Evaluation of Toner Charging Capability of Trianilino-triphenylmethane (TATPM) Coating Layer on Toner or Carrier Surface

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Abstract

Charge control capability of trianilino-triphenylmethane (TATPM: a positive type CCA) for a styrene-acryl (St-Ac) model toner is evaluated using two types of two-component developer samples. One of the samples is a mixture of St-Ac model toner T_P which has a TATPM coating layer on its surface and a ferrite carrier C, and the other is a mixture of CCA-free St-Ac model toner T and a ferrite carrier C_P which has a TATPM coating layer on its surface. The toner charge q/m of the developers having T_P-C and T-C_P combinations is measured by the blow-off method. Both of toner brown off from the developer of the T_P-C combination and that from the developer of the T-C_P combination show a positive charge. The positive charge on the toner T from the developer of the T-C_P combination, (that is, the toner first brought in contact with and then separated from the carrier) C_P having a strongly positive charge, is contrary to expectation. The values of the toner charge q/m for the developers are nearly equal if the amount of TATPM on the T_P surface or on the C_P surface is identical. The q/m values increase linearly with an increase in the amount of TATPM coated on the two surfaces and reach a saturation value. On the surface of a carrier C_S, which was collected after the blow-off measurements of the developer of the T_P-C combination, a small amount of TATPM was detected by a calorimetric method.

From the above results, it is confirmed that, in the toner charging of the two component developer of the T_P-C or T-C_P combination, the TATPM particles from the TATPM coating layer of the T_P or C_P surface served as a positive charge messenger according to the following steps; a) the TATPM layer coated on the T_P surface or C_P surface is peeled off by a mixing operation, b) the generated TATPM fine particles adhere on the carrier C or carrier C_P surface and acquire a positive charge, c) the positively charged TATPM particles adhere to the toner T or toner T_P surface to provide positively charged toner particles.

Introduction

It is said that electrical charge transfer occurs by contact of the surfaces of two dissimilar materials. When the two materials are separated after the contact, each material obtains a charge of the same amount but opposite polarity. In the case of tribo-charging of toner particles in a two component developer, the charging mechanism is considered as identical as described above; electrical charge transfer occurs between the surfaces of toner particles and carrier particles, and, after the separation, the two kinds of particles obtain a charge of the same amount but opposite polarity.

Almost for every toner, a Charge Control Agent (CCA) is considered as a key component to control the amount of tribo-charge. Usually, the CCA is mixed and kneaded with other toner components such as pigment, wax and thermoplastic resin, and the toner particles are finally obtained through pulverizing and classifying processes. It is generally assumed that CCA particles which become exposed on the toner surface through the pulverizing process act as a charging site when the toner is brought into contact with carrier particles[1)].

In a previous paper[2)], the present authors investigated the toner charging which is brought about by the positive type CCA (trianilino-triphenylmethane sulfate, TATPM) particles that are externally added to the interface between CCA-free model toner and a carrier. An interesting phenomenon was confirmed in which the CCA particles acted as a positive charge messenger from the carrier surface to toner surface, and positively charged toner with a stable and a large amount of positive *q/m* was obtained.

In this paper, the authors evaluated the toner charge control capability of the same positive type CCA (TATPM) that was coated either onto the styrene-acryl (St-Ac) model toner surface or onto the carrier surface. It was confirmed that the positively charged TATPM particles which peeled off from the TATPM coating layers on the surfaces of St-Ac model toner or the carrier acted as a positive charge messenger and contributed to increase the positive charge on the St-Ac model toner. The details of the investigation will be mentioned below.

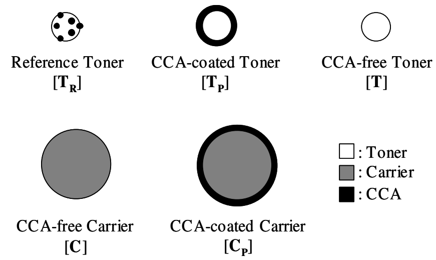
Experimental

Preparation of toner and carrier

Figure 1 shows the toner and carrier for two-component developers that were used in this experiment. As the toner, CCA (TATPM) free St-Ac model toner (T), TATPM-coated St-Ac model toner (T_P) and St-Ac toner containing 1 wt% (10,000 ppm) TATPM in its bulk (T_R) were prepared. Those three types of toner have an average diameter of 8.5 ± 0.5 µm. As the carrier, a TATPM-free spherical ferrite carrier with a fluorocarbon coating layer on its surface (C) and a spherical ferrite carrier with a TATPM coating layer on the fluorocarbon coating layer (C_P) were prepared. Those two carriers have a particle size ranging from 44 to 125 µm.

The T_P or C_P particles were prepared by putting a 1.0 parts by weight of T or 19.0 parts by weight of C into separate mixers, adding 0.5 parts by weight of TATPM/ethanol solution with prescribed TATPM concentrations, respectively, and then agitating and drying the contents of the mixtures.

For evaluation of the toner charge control capability of TATPM coated on the T_P or C_P surface, two-component developer samples which consist of the T_P-C or C_P-T combination were used. For the reference developer samples, a T-C or T_R-C combination were used.



2-component developer	Toner	Carrier
T_R–C (Reference 1)	[T_R]	[C]
T_P–C	[T_P]	[C]
T–C_P	[T]	[C_P]
T–C (Reference 2)	[T]	[C]

Figure 1. *Toner and Carrier for two-component developers.*

Measurement of toner charge q_1/m

A blend of 19 g of the carrier and 1 g of the toner was put into each of five 100 ml wide-mouth polyethylene bottles, and the bottle contents were left for 24 h under a 20 to 25 ºC, 50 to 60 % RH atmosphere to adjust the moisture content of the components. The bottles were set to a paint shaker for mixing the bottle contents for 2, 4, 8, 16 or 32 min. The toner charge q_1/m at each mixing time was measured by the blow-off method complying the standard measurement procedure stipulated by ISJ.

Detection of TATPM particles transferred from T_P to C

As shown in Figure 2, detection of TATPM transferred from T_P to C was carried out by determining the amount of TATPM on the C_S surface. After the blow-off q_1/m measurement with the developer of the T_P-C combination, the carrier particles C_S remaining in the Faraday cage were collected. The TATPM adhered on the surface of 1 g of the collected carrier C_S was dissolved into an ethanol solution. From the peak absorbance at 598 nm in the UV-Vis spectrum of the solution, the amount of TATPM on the C_S surface was determined by using the relationship between TATPM concentration and the peak absorbance at 598 nm of the TATPM/ethanol solution.

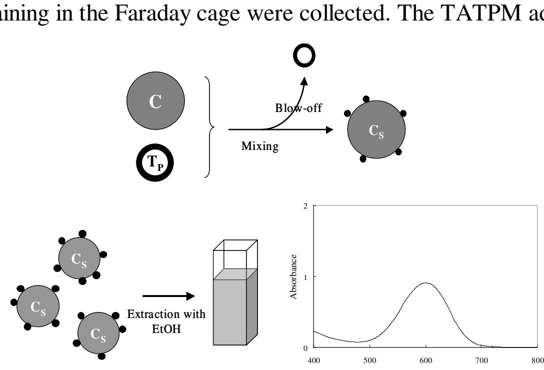


Figure 2. *Process for determining amount of TATPM on C_S surface.*

Measurement of toner charge q_2/m

A blend of 4.75 g of carrier C_S and 0.25 g of CCA-free model toner T was put into a 30 ml wide-mouth polyethylene bottle. The toner charge q_2/m was measured according to the same procedure as in the q_1/m measurement mentioned above.

Results and discussion

Toner charge q_1/m in T_P-C combination

Figure 3 shows the relationship between q_1/m and mixing time in the T_P-C combination. The amounts of TATPM coated on the T_P surface are shown in terms of parts by weight for one million parts by weight of toner T. The reference curve 1 in Figure 3 was obtained for the T_R-C combination in which T_R is the reference toner that contains 10,000 ppm of TATPM in its inner part. The reference curve 2 in Figure 3 was obtained for the T-C combination in which T is the CCA-free reference toner. In the case of the T_P-C combination, all curves show rapid charge up and reach a saturation value within 4 minutes. According to the obtained result, the toner T_P that has a 200 ppm of TATPM coated on its surface shows nearly the same charge-up and saturation behavior as that shown by the reference curve 1. This means that the TATPM-coated toner T_P demonstrates the charge control capability of about 50 times as high as that of T_R which contains 10,000 ppm TATPM in its toner bulk.

Figure 4 shows the relationship between the amount of q_1/m on toner T_P and the amount of TATPM coated on the T_P surface. In each curve, mixing time is taken as a parameter. Within the amount of coating ranging from 0 to 200 ppm, the q_1/m value increases linearly with an increase in the amount of the coated TATPM. The q_1/m reaches a saturation value at 500 ppm and then

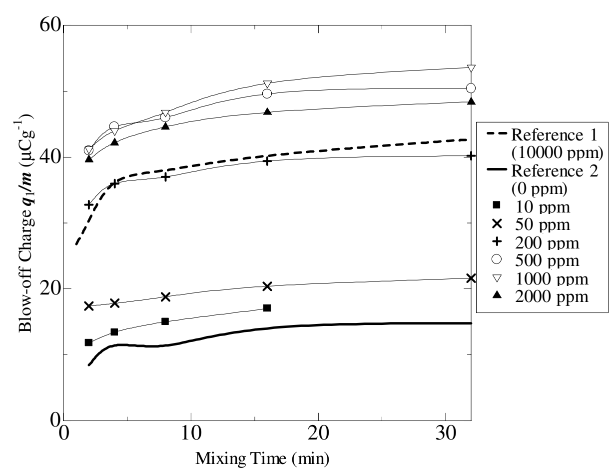


Figure 3. *Relationship between q_1/m and mixing time in T_P-C combination.*

gradually decreases with an increase in the amount of the coated TATPM.

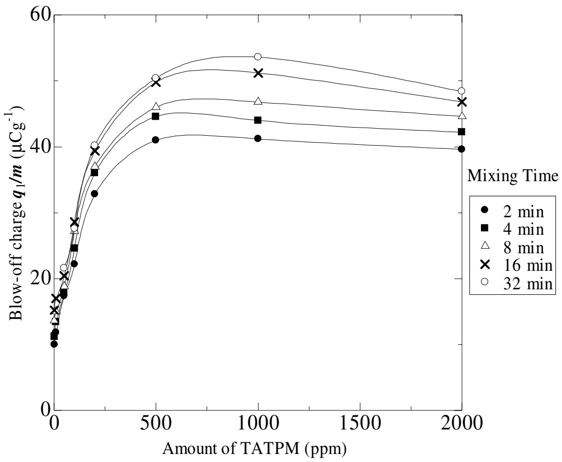


Figure 4. Relationship between q_1/m on toner T_P and amount of TATPM in T_P-C combination.

Toner charge q_1/m in T-C_P combination

Figure 5 shows the relationship between q_1/m and mixing time obtained from the T-C_P combination. The amounts of coated TATPM are shown in terms of parts by weight for one million parts by weight of toner T. The reference curves 1 and 2 show the results obtained from the T_R-C and T-C combinations, respectively.

All the curves obtained from the T-C_P combination with different amount of TATPM coated on the carrier C_P surfaces show positive charges. This result was strange from an expectation that all types of CCA-free model toner T in the T-C_P combination necessarily to acquire a negative charge after contact with and separation from the strongly positive charging TATPM layer coated on the C_P surface. In this case, the positive charge value q_1/m increases with the amount of increase of TATPM coated on the carrier surface. The result suggests that, as shown in Figure 6, the TATPM layer that is coated on the carrier surface is not so firm to maintain a positively charged surface after the mixing operation; during the mixing operation, the coated TATPM layer is easily peeled off to generate fine positively charged TATPM particles, and part of generated TATPM particles necessarily adhere to the CCA-free toner surface and finally yield the positively charged toner.

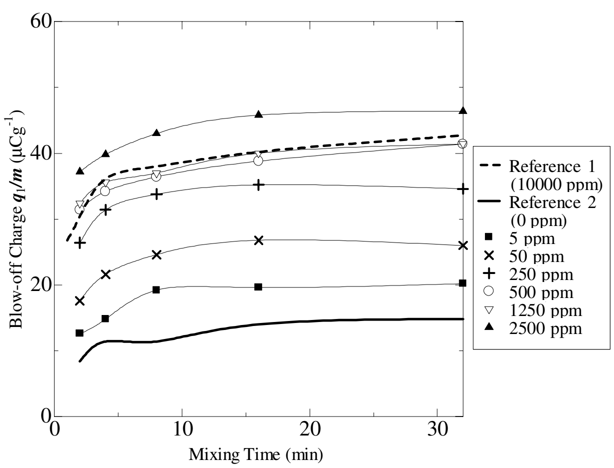


Figure 5. Relationship between q_1/m and mixing time in T-C_P combination.

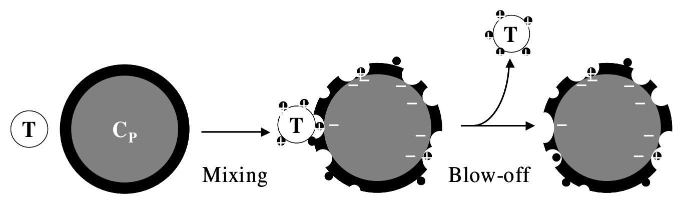


Figure 6. Mechanism of charging toner T by TATPM particles generated on C_P surface.

According to the result of Figure 5 obtained from the T-C_P combination, the carrier C_P that is coated with 500 ppm TATPM on its surface shows nearly the same charge-up and saturation behavior as that shown by the reference curve 1. This signifies that the TATPM-coated carrier C_P has the charge control capability about 20 times as high as that of T_R which contains 10,000 ppm TATPM in its toner bulk.

Figure 7 shows the relationship between q_1/m and the amount of TATPM coated on the carrier C_P surface. In each curve, mixing time is taken as a parameter. Within the amount of coating of TATPM ranging from 0 to 500 ppm, the q_1/m value increases with an increase in the amount of the coated TATPM. The increase of the q_1/m values then becomes gradual with an increase in the amount of coating in the range from 500 ppm to 2500 ppm.

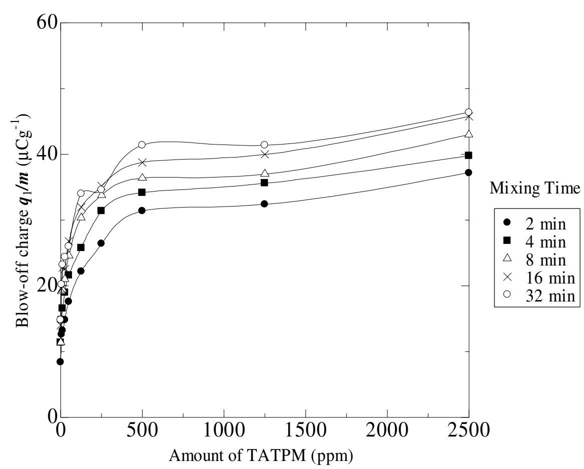


Figure 7. Relationship between q_1/m and amount of added TATPM in T-C_P combination.

Generation of fine TATPM particles from T_P surface in T_P-C combination

From the charging mechanism of the T-C_P system shown in Figure 6, it is expected that the following charging steps would also be possible for the toner charging in the T_P-C combination; a) by the mixing operation, the TATPM layer coated on the toner T_P surface is peeled off, b) the generated fine TATPM particles adhere on the carrier C surface and acquire a positive charge, and c) part of the positively charged TATPM particles on the C surface return to the toner T_P surface and yield positively charged T_P toner particles.

Through steps a) and b), carrier particles C_S on the surface of which fine TATPM particles adhere are generated. The amount of TATPM adhered on the surface of the carrier C_S was determined by using the process shown in Figure 2.

An amount of 12 ppm TATPM was detected on the C_S surface that was obtained from the T_P-C combination which contains T_P particles having 1,000 ppm TATPM coated on its surface.

Figure 8 shows the results of q_2/m measurements obtained from a T-C_S combination (C_S was obtained from T_P (TATPM: 1,000 ppm)-C combination). Only 12 ppm of TATPM on the C_S surface provides a highly positive toner T that has a q_2/m of grater than 30 μC/g.

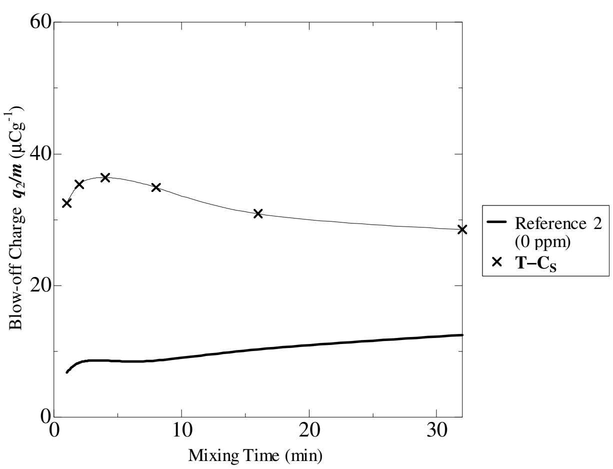


Figure 8. *Relationship between q_2/m and mixing time in T-C_S combination.*

As a result, it was confirmed that, in the mixing operation, the TATPM layers on both T_P and C_P surfaces are regarded as a resource for fine TATPM particles. The generated fine TATPM particles acquire a positive charge by contact with the carrier surface and act as a positive charge messenger to provide the positively charged toner.

Conclusion

Charge control capability of trianilino-triphenylmethane (TATPM: a positive type CCA) for styrene-acryl (St-Ac) model toner was evaluated using two types of two-component developer samples. One type of the samples was a mixture of the St-Ac model toner T_P which has a TATPM coating layer on its surface and a ferrite carrier C, and the other sample was a mixture of the CCA-free St-Ac model toner T and the ferrite carrier C_P which has the TATPM coating layer on its surface. In the T_P-C and T-C_P combinations, both types of toner T_P and T show the polarity of a positive charge, and the amount of tribo-charge q_1/m increases with an increase in the amount of TATPM coated on the T_P or C_P surface.

It is confirmed that, in the two-component developer with the T_P-C or T-C_P combination, the TATPM coating layer of the T_P or C_P surface acts as a resource of TATPM particles that are easily generated during the mixing operation. The generated TATPM particles serves as a positive charge messenger according to the following steps; a) the TATPM layer coated on the T_P surface or C_P surface is peeled off by the mixing operation, b) the generated fine TATPM particles adhere on the carrier C or carrier C_P surface and acquire a positive charge, and c) the positively charged TATPM particles adhere to the toner T or toner T_P surface to provide positively charged toner particles.

Reference

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[2] A. Suka, M. Takeuchi, K. Suganami, and T. Oguchi, J. Imaging Soc. Jpn., 45, 127-132 (2006).

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