An observation of toner scatterings behavior in the transfer process

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Abstract

A toner motion between parallel plates in a transfer process is observed with a model experimental setup. The number of toner scatterings is counted by the image analysis software and it increases with the decreasing of the transfer gap. In order to analyze the toner scattering phenomena, a three-dimensional toner motion is calculated with an electrostatic simulation and Distinct Element Method. The experimental and simulated results referring to the relationship between the number of toner scatterings and the transfer gap are in good agreement. The observations of toner scattering process are carried out for various combinations of parameters in the transfer process, and the quantitative relationship between the number of toner scatterings and the parameters is obtained.

Introduction

Control of image degradations in a transfer process such as toner scatterings and hollow character is important to obtain a fine printed image by the electrophotographic process. In order to control the image degradation, it is necessary to understand the formation mechanism of the image degradation.

In recent years, there have been done various investigations of electrophotographic process applying to visualization techniques.[1-5] The visualization technique of a toner motion is useful for the investigation of the image degradation and the verification of the simulation of a toner motion.

The toner scattering behavior between parallel plates calculated by the 3D simulation was demonstrated in NIP21.[6] In this study, a toner motion between parallel plates is observed with the model experimental setup, and the experimental and simulated results of the toner scattering behavior is compared.

The toner scattering behavior is dependent on various parameters of the transfer process. It is important to clear the effect of the parameters on the toner scatterings quantitatively. In this study, the quantitative relationships between the number of toner scatterings and various parameters of transfer process are reported.

Experiment

The model experimental setup is illustrated in Figure 1. The apparatus consist of the development sub-unit, the transfer sub-unit and the microscope. A glass plate with line-patterned electrodes is used as a virtual photoconductor. The electrodes on the glass plate are made of ITO (Indium Tin Oxide) and overcoated with polycarbonate. The width and the period of line image area are 0.1mm and 1mm, respectively. A piece of an intermediate transfer belt on a metal electrode is used as a transfer media. At first, the constant voltages VL and VD are applied to the electrodes of the image and non-image area, respectively. Toner particles are deposited on the image area by the development sub-unit. Then, the constant voltage VT is applied to the transfer media moving to the glass plate with the constant velocity (4μm/s). Toner particles on the glass plate move down to the transfer media. During this transfer process, a toner motion is observed through the glass plate by the microscope.

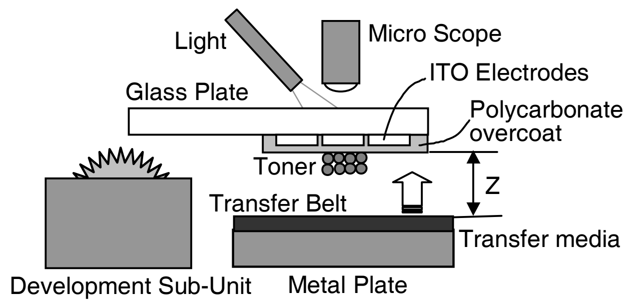

Fig.1 Schematic diagram of the experimental set.

Figure 2 shows the line image on the glass plate before transfer. Toner particles around the line are adhered on the glass plate in the development process. Figure 3 shows the toner scattering behavior observed by the model experiment. In fig. 3, the adhesion of toner particles on both the glass plate and the transfer media are shown. The number of toner scatterings is counted by the image analysis software (Image-Pro Plus) for each frame. The number of toner scatterings N is defined as

$$N = (N1 - N0) / L, \tag{1}$$

where N1 and N0 are the number of toner particles separated from the line in each frame of fig.3 and fig. 2, respectively. L is the line length. Transfer gap Z of each frame are calculated from the recording time and the velocity of the transfer media.

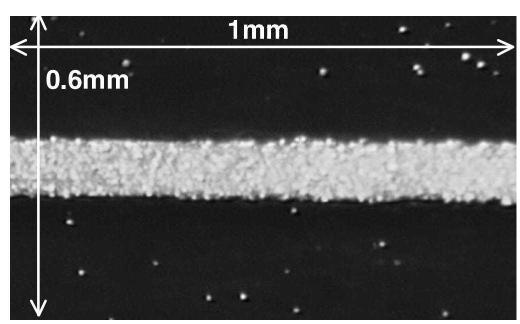

Fig.2 Line Image on the glass plate before transfer.

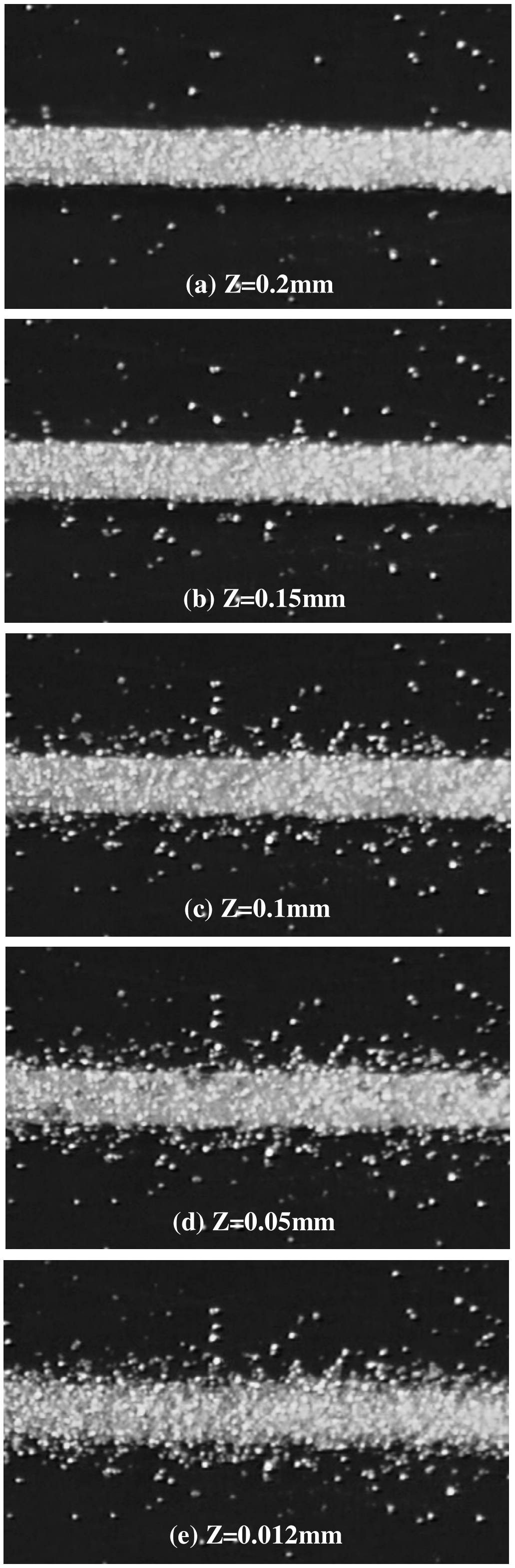

Fig.3 Toner scattering behavior.

Simulation

The simulation of the three-dimensional toner motion is carried out with the same condition as the model experiment. This simulation consists of the three calculations, i.e. the electrostatic field, the discharge and toner movement. These calculations are carried out with changing the transfer gap. The effect of discharge is considered when the electric potential difference across the air gap exceeds the Paschen's limit. A toner particle begins to move when the electrostatic force overcomes the toner adhesion, and the motion of the toner particle is calculated as a Newtonian motion. Collisions among toner particles are not considered here. More details are described in ref. 6.

Results and Discussion

Relationship between the number of toner scatterings and the transfer gap

As shown in fig. 3, the number of toner scatterings N increases and toner particles adhere nearly the line edge with decreasing the transfer gap Z. The relationship between N and Z measured for fig. 3 is shown in fig. 4. The set of experimental condition is shown in Table 1. As shown in fig. 4, N increases and saturates with decreasing Z. Z_{th} and N_{max} are defined as the transfer gap where toner scattering begins and the maximum number of toner scatterings, respectively. In most cases, some scattering toner particles contact with the disordered line edge, then N is smaller than N_{max} in small Z. The dash-dotted line shows the maximum air gap where discharge happens between the non-image area on the glass plate and the transfer media. The maximum air gap is calculated from the Paschen's limit. This result tells toner scatterings happen before discharge happens as predicted in ref. 6.

Table 1. Experimental condition

Electric potential of image area VL	-100V
Electric potential of non-image area VD	-280V
Amount of toner after development M/A	0.6mg/cm^2
Charge-to-mass ratio of toner Q/M	-27μC/g
Electric potential of Transfer VT	400V

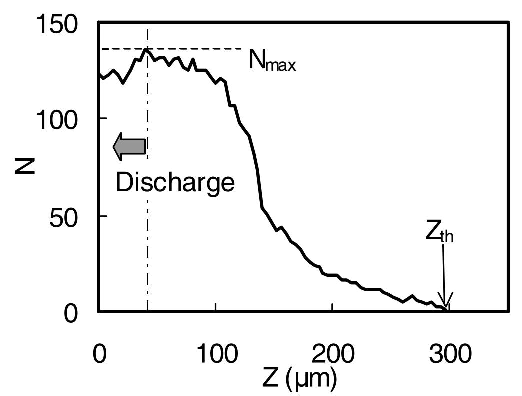

Fig.4 Relationship between the number of toner scatterings and the transfer gap.

Experimental and simulated results of the relationship between N and Z for various VT are shown in fig. 5. The experimental conditions except for VT are shown in Table 1. As shown in fig. 5, the experimental and simulated results are in good agreement. The simulated toner scattering behavior is verified by the observation.

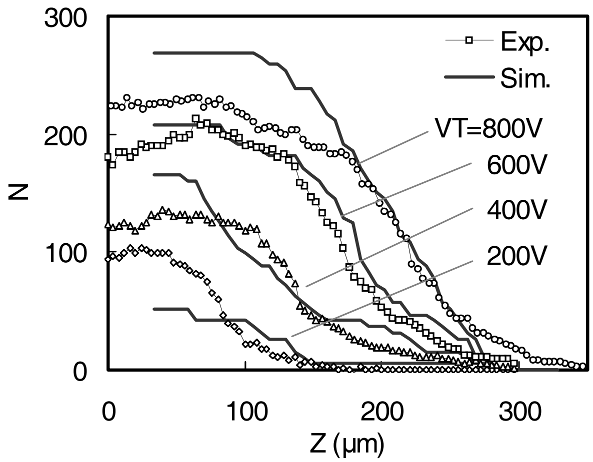

Fig.5 Experimental and simulation results of relationship between the number of toner scatterings and the transfer gap.

Relationship between the number of toner scatterings and parameters of transfer process

The observations of toner scattering behavior are carried out for various combinations of parameters in the transfer process. N_{max} and Z_{th} are measured for each combination.

First, the experiments are carried out for various combinations of VT and VD. Any other parameters are fixed as shown in Table 1. The relationship between N_{max} and the electrical potential deference (VT-VL) are shown in fig. 6. N_{max} increases almost linearly with increasing (VT-VL), and decreases against the electrical potential deference (VL-VD) increases. N_{max} is plotted against (VT-VL)-(VL-VD) in fig. 7. As shown in fig. 7, N_{max} increase almost linearly with increasing (VT-VL)-(VL-VD).

Next, the experiments are carried out for various combinations of VT and VD with M/A=0.3 and 0.9 mg/cm^2. VL and Q/M are shown in Table 1. In these experiments, VD is fixed for each M/A at the development and changed before the transfer media moves up to the glass plate. As shown in fig. 8, N_{max} increases almost linearly with increasing (VT-VL)-(VL-VD), and increase as M/A increases.

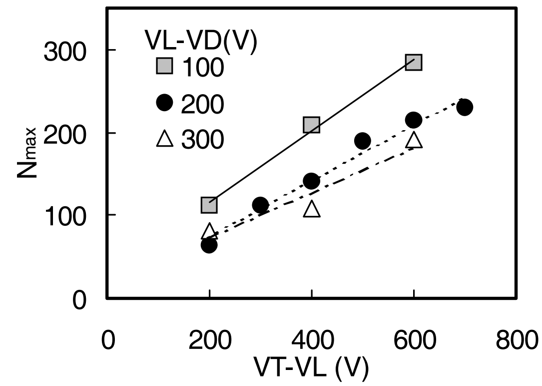

Fig.6 Relationship between maximum number of toner scatterings and (VT-VL).

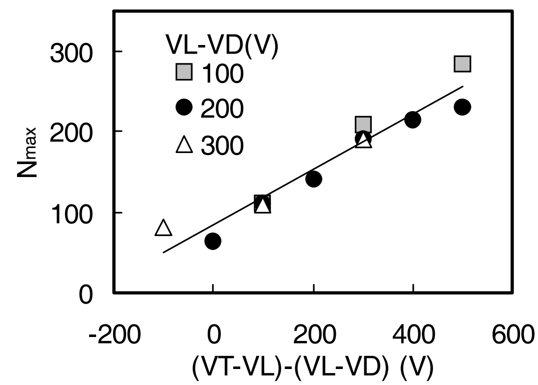

Fig.7 Relationship between maximum number of toner scatterings and (VT-VL)-(VL-VD).

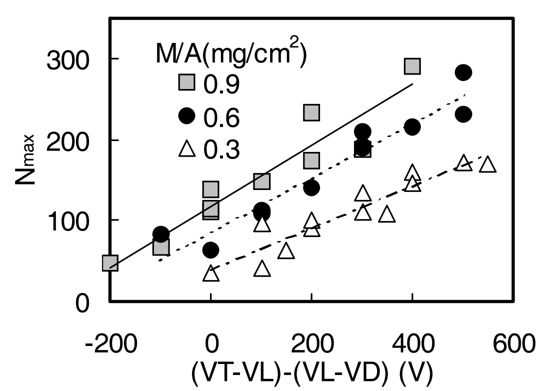

Fig.8 Relationship between maximum number of toner scatterings and (VT-VL)-(VL-VD).

The surface potential of toner layer V_{toner} is given by

$$V_{toner} = \frac{\rho d_t}{\varepsilon_0}\left(\frac{d_p}{\varepsilon_p} + \frac{d_t}{\varepsilon_t}\right) + VL, \quad (2)$$

where ε_o is the vacuum permittivity, ρ is the charge density of the toner layer, d_t and ε_t are the thickness and the relative dielectric constant of the toner layer, d_p and ε_p are the thickness and the relative dielectric constant of the polycarbonate film, respectively. N_{max} is plotted against (VT-V_{toner})-(V_{toner}-VD) in fig. 9. N_{max} increase almost linearly with increasing (VT-V_{toner})-(V_{toner}-VD). This result indicates that relationship between the number of the toner scatterings and the parameters VT, VD and M/A can be expressed by the single electrical potential (VT-V_{toner})-(V_{toner}-VD).

Relationship between N_{max} and Z_{th} is shown in fig. 10. N_{max} increase with increasing Z_{th}.

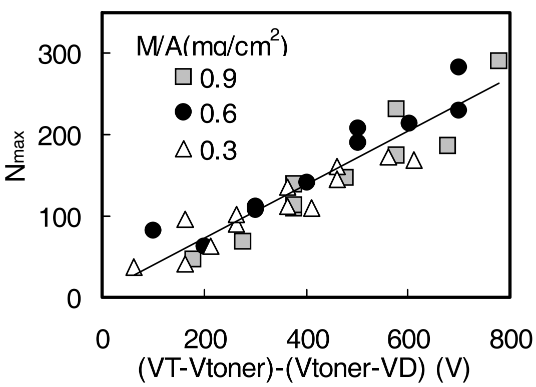

Fig.9 Relationship between maximum number of toner scatterings and (VT-Vtoner)-(Vtoner-VD).

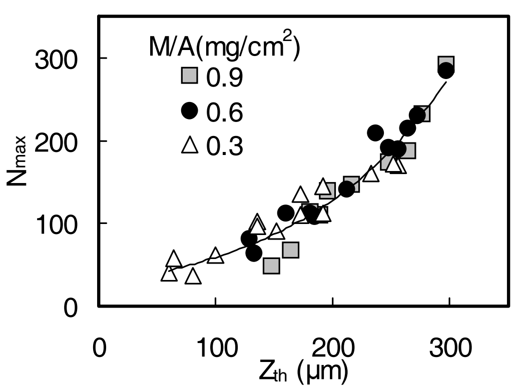

Fig.10 Relationship between maximum number of toner scatterings and maximum transfer gap of toner scatterings happen.

These results are discussed with the simple model. $n_d(Z)$ and $n(Z)$ are defined as the number of toner particles detached from the toner layer and deposited on the non-image area at the transfer gap Z, respectively. N_{max} is calculated as follows:

$$N_{max} = \int_{d_t}^{z_{th}} n_d(z) p(z) dz, \; p(Z) = n(Z) / n_d(Z). \quad (3)$$

Because $n_d(Z)p(Z)$ is integrated from d_t to Z_{th}, N_{max} increase with increasing Z_{th} as shown in fig. 10. p(Z) is the probability of toner scattering. As shown in fig.11, the space the detached toner particles can move reduces with decreasing Z. p(Z) decrease with reducing the toner movement space. Therefore p(Z) decreases with decreasing Z. As the electric potential (VT-V_{toner}) decreases, the electric field that detaches the toner particles from the toner layer decreases, and the transfer gap where toner particles begin to move decreases. Because p(Z) decreases with decreasing Z, $n_d(Z)p(Z)$ decreases with decreasing (VT-V_{toner}). As the electric potential (V_{toner}-VD) increases, the electric field moves the detached toner particles to the image area increase, and the toner movement space reduces. Therefore p(Z) decreases with increasing (V_{toner}-VD).

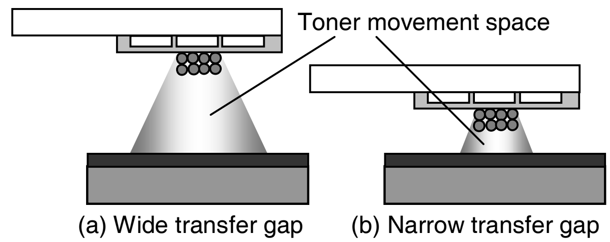

Fig.11 Toner movement space between parallel plates in a transfer process.

Conclusion

Toner scattering behavior between parallel plates is observed with a model experimental setup, and the number of toner scatterings is investigated with the image analysis software. The toner scattering behavior calculated by the three-dimensional simulation is verified with this method. The quantitative relationship between the number of toner scatterings and the electric potential in the transfer process is obtained.

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Author Biography

Haruo Iimura received his BS and MS in physics from Tsukuba University and joined Ricoh in 1985. He has been working in the field of liquid crystal display, and recently he has been working on the field of electrophotography. He is a member of the physical society of Japan and the imaging society of Japan.