Influence of Charge and Particle Size on Adhesion Forces of Toners

Manabu Takeuchi and Kenichi Noguchi
Department of Electrical and Electronic Engineering
Ibaraki University, Hitachi, Japan
Masayasu Anzai and Ryoji Kojima
Katsuta Research Laboratory, Hitachi Koki Co., Ltd., Hitachinaka, Japan

Abstract

Toner adhesion forces to aluminum substrates were measured by centrifugal method. Polystyrene-acrylic irregular and spherical toners of mean particle size of about 10 µm were used for the centrifugal measurements. Effects of charge to mass ratio (q/m) and particle size of the toners on their adhesion forces were studied. The toner q/m was changed by corona-charging. The influence of the colloidal silica added to the toners was also examined. Adhesion forces of the toner to the aluminum substrate were distributed mainly from the orders of 10^{-10} to 10^{-6} N and shifted to the larger direction with an increase in q/m of toners. In our experiment, van der Waals forces may be predominant for the spherical toner without colloidal silica. particularly for small toner particles and for small q/m. Charge elimination process by ac corona-discharge decreased the q/m of the toner, but not its adhesion forces.

Introduction

It is well known that adhesion of toner to carrier and photoreceptor play an important role in electrophotographic performance. A detailed understanding of adhesion behavior of toner is necessary for improving image quality in electrophotography. Several studies have been made on the adhesion of toners to photoreceptors and carriers. and the mechanism of toner adhesion has been discussed.[1-4] We also measured toner adhesion forces onto an OPC (organic photoconductor) drum and ferrite carriers under various experimental conditions by the centrifugal method and discussed factors which affected the toner adhesion.[5,6] However, the adhesion of toner is really complicated and has not been elucidated yet. The adhesion of toner is affected by many factors such as kinds of toners, photoreceptors and carriers, amount of toner charge. environmental conditions, etc. In this study, we have examined effects of size, amount of charge and shape of toners on their adhesion forces onto an aluminum substrate. First, we describe the experimental procedure for measurements of toner adhesion forces by the centrifugal method briefly. Then, experimental results are given. Finally factors which affect the toner adhesion are discussed.

Experimental

Toner adhesion forces were measured by centrifugal method using an ultracentrifuge (Hitachi Koki: SCP85H2). A toned aluminum substrate and a collecting plate was placed, facing each other, in a capsule and was mounted in the rotor of centrifuge. The gap between the toned aluminum substrate and the collecting plate was 2 mm. The centrifugal force was normal to the aluminum substrate. Toner particles take a flight from the aluminum substrate to the collecting plate due to the centrifugal forces. The centrifuge was driven at a rotating frequency for a definite time, and then the surface of the collecting plate was observed by an optical microscope and a TV camera so that the number and the size of toner particles transferred from the aluminum substrate were measured by a personal computer. This step was repeated, increasing the rotating frequency. Detailed experimental procedures of the centrifugal measurements were described in a previous paper.[7] Three kinds of toners were used in this study, the details of which are shown in Table 1.

Table 1. Toners used in this study.

Toner	Resin	d*	Shape	Additive
Toner A	polystyrene-acrylic	11 µm	irregular	colloidal silica
Toner B	polystyrene-acrylic	10 µm	spherical	colloidal silica
Toner C	polystyrene-acrylic	9 µm	spherical	free

* d: mean particle size. The particle sizes are distributed from approximately 4 to 20 µm for all the three toners.

All the three toners are of negative type and made of polystyrene-acrylic resin. The toner A is irregular and the other two are spherical. The toners A and B contain a few amount of colloidal silica to improve their fluidity while the toner C is free of colloidal silica. A ferrite carrier was used to form a dual-component developer. The toner was deposited on an aluminum substrate by developing with the dual-component developer consisting of a sample toner and the carrier. In order to change the charge to mass ratio, q/m, of the toner, corona-charging was made over the deposited toner on the aluminum substrate at various corona-discharge voltages. Through these experiments, influence of q/m, particle size and shape of the toners and colloidal silica on the toner adhesion forces were determined.

Results and Discussions

Adhesion Force Distribution of Toners of Various q/m

Adhesion force and particle size of each toner particle to an aluminum substrate were measured by centrifugal method in this study. First influence of the toner q/m on the adhesion force distribution was examined. Figure 1 shows the distribution of adhesion forces for the toner A, which includes the results of all the toner A particles of various particle sizes. Figure 1 (a) represents the results for the toner A without corona-charging, which means that the toner was tribocharged with the ferrite carrier and was developed on the aluminum substrate. The toner adhesion forces are widely distributed in the range of from 10^{-10} to 10^{-6} N. The average and median adhesion forces are 8.9×10^{-8}N and 8.6×10^{-8} N, respectively. When q/m of the toner increased by corona-charging, the adhesion force distribution of the toner was shifted to larger direction, and also increased the average and median values. For example at q/m of 24 μC/g, the average was 4.0×10^{-7} N and the median was 4.5×10^{-7} N.

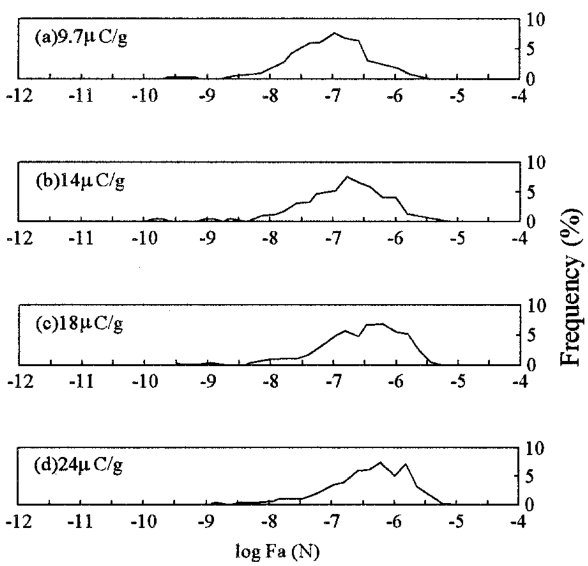

Figure 1. Adhesion force distributions of the toner A (irregular; with colloidal silica) at various q/m values.

Similar results were obtained for the toners B and C as shown in Figures 2 and 3, respectively. Figures 2 (a) and 3 (a) represent the results for the specimens with only tribocharging with the ferrite carrier.

Particle-Size-Dependence of Average Adhesion Forces

As mentioned above, all the three kinds of toners used in this study have particle size distribution in the range of 4 to 20 μm. Although Figures 1 to 3 are presented regardless of particle size, adhesion force and particle size was measured for each toner particle by the experiments. Here, particle-size-dependence of average adhesion forces are discussed for the toners.

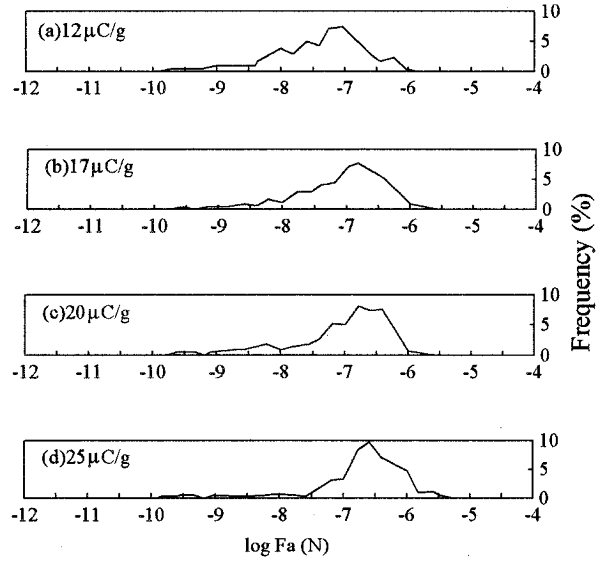

Figure 2. Adhesion force distributions of toner B (spherical, with colloidal silica) at various q/m values.

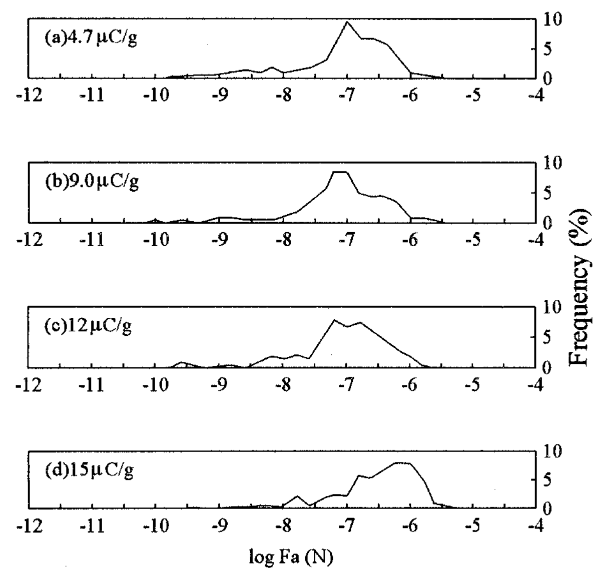

Figure 3. Adhesion force distributions of toner C (spherical, without colloidal silica) at various q/m values.

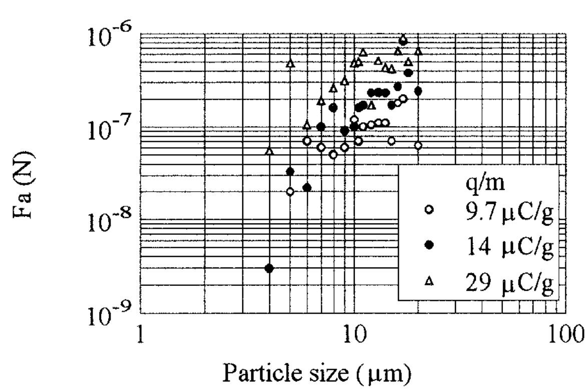

Figure 4. Particle-size-dependence of average adhesion forces of toner A (irregular, with colloidal silica) for three choices of q/m.

Figure 4 shows relationship between average adhesion forces and particle sizes, for three choices of average q/m, for the toner A. The average adhesion force increased with the square of the particle size. Similar results were obtained for the toner B as shown in Figure 5. The toner C is a little different from the other two toners as shown in Figure 6. Although the average adhesion force increased by 2nd power of particle size at larger values of q/m, it was approximately proportional to the particle size at the small value of q /m (4.7 μC/g). Since the toner C is spherical and colloidal silica free, van der Waals force may be predominant in this case, particularly at small q/m.

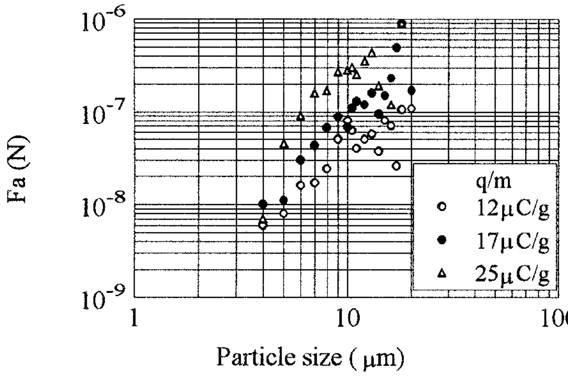

Figure 5. Particle-size-dependence of average adhesion forces of toner B (spherical, with colloidal silica) for three choices of q/m.

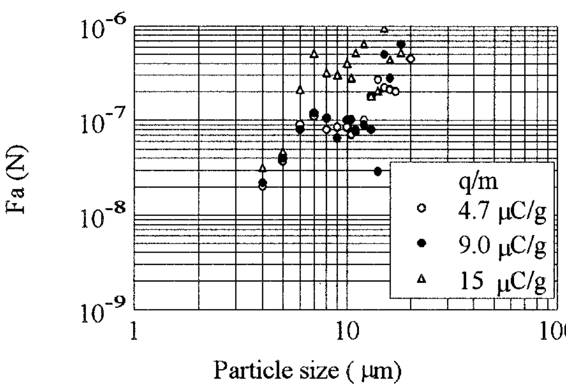

Figure 6. Particle-size-dependence of average adhesion forces of toner C (spherical, without colloidal silica) for three choices of q/m.

q/m Dependence of Average Adhesion Forces

q/m dependence of average adhesion forces for toners A, B and C are shown in Figures 7, 8 and 9, respectively. It should be noted that here we used the average values of q/m. Let us consider that the average adhesion force increases by nth power of q/m, and the values of n are given in the inset of the figures. The values of n are as a whole around 2 for large toner particles. While the values are smaller than that for small toner particles, indicating contribution of forces except for electrostatic one. In addition, q/m dependence of the adhesion forces are weak for the toner C, particularly for the small toner particles.

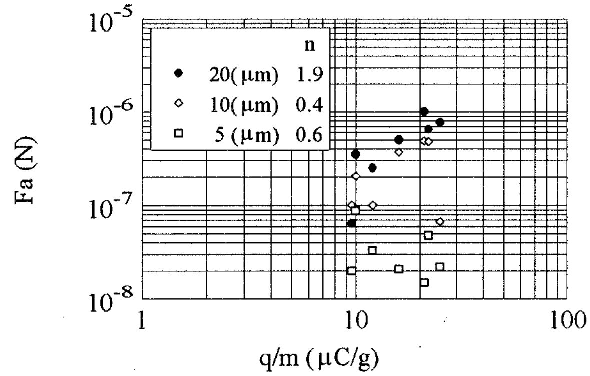

Figure 7. The q/m dependence of average adhesion forces of toner A (irregular, with colloidal silica) for various the particle sizes.

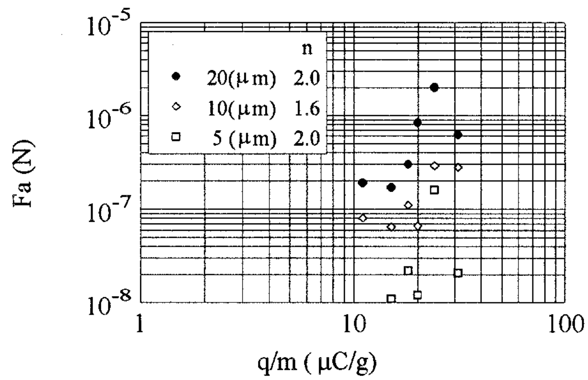

Figure 8. The q/m dependence of average adhesion forces of toner B (spherical, with colloidal silica) for various particle sizes.

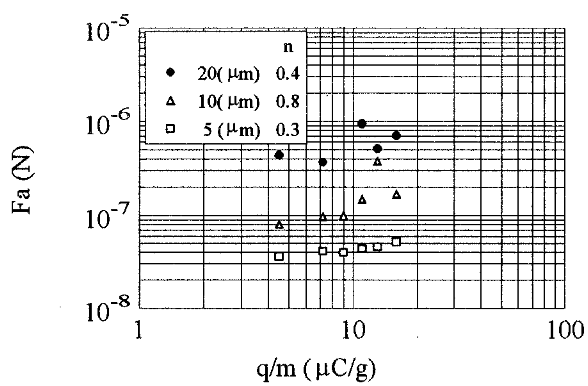

Figure 9. The q/m dependence of average adhesion forces of toner C (spherical, without colloidal silica) for various particle sizes.

Effect of Charge Eliminating

In order to reduce q/m of the toner to close to zero, charge eliminating process was applied to the deposited toner on the aluminum substrate. For that purpose a dc corona-discharge of +7,000 V was applied to the toner A deposited on the aluminum substrate by developing. The value of the toner q/m was 9.7 and 0.3 μC/g before and after charge eliminating, respectively. The adhesion force distributions before and after the charge elimination are shown in Figure 10. In spite of decrease in q/m close to zero, the adhesion force distribution shifted to larger direction for the charge eliminated specimen. Positive and negative charges are contoner particles, and both charges may contribute to the adhesion forces of the toner.

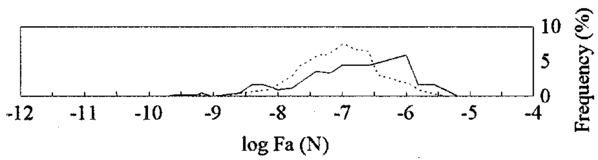

Figure 10. Adhesion force distributions for the as developed toner (solid curve, q/m = 9.7 µC/g) and charge eliminated toner (dashed cure, q/m = 0.3 µC/g).

Conclusions

Toner adhesion forces to an aluminum substrate were determined by centrifuge study, and influence of q/m. Particle size and shapes of the toners on their adhesion forces were discussed. The following conclusions were obtained.

- Adhesion forces of the toner to the aluminum substrate was distributed mainly from the orders of 10^{-10} to 10^{-6} N.
- The distributions of the toner adhesion forces shifted to the larger direction with an increase in q/m of toners.
- van der Waals forces may be predominant for the spherical toner without colloidal silica, particularly for small toner particles and for small q/m.
- Charge elimination process by dc corona-discharge decreased the q/m of the toner, but not its adhesion forces.

References

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