Analysis of Tribo-charging Characteristics on Toner Particles in Two-Component Developer

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Abstract

Tribo-charging characteristics on toner in a two-component developer are affected by various factors such as material component, shape, and methods of tribo-charging or measuring. It is, therefore, important to evaluate tribo-charging behavior in details under certain conditions. Tribo-charging on toner is performed by using a mixing shaker with arm length of 200mm. Rotation speed corresponding with shaking frequency is 150rpm and 180rpm. Charge quantity is measured by the E-SPART method. As toner sample, a negative yellow type of toner based on bisphenol A and polyester resin is used. From the experimental results, it is showed that the q/m dependence on shaking time is saturated at near 5min with a negative value of -20 μC/g. After 5min, the q/m decreases slightly to a constant value of -15 μC/g. Charge quantity on toner shows approximately a parabolic dependence on toner diameter in the region up to 10μm in the two-component developer. The charge quantity q on toner is shown to be limited by the upper value deduced from the discharge condition in air and the q at 10μm was about 6fC less than 8.35fC.

Introduction

In the electrophotographic process, two-component developers have been widely used. Toner particles used in developing process have a main role for reproducing original images in a copying machine. Imaging quality is influenced by tribo-charging characteristics on toner. These characteristics are affected by various factors such as material component, shape, and methods of tribo-charging or measuring. It is, therefore, important to evaluate tribo-charging behavior on toner. Measurements of charge quantity on toner have been done by various methods and theoretical approaches on toner particles with carrier beads have been proposed.

We have reported the results of tribo-electric charge on toner by a laser-based instrument due to the Electrical Single Particle Aerodynamic Relaxation Time (E-SPART) method.[1] As this method enables us simultaneous measurement of aerodynamic diameter *d* and electric charge to diameter ratio *q/d* on each toner particle in principle, the data set of *d* and *q* is capable to be deduced in addition to *q/m*. We present here some experimental results on the effects of tribo-charging conditions for toner particles by preparing a mixing shaker.

Experimental

A developed mixing shaker with arm length of 200 mm corresponding approximately to a human arm length was used for tribo-charging on toner. Rotation speed corresponding with shaking frequency was 150rpm and 180rpm. Mechanical mixing procedure was followed after preliminary manual shaking over 15cycles, where shaking time was varied from 1min to 20min. As a toner, a negative yellow type of toner based on bisphenol A and polyester resin was used. As carrier, a coated ferrite type was used. For preparation of samples to examine mixed states of toner and carrier, a certain amount of toner was poured on a carrier layer in a glass bottle. Toner nominal concentration in the two-component developer was maintained at 5wt%. In *Figure 1*, photograph of toner mixing shaker with arm length of 200mm is shown. Measurement of charge to mass ratio *q/m*, electric charge *q* and size *d* has been conducted with a modified type of E-SPART analyzer.[2]

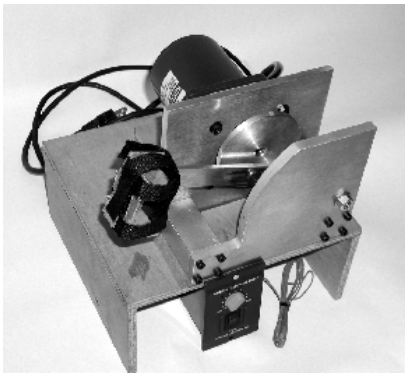


Figure 1. Photograph of Toner Mixing Shaker.

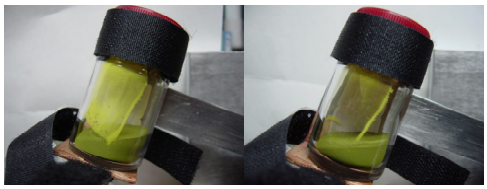
Results and Discussions

At 120rpm via a shaker with the arm length of 200mm, the yellow toner particles were not sufficiently mixed with the black carrier beads for 4min shaking time as shown typically in *Figure 2*. In case without a manual shaking in *Figure 2(a)*, some amount of carrier beads remained in the bottom of the bottle and a small amount of toner remained in non-mixed states even in case with a manual shaking in *Figure 2(b)*.

On the other hand, in case of 150rpm and 180rpm, it was found that the fluently mixed states were obtained. In *Figure 3*, the mixed states at 150rpm for 4min shaking time are shown. The shaking conditions at 150 rpm and 180 rpm are good enough for tribocharging.

(a) (b)

Figure 2. Mixed states for yellow toner after 4min shaking at 120 rpm. (a):without manual shaking (b):with manual shaking



(a) (b)

Figure 3. Mixed states for yellow toner after 4min shaking at 150 rpm. (a) without manual shaking; (b) with manual shaking

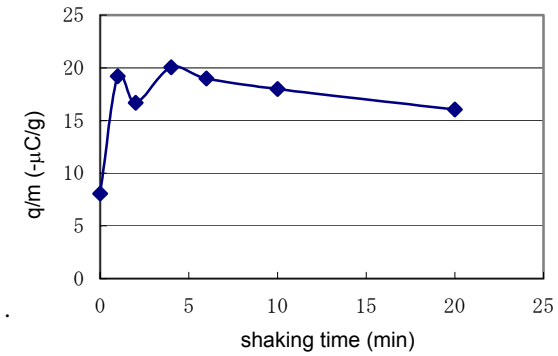


Figure 4. q/m dependence on shaking time for 150rpm

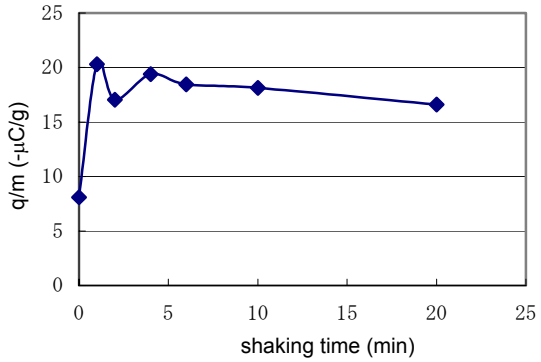


Figure 5. q/m dependence on shaking time for 180rpm.

In *Figure 4*, the experimental result of saturation curve on tribo-charging *q/m* characteristics on shaking time at 150rpm with the 200mm arm length is shown. The absolute value of *q/m* increased to 20.1μC/g at 4min of shaking time and gradually decreased down to a constant saturated value of 16μC/g at 20min for yellow toner particles. In *Figure 5*, the saturation curve of *q/m* at 180rpm is also shown. The *q/m* dependence on shaking time showed a similar tendency and the saturated value of *q/m* was about 16μC/g.

It is suggested that decrease of *q/m* from 20μC/g to 16μC/g is due to CCA additives removed from the toner surface and transferred to the carrier. In *Figure 6* and *Figure 7*, the results of electric charge *q* dependence on toner diameter are shown. In *Figure 6*, the *q* was about 6fC at 10μm, and showed a nearly parabolic increase with toner diameter d in the region up to 10μm. In *Figure 7*, the *q* also showed a similar tendency. The charge quantity of 6fC on toner is a reasonable value less than the upper limited of 8.35fC deduced from the discharge condition in air. As electric charge to mass ratio *q/m* can be expressed by the surface state theory[3], it is shown that electric toner charge *q* is deduced approximately in low density limit $N_t \ll N_c$, in terms of toner radius *r*, as

$$q \approx 4\pi e \Delta\varphi N_t r^2 .$$

Here, e: electric charge, Δφ: energy difference corresponding to tribo-charging tendency between toner and carrier, Nt, Nc: number of charge states on toner or carrier per unit energy and area. Therefore, the tendency in a parabolic dependence of q on toner diameter is expected to be consistent with the theory.

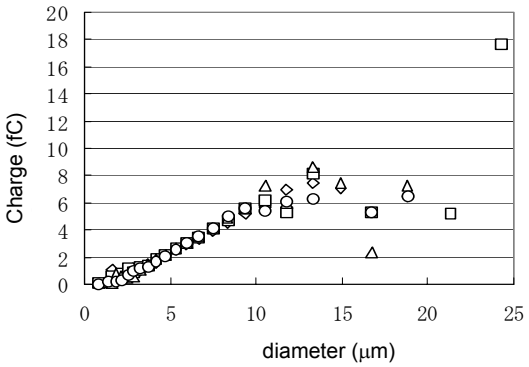


Figure 6. Toner charge dependence on diameter d at 4min for 150rpm.

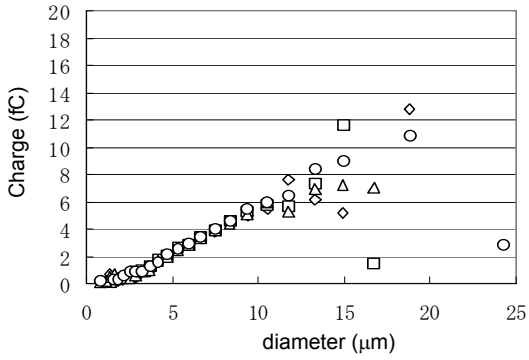


Figure 7. Toner charge dependence on diameter d at 4min for 180rpm.

From a data analysis of distribution of charge quantity *q* on diameter *d*, the tribo-charging state was suggested to be a mixed state of two different types, a higher charged group and a lower one.

Conclusion

In a electrophotographic two-component developer consisted of negative yellow toner based on bisphenol A and polyester resin and coated black carrier, the mixed states were visually examined and the tribo-charging characteristics on toner in terms of *q/m* and *q* were also examined via a shaker by E-SPART method. From the experimental results of the *q/m* dependence on shaking time, it was shown that the absolute value of *q/m* increased up to 20μC/g at 4min and gradually decreased to a saturated value of 16μC/g at 20min. The electric charge *q* increased with toner diameter with a parabolic tendency.

References

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Author Biography

Youichi Nakamura received his B.S. degree in Applied Physics from Waseda University in Tokyo in 1966, and his M.S. and Doctor of Science from Tokyo Metropolitan University in 1968 and 1973, respectively. He joined in R&D Div. of Semiconductor LSI Works of Hitachi Co., Ltd. in 1971. Since 1987 he carried out on electrical and physical evaluation for electrophotographic materials at Nippon Institute of Technology. He is a member of the IS&T, the ISJ and the Japanese Society of Applied Physics. nakamura@nit.ac.jp