

The parameter set of Eq. 3 was obtained by the Monte Carlo parameter fitting, and the fitting curves were obtained by numerical analysis (Runge-Kutta method). The fitting curves derived from Eq. 3 are in good agreement with the experimental data as shown in Figs. 2, 3 and 4. The correspondence of obtained parameters was investigated. Figures 6, 7 and 8 show the relationship between toner concentration and the value of β, E_0 and C_{0E} , respectively. The obtained value of β, E_0 and C_{0E} must be common to toner A, B and C because our model is based on the assumption that there is no tribo-electorical interaction between the toner and the external additive. Therefore, the values of β were calculated from the fitting data of toner C as typical data.

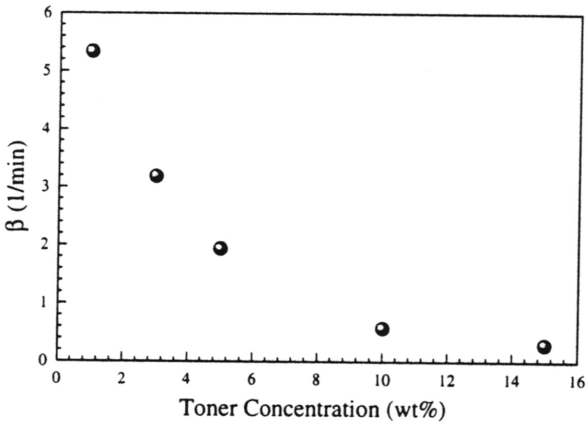

Figure 6. Relationship between toner concentration and the value of β.

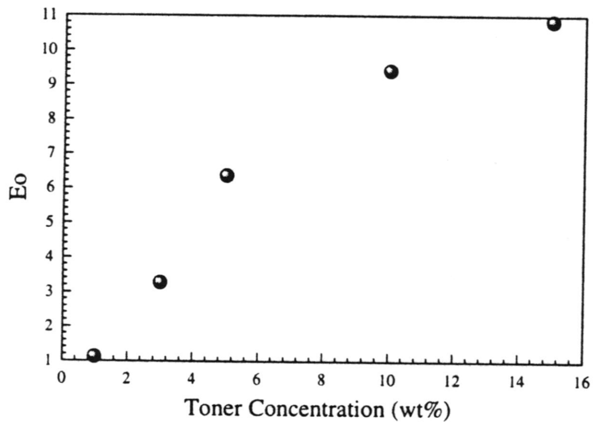

Figure 7. Relationship between toner concentration and the value of E_0.

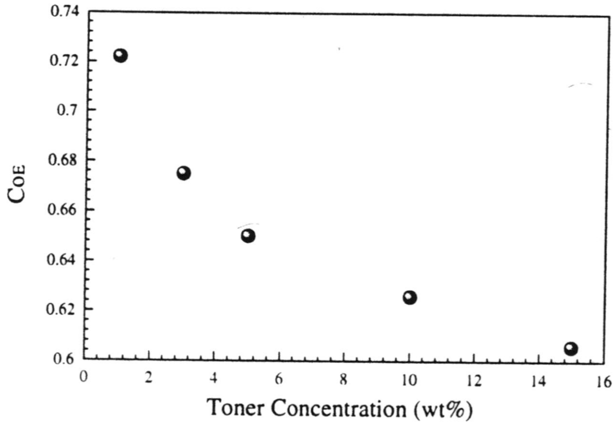

Figure 8. Relationship between toner concentration and the value of C_{0E}.

Figure 9 shows the relationship between toner concentration and the value of the discharging rate constant k for the external additive and the carrier. As shown in Fig. 9, the value of k decreases by two orders or more with increasing toner concentration, and the tendency dose not depend on the toner species.

Figure 10 shows the relationship between toner concentration and the value of the charging rate constant α for the toner and the carrier. As shown in Fig. 10, the value of α decreases with increasing toner concentration. Toner C(CCA free) has a smaller value of α than the others. This means that CCA increases the value of the charging rate.

Figure 11 shows the relationship between toner concentration and the number of effective tribo-charging sites T_0 of the toner. As shown in Fig. 11, the value of T_0 decreases with increasing toner concentration. Toner C has a much larger value of T_0 than the others in high toner concentration region. In the calculation,[7] when the toner concentration is about 12wt%, the carrier is completely covered by the toner. Therefore, the value of T_0 will include errors resulting from the excessive toner concentration. Toner A has a smaller value of T_0 than toner C at each toner concentration. From this result, it was found that the number of the sites does not necessarily increase by adding CCA.

Figure 12 shows the relationship between toner concentration and the number of the effective tribo-charging sites of the carrier against the toner. As shown in Fig. 12, the value of C_{0T} decreases with increasing toner concentration. In this case, the value of C_{0T} strongly depends on the kind of toner. This suggests that the combination of toner and carrier is important to control their tribo-charging behavior. During experiment, no parameter changes linearly in relation to the toner concentration, and both the charging rate constant and the discharging rate constant decrease with increasing toner concentration. Therefore, the average distance of the sites is expected to increase with increasing toner concentration.

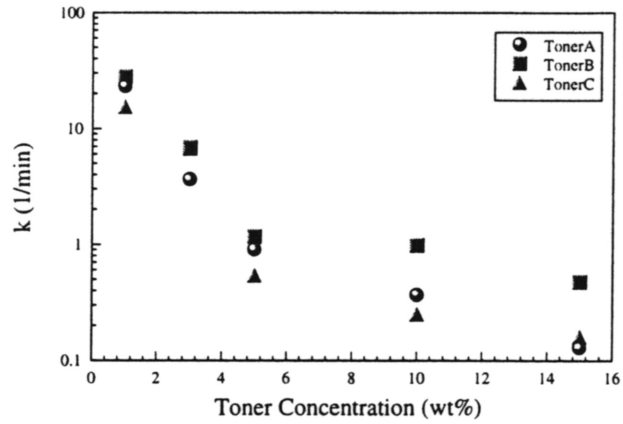

Figure 9. Relationship between toner concentration and the value of k.

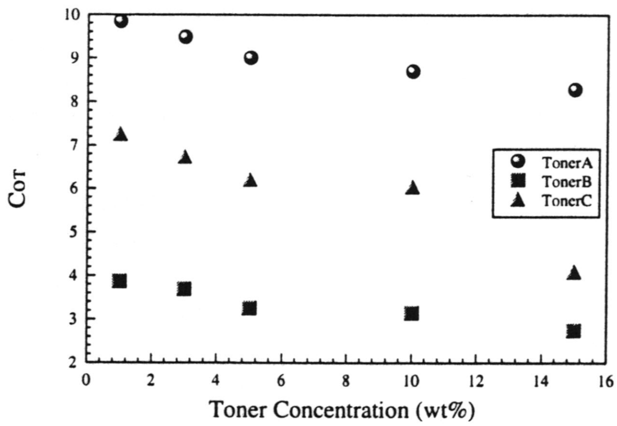

Figure 12. Relationship between toner concentration and the value of C_{0T}.

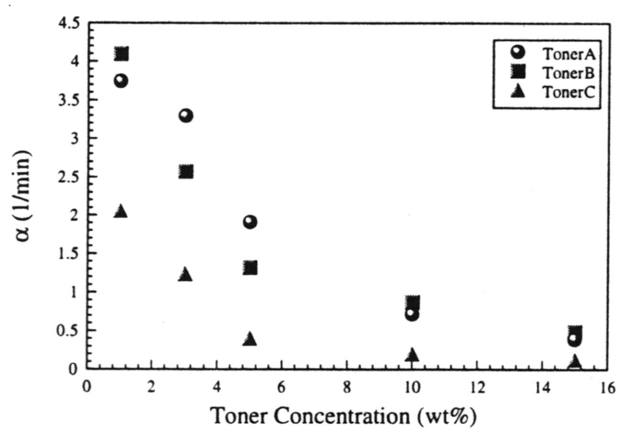

Figure 10. Relationship between toner concentration and the value of α.

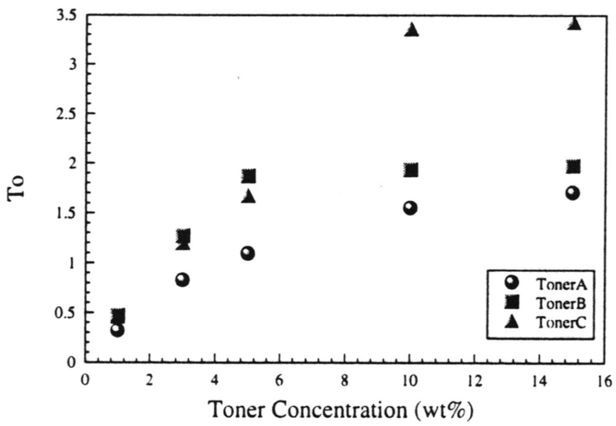

Figure 11. Relationship between toner concentration and the value of T_0.

Conclusion

We made a new model based on the assumption that recombination of the charges between external additive and carrier caused the decay of the tribo-charge. Since the fitting curves derived from this model agree well with the experimental values and the toner concentration dependence of the obtained parameters is quite natural, it was clarified that the assumption is appropriate.

References

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