Toner Jumping Characteristics in Electric Field Using Dented Electrode

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Abstract

Toner is important element in electrophotography. Toner motion is controlled by the electric force, adhesive force, mechanical force and so on. Adhesive force is estimated by electric field forced toner jumping. Conductive toner is sprayed on the one of electrodes which are spaced parallel. Voltage of increasing constant rate is applied to electrode and toner jumping starts at certain voltage that electric force (charge induced to toner x electric field) overcomes adhesive force and gravitation force. Jumping toners are confined in dented area of electrode. The shape of dent is like thin lens. From the toner jump beginning and stopping voltages, adhesive force is estimated.

Introduction

Electrophotographic technology is applied to copy machine and printer. Electrophotographic printing process has six processes, which are charging, exposure, developing, transfer, fixing and cleaning. In these processes, the processes of developing, transfer and cleaning are mainly based on movement of toner. The movement is controlled by applied forces to toner as electric force, adhesive force, gravitational force, acceleration force and so on. Magnetic force is also worked in the case of magnetic toner.

Adhesive force has an important effect on printing characteristics, as much as the electric force.[1-4] Adhesive force is depended on the substrates. In electrophotography, there are adhesive forces between toner and photoconductor, carrier, paper and toner. Several researches about the force were carried out, but more studies is expected to understand and improve these printing processes.[5]

A method of estimating toner adhesive force to substrate was proposed.[6] The method is improved by using dented electrode.

Measuring Mechanism

The schematics of toner motion between electrodes is shown in Figure 1. Toner sample for measure is distributed freely on the under electrode. Two electrodes are arranged parallel. Voltage applied to electrode increases linearly with time. The current flows through this circuit is measured by electrometer and is recorded. The current I is shown as:

$$I = I_{capacitance} + I_{toner\ jumping}, \quad (1)$$

$$I_{capacitance} = C(dV/dt), = C\beta, \quad (2)$$

where I capacitance is current component by capacitance charging, Itoner jumping is current component by toner jumping, C is capacitance between electrodes, V (=β t) is the voltage applied to electrode, t is time and β is the increasing rate of applied voltage.

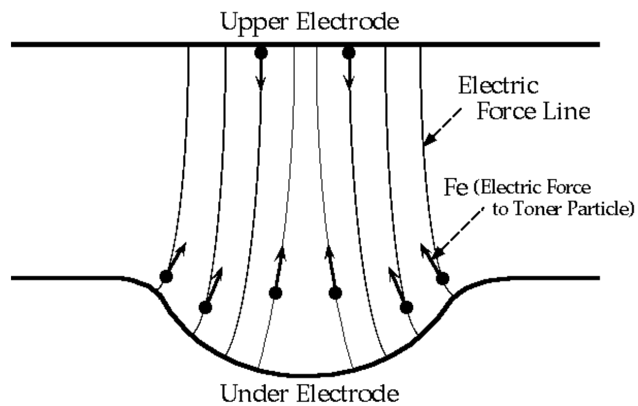

Figure 1. Schematics of toner motion between electrodes.

It is shown from Equation 1 and 2 that the current measured I consist of Itoner jumping + constant term. Toner jumping arises when electric force induced by applied voltage overcomes adhesive force and gravitational force. After start of toner jumping, toner moves up and down between electrodes and Itoner jumping rises from zero because toner carries electric charge.

Figure 2 shows the method of obtaining the voltage, at which toner begins to jump. The forces worked on the toner on electrode are electric force, adhesive force and gravitation force. Toner starts to jump, when electric force overcomes adhesive force and gravitation force. Electric force is estimated as Equation 3, when toner is conductive,

$$Fe = QE, = (\varepsilon ES)E, = \varepsilon SE^2 \quad (3)$$

where Q is charge amount of toner induced by electric field, E is electric field applied between electrodes, ε is dielectric constant of air and S is effective area of toner, which means electric flux reach toner. Figure 3 shows the relation between toner shape and the area S.

When toner has conductivity, toner is charged up with certain relaxation time, which is controlled by capacitance of toner and conductivity of substrate to toner. It is a good assumption that toner is charged up with applied voltage, when relaxation time is negligibly small compared with the time scale of the measurements in the resistivity range of ~10^6 ohm • cm.

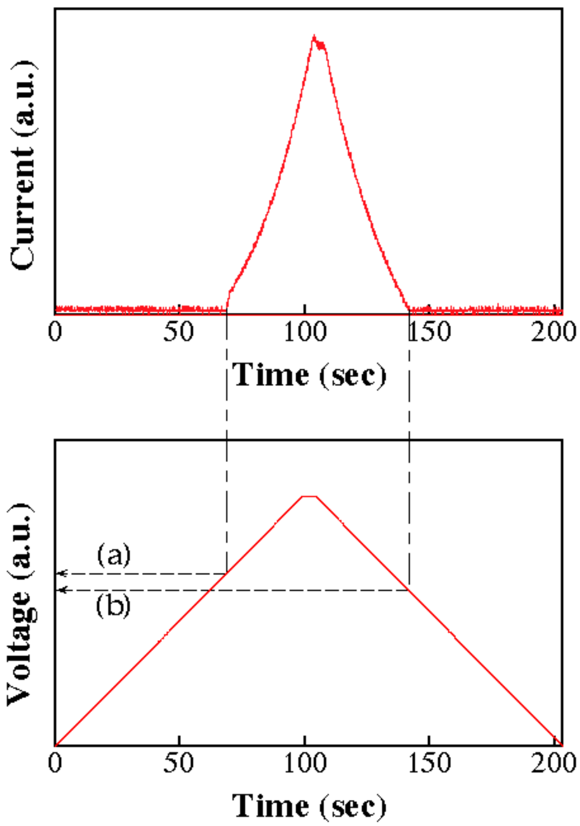

Figure 2. Current versus Voltage, when voltage wave form is trapezoid. The marks (a) and (b) mean the voltage of jump beginning and stopping, respectively.

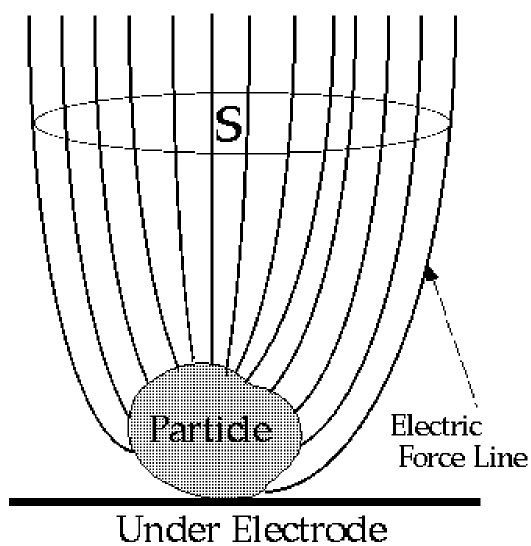

Figure 3. Relation between toner shape and the area S.

Experiments

The toners used in this experiments are made from same raw materials and then classified. The electrodes used in the experiments are brass and ITO (Indium Tin Oxide) spattered glass. The space of electrodes is arranged 0.5 - 0.7mm. Ramp voltage is generated by voltage source (Hewlett Packard: model HP 4140B) and is amplified by DC amplifier (maximum voltage 1000V). The increasing rate of voltage are 2.5V/sec., 5V/sec. and 10V/sec. The current is detected by electrometer and is recorded.

Results and Discussion

Figure 4 shows the typical current wave form versus ramp voltage applied to electrode. Current (a) and (b) correspond to the dented electrode and flat electrode, respectively. The amplitude of current has a linear relation to number of jumping toners in Fig. 4. It is understood that dented electrode is effective to confine jumping toners. the confinement is confirmed by observing the toner motion through the upper electrode that is transparent ITO glass. The reason is thought that the electric force to toner is toward to central axis.

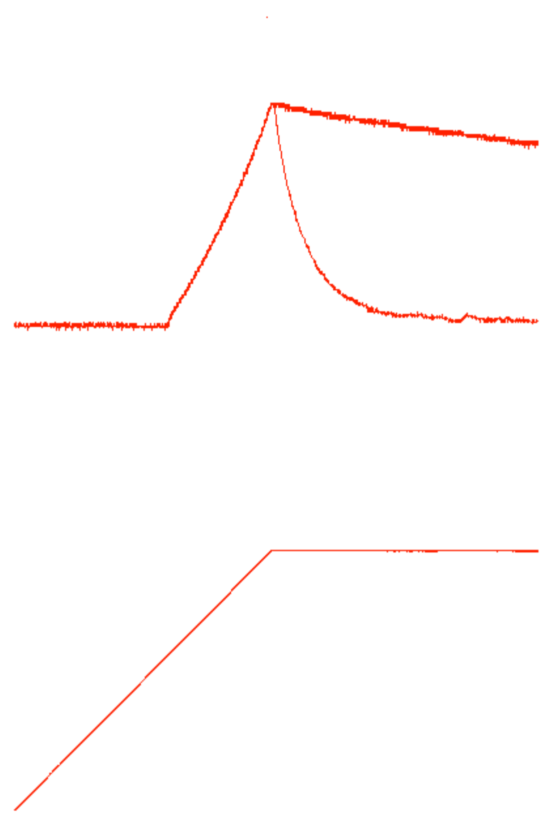

Figure 4. Current wave form versus voltage. The marks (a) and (b) mean when dented electrode is used and when flat electrode is used, respectively.

Figure 2 shows the typical current wave form versus applied voltage, which wave form is trapezoid. Current begins to increase at certain voltage and drops at certain voltage. From these experiments, toner jump beginning and stopping voltage are obtained. It is found that there are slight difference between these voltages. The reason are considered that the difference is due to the difference between static adhesive force and dynamic adhesion force, which force include collisional repulsion.

Figure 5 and 6 show the diameter dependencies of the voltages of toner jump beginning and stopping. Both voltages are same dependencies of the voltage versus toner diameter. This dependency was obtained in other series of toner.[7] Table 1 summarizes the data of average voltage of toner jump beginning and stopping. In these three types of toner, jump beginning voltage larger than stopping voltage. It is found that the difference increases as the diameter increases. So, it is thought that part of the difference arises from collisional repulsion.

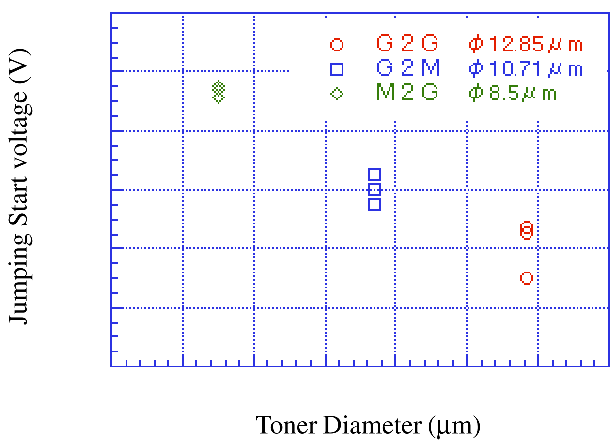

Figure 5. Toner jumping start voltage dependency of toner diameter.

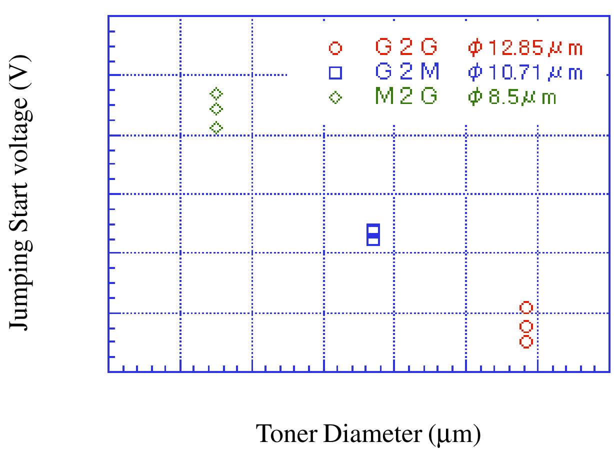

Figure 6. Toner jumping stop voltage dependency of toner diameter.

Summary

Jumping conductive toners are confined between electrodes, one of which is dented as thin lens shape. So, toner jumping characteristics of jumping begin and stop are measured for increasing ramp voltage and decreasing ramp voltage. Adhesive forces correspond to static state and dynamic state are estimated.

The confining technique is thought to be useful in the applications.

Table 1. Diameter dependency of Voltage

Diameter / Voltage	8.5 (μm)	10.71 (μm)	12.85 (μm)
Jumping Start Voltage (V)	253	220	201
Jumping Stop Voltage (V)	247	207	176

Acknowledgements

The authors would like to express sincere thanks to Drs. M. Omodani, N. Tetsutani and Y. Ando for valuable discussions and their help.

References

1. C. J. Mastrangelo, "The Effects of Charge, Size, and Shape on Toner Photoconductor Adhesion in Electrophotographic Systems", *Photographic Sci. and Eng*. **26**-4 (1982) pp194-197.
2. M. H. Lee and J. Ayala, "Adhesion of Toner to Photoconductor", *J. Imaging Tech*. **11**-8(1985) pp 279-284.
3. S. Banerjee and M. K. Mazumder, "Adhesion of Charged Powders on Metal Surface in Powder Coating Process", private communication.
4. H. Krupp and G. Sperling, "Theory of adhesion of Small Particles", *J. Appl. Phys*. **37**-11(1966) pp 4176-4180.
5. K. Terao and K. Shigehiro,"Non-Electrostatic Adhesive Force between Photoreceptor and Toner Particles", *Electrophotography* **34-2**(1995) pp 83-88 (in Japanese).
6. Y. Hoshino, N. Kutsuwada, Y. Watanabe and H. Izawa, "Estimation of Toner Adhesive Force by Toner Jumping in Increasing Electric Field", *IS&T's Tenth Internatinal Congress on Advances in Non-Impact Printing Technologies*, (1994) pp. 167-170; (see page 5, this publication).
7. Y. Hoshino, S. Kiatkamjornwong, S. Noppakundilograt, and Y. Ando, "Adhesive Force Estimation from Toner Jumping by Electric Field: Difference in Adhesion Methods", *Extended Abstracts of the 55th Autumn Meeting of The Japan Society of Applied Physics* (1994) (in Japanese).