Behavior of Charge Control Agent (CCA) in Two-Component Developer

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Abstract

The relationship between the charge control capabilities of CCA and its modes of existance in two-component developer was investigated. Trianilino-triphenyl-methane TATPM was used as a positive type CCA. The highest charge up speed and the largest amount of charge were observed on the CCA-free toner particles which were in contact with the carrier particle surface on which the fine TATPM particles were deposited. The amount of positive charge on the CCA-free toner particles caused by the externally added TATPM particles in a toner-carrier mixture was larger than that on the conventional pulverized toner particles in which almost all TATPM particles are in its inner part. The results show that, during the toner-carrier mixing process, fine TATPM particles were produced and deposited onto the carrier particle surface. Then, the TATPM particles moved to the toner particle surface. As a result, the contact charge generated between the fine TATPM particles and the carrier particle surface took the main part of the positive charge on the CCA-free toner particles. The amount of TATPM deposited on the carrier surface was determined by the absorption at 602 nm of the TATPM / ethanol solution extracted from the carrier/ethanol dispersion. The relationship between the amount of TATPM on carrier surface and amount of positive charge on the toner was discussed.

Introduction

The charge control agent (CCA) is an indispensable component for the toner in electrophotographic developer.[1] Usually, CCA is mixed and kneaded with other toner components such as pigment, wax and thermoplastic resin, and the toner particles are obtained through pulverizing and classifying processes. It is said that the CCA particles which appear on the toner surface through the pulverizing process act as a charging site when the toner is brought into contact with carrier particles and that, during the contact, the charge transfer occurs at the interface between the CCA particles and carrier particles and both particles acquire the same amount of charge but opposite polarity. This charging mechanism, however, has not been elucidated.

Usually, the average particle size of commercially available CCA particles is within a range from several micrometers to several tens of micrometers. After the pulverizing process, the free CCA particles having the size of several micrometers are produced. These free CCA particles mix with the toner particles and act as the toner particles. It is said that the very fine CCA particles produced in the pulverizing process are adhering on the toner particle surface and work as a charge control agent.

Nash[2] investigated the amount of toner charge *q/m* generated between toner and carrier at different toner concentration Ct. Toner particles contained a positive type CCA and showed a positive charge. At a Ct of less than 1.0 wt%, however, not only a small *q/m* was obtained but also a negative charge was observed with the increase of the mixing time. The result was attributed to the lack of CCA particles on the toner surface because they moved from the toner surface to the carrier surface during the mixing operation. He confirmed that the reasonable amount of positive *q/m* was obtained by adding an extremely small amount of positive CCA to the carrier surface or to the toner surfaces.

The objective of this report is to investigate the behavior of positive type CCA particles when they are added to the interface between the toner surface and carrier surface. The *q/m* of toner particles was measured by the blow-off method when a small amount of CCA was added to the interface. Very interesting phenomena were observed in which the CCA particles acted as a positive charge messenger from the carrier surface to toner surface, and a positively charged toner with a stable and a large amount of positive *q/m* was obtained. The precise results are described below.

Experimental

Sample Preparation

Styrene-acryl copolymer (acid value: 0.3) particles which have an average particle size of 8.5 ± 0.5 μm and were prepared by pulverizing and classifying processes were used as a model toner for the *q/m* measurement.

Spherical fluoro-carbon coated ferrite particles that have an average particle size of 44 to 125 μm were used as carrier particles for *q/m* measurements.

The chemical structure of Trianilino-triphenylmethane sulfate (TATPM) that was used as a positive type CCA in this experiment is shown in Fig. 1.

A mixture of 19 g of carrier, 1 g of model toner and a prescribed amount of TATPM (1, 2, 4, 8, 16, 30, or 60 mg) was put into a 100 ml wide-mouth polyethylene bottle and maintained for 24h under a 20 to 25ºC, 50 to 60%RH atmosphere to adjust the moisture content. The bottle was set to a paint-shake type blender and mixed for 1, 2, 4, 8, 16, or 32 min. The toner *q/m* at each mixing time was measured by the blow-off method according to the standard measurement procedure issued by ISJ.[3] The relationship between the *q/m* and the mixing time and the relationship between *q/m* and added amount of TATPM m_0 were observed.

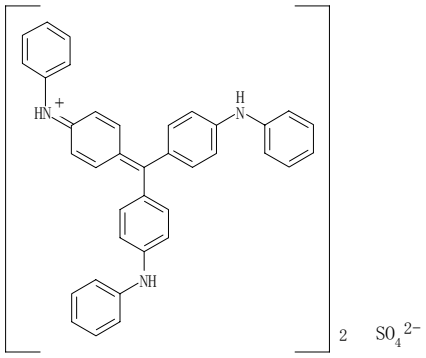

Figure 1. Trianilinophenylmethane sulfate (TATPM).

Determination of Amount of TATPM Adhered on Carrier Surface

After the blow-off measurement, the carrier particles remaining in the Faraday cage (used carrier) were collected. The TATPM adhered on the 1 g of collected carrier surface was dissolved into a 0.5N potassium hydroxide-ethanol solution. The pH of the obtained solution was adjusted to 7.5 with acetic acid, and its volume was adjusted with ethanol. From the peak absorbance at 602.5 nm in UV-Vis spectrum of the solution, the amount of TATPM (m_1) was determined.

Dependence of Charge Control Capability on the Amount of TATPM (m_1)

A mixture of 5.0 parts by weight of model toner and 95 parts by weight of the collected carrier was prepared after blow-off measurements. The amount of toner charge q_2/m (q/m obtained with used carrier) was measured according to the same blow-off measurement procedure as mentioned above. The relation between the q_2/m and the amount of TATPM (m_1) was observed.

Results and Discussion

Relationship Between q/m and m_0

The relationship between q_1/m (q/m obtained with vergin carrier) and mixing time with different added amounts of TATPM (m_0) is shown in Fig. 2. The added amounts of TATPM (m_0) are shown in milligrams to the mixture of 19 g carrier and 1 g toner. The addition of 1 mg of m_0 corresponds to 0.1 wt% of TATPM for 1 g of toner.

The reference curve in Fig. 2 shows the measurement result with a pulverized toner in which 1wt% of TATPM is contained. The blank curve in Fig. 2 shows the result with the model toner.

All curves obtained by the toner-carrier mixtures with different amounts of added TATPM (m_0) show rapid charge up and reach a saturation value within 4 minutes. The q_1/m values after saturation stay constant with the mixing time. The two curves obtained by the reference toner and the blank toner show a slow charge up and continuous increase with mixing time, and the values of q_1/m do not reach a saturation value.

The q_1/m value obtained with the toner-carrier mixture that contained 1 mg (or 0.1wt%) of TATPM is larger than that of the reference toner. The result shows that the addition of TATPM to the interface between the toner and carrier exhibits a stronger charge control effect than that of TATPM added in the toner bulk.

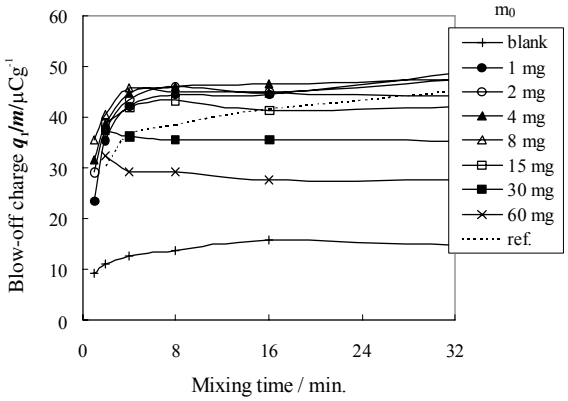

Figure 2. Amount of charge (q_1/m) on TATPM-added toner.

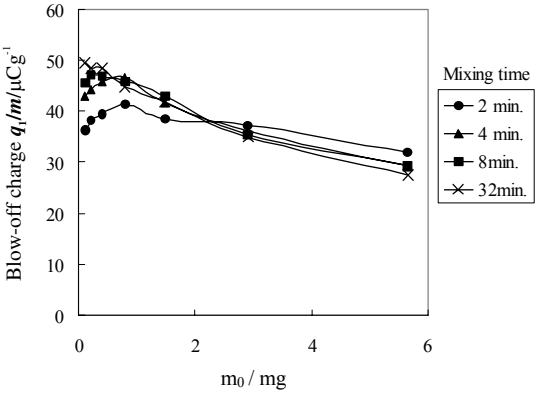

Figure 3. Relationship between toner charge (q_1/m) and amount of added TATPM

Figure 3 shows the relationship between q_1/m and the added amount of TATPM m_0 at different mixing time. The following two points are remarkable.

a) The value of q_1/m shows a peak value at certain m_0. When mixing time is increased, q_1/m reachs a peak value at smaller m_0.

b) As m_0 increases beyond the point which gives the peak value, the value of q_1/m decreases monotonically.

These results suggest that the existing mode of TATPM particles on the toner and carrier particle surface changes with increase of the mixing time. In the case of the mixing time of 32 min. (the longest mixing time), the largest peak value is obtained at the smallest added amount (0.1 wt%) of TATPM.

Originally, the primary particle of TATPM is a nanometer size particle having a diameter of 10 nm or less. The TATPM particles we are handling, however, are larger coagulated particles having a diameter of several micrometers. The above result suggests that,

during the vigorous toner-carrier mixing with a paint conditioner, the primary size of TATPM particles may be separated from the coagulated particle surface and these namometer size particles contribute to generate a large amount of charge even when the added amount of TATPM is as extremely small as 1 mg for 1 g toner.

The q_1/m decreases with increase of the mixing time. This is caused by the excess primary TATPM particles that form a dense particle layer on the toner surface and the carrier surface; these excess particles interrupt the charge exchange between the toner surface and the carrier surface.

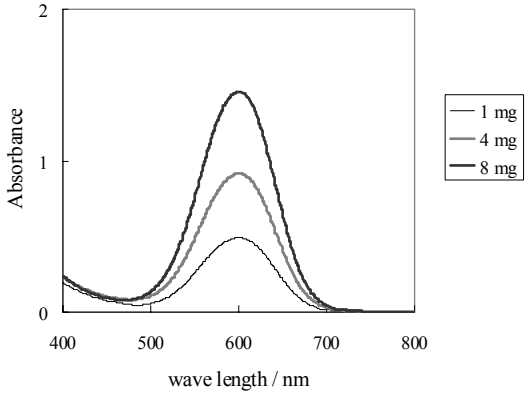

Figure 4. Absorption spectra of ethanol-extracted TATPM from carrier surface

Charge Control Capability of TATPM Particles Adhered on Carrier Surface

The amount of TATPM (m_1) that adhered on the carrier particles which were remaining in the Faraday cage after q_1/m measurements was determined according to the procedure mentioned above. Obtained UV-Vis spectra for the ethanol-extracted TATPM solution are shown in Fig. 4. In the spectra, the peak absorbance is seen at 602.5 nm. The amount of TATPM m_1 was determined from the absorbance and listed in Table 1.

Table 1: Am ount of TATPM Remaining on Carrier Surface After Blowoff Measurement

entry	m_0	m_1	m_2	$m_1 - m_2$
	mg	mg	mg	mg
a	1	0.2	trace	0.2
b	4	0.4	trace	0.4
c	8	0.6	trace	0.6
d	15	1.4	–	–
e	30	2.2	trace	2.2
f	60	3.7	–	–

The relationship between m_1 and m_0 is shown in Fig. 5. Both parameters are in a linear relationship with each other; the amount of TATPM adhered on the carrier (m_1) increases linearly with increase of the amount of TATPM added to the toner-carrier interface (m_0).

A 5 parts by weight of CCA-free model toner was added to the 95 parts by weight of the carrier particles on which the different amount of TATPM was adhered on the surface. The amount of toner charge q_2/m was measured according to the same measurement procedure mentioned above. Figure 6 shows the relationship between q_2/m and m_1.

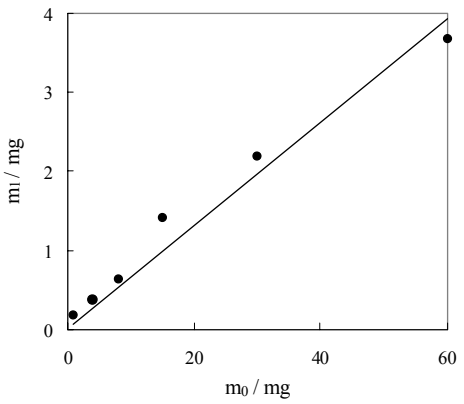

Figure 5. Relationship between amount of TATPM remaining on carrier surface (m_1) and amount of added TATPM (m_0).

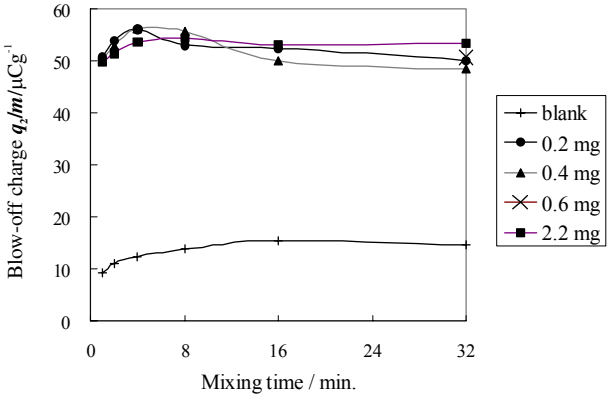

Figure 6. Toner charge q_2/m measured with the carrier particles that has a remained TATPM on the particle surface.

The q_2/m saturates in less than a minute, which is faster than that of charge up characteristics of q_1/m in Fig. 2. The saturation values are nearly the same as in the cases of four carriers with different m_1 on the carrier surface, and the value stays constant with the increase of the mixing time.

The amount of TATPM (m_2) that adhered on the carrier particles which were remaining in the Faraday cage after the q_2/m measurement was determined according to the same procedure above. Figure 7 shows the relation between m_1, $m_1 - m_2$ and m_0. The m_2 can be estimated to be nearly 0 mg. The results show that, after the q_2/m measurement, the whole amount of TATPM (m_1) that adheres on the carrier particle surface moves to the newly added model toner surface.

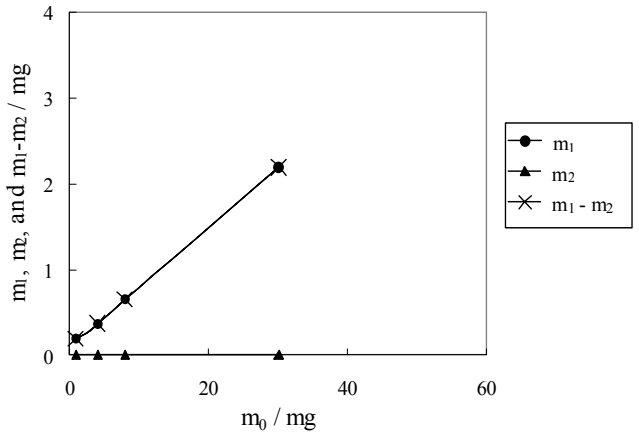

Figure 7. Relationship between amount of TATPM remaining on the carrier surface (m_1, m_2 and m_1 and m_2) and amount of added TATPM (m_0).

The results suggest that an extremely small amount of TATPM (0.2 to 2.2 mg for 1 g toner) that adhered on the carrier imparts a large amount of positive charge (50 to 55 μC/g) to the newly added CCA-free toner, and suggest that such a large amount of positive charge was brought about by the positively charged fine TATPM particles that were transferred from the carrier surface to the toner surface.

The saturated q_2/m values maintained nearly the same level although m_1 was varied more than ten times (from 0.2 mg to 2.2 mg). It is considered that the amount of TATPM which is adhering on the carrier surface to contribute to the charge exchange between the surface is small; m_1 = 0.2 mg is enough for covering the 19 g of carrier particles surface.

Assuming that the increased amount of toner charge $q/m = q_2/m - q_0/m$ (where q_0/m is the blank toner charge) in Fig. 6 is brought from 0.2 mg of TATPM particles adhered on the carrier surface, the amount of charge on TATPM particles can be estimated to be 0.2 C/g. This estimated amount of charge corresponds to $1/10^3$ against the 200 C/g, which is generated by the ionization in 1 g of TATPM molecules. If the TATPM particles which have moved from the carrier surface to the toner surface possess a unit electron par particle, it can be estimated that one TATPM particle consists of 10^3 molecules having a size of 10 nm.

Conclusion

The behavior of Trianilino-triphenyl-methane TATPM particles that were added to the toner-carrier interface was investigated. The amount of generated positive charge q/m on the model toner was larger than that on the conventional pulverized toner in which almost all TATPM particles were in its inner part. It was confirmed that the charging mechanism of the model toner by the externally added TATPM particles is as follows.

a. During the toner-carrier mixing process, fine TATPM particles are produced and adhere onto the carrier particle surface.
b. The charge exchange between the adhering TATPM particles and carrier particle surface occurs, and TATPM particles acquire a positive charge.
c. Transfer of positively charged TATPM particles from the carrier particle surface to the toner particle surface occurs.
d. Model toner acquires the positive charge.

The relationship between the amount of TATPM on the carrier surface and the amount of positive charge on the toner was discussed.

References

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Author Biography

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