Charging Behavior of Toner Layer in Contact-type Non-magnetic Single Component Developing Process

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Abstract

Properties of a toner layer, especially toner charge of the toner layer formed onto a developing roller in developing unit influences significantly the developing performance in an electrophotographic developing process. In contact-type non-magnetic single component developing process, the properties of the toner layer change in the developing step due to contact the toner layer with surface of a photoreceptor under the developing electrical field.

The toner layer formed onto the developing roller was transferred to a metal plate connected to a bias voltage supply by contact developing method. Controlling the bias voltage applied to the metal plate changed developing electrical field formed on between the developing roller and the metal plate. Charging behavior of the toner layer in this process were studied by measuring the properties of the toner layer before and after the developing step.

Amount of toner charge of the toner layer formed onto the developing roller was divided equally by in this developing step. It was clarified that the amount of toner charge changed by charge injection, which depend on the developing electrical field in the contact developing step. In the toner layer consisting of the lower electrical resistivity toner, amount of the toner charge decreased even when the developing electrical field was zero.

1. Introduction

Non-magnetic single component developing process have widely been used in practical monochrome electrophotographic printer, which have also recently been used as developing method in compact electrophotographic color printer. In this developing process, there are two types of developing methods. One is non-contact jumping developing method; other is impression developing method. The former has a issue that it is difficult to develop faithfully latent images formed on a photoreceptor due to small gap between the toner layer on the developing roller and surfaces of the photoreceptor. AC bias superimposed on DC bias is sometimes applied to the developing roller as the developing bias voltage in order to solve this critical issue. On the other hand, the later is able to develop faithfully the latent image because the toner layer on the developing roller contact with the surface of the photoreceptor. This method, however, has a fear of generating image noise such as fog or blur.[1–6] In addition, the properties of the toner layer, especially the toner charge, are changed by the reason of contact performance in the developing electrical field. As the result of this, the toner charges of the toner image formed onto the photoreceptor after the developing step are not uniformed.[7] It can be considered that the uniformed toner charge distribution within the toner image will cause deterioration of the image qualities on a transfer process and fusing process. By the reason mentioned above, measurements of the charging behavior of the toner layer in this contact-type developing process are required.

In this study, relationship between the developing electrical field and the toner charge in the contact-type non-magnetic single component developing process was investigated. First, development characteristics of a developing unit used in this experiment were measured by developing the toner to the metal plate with various bias voltages. Next, toner charge of the toner layer after the developing step were compared with that before the step at various developing electrical fields, reasons of the change of the toner charge at the contact developing step were discussed. Finally, an influence of toner electrical resistivity was also studied experimentally.

2. Experimental

2.1. Developing Unit

The scheme of the developing unit used in this study is shown in figure 1. The developing roller is made of a metal cylinder, the regulating blade and the toner supply roller are made of silicone rubber and rayon fibers, respectively. All of them are connected with each bias voltage supply expressed as VD, VB and VF. Same bias voltage (-600V) ware applied to each these parts in this experiment.

The developing roller and the toner supply roller ware rotated at a velocity of 90mm/s in the directions indicated in Figure 1. The regulating blade was abutted on the developing roller at its abdominal portion including its edge with pressures around 104Kg/m2.

Two types toner were used as the sample toners whose electrical resistivities were 6.2 x 1010 Ω-cm and 2.6 x 1010 Ω-cm. Here, the former and the later are expressed as normal toner and lower electrical resistivity toner, respectively. These toners are negative charge type toners with average diameter of 8 µm made of polyester polymer.

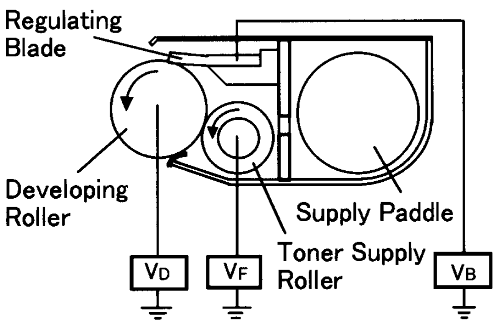

Figure 1. Scheme of the developing unit.

2.2. Measurements

The developing characteristics were measured by developing a metal plate connected to a bias voltage supply in contact development method. A stainless steel plate, whose thickness is 20µm, was used as the metal plate. The plate was supported onto polyurethane foam and pressed against the developing roller at the pressure of 35g/cm. The bias voltage applied to the metal plate, expressed as VP, was from –400V to –800V. The developing characteristics were evaluated by the toner mass transferred to the metal plate following or against the difference between VD and VP. For convenience, VPD are used as the expression of potential difference between VD and VP, i.e., VPD =VP-VD.

The properties of toner layer in contact-type non-magnetic single component developing process were evaluated by measuring the toner mass, M/A and the average toner charge, Q/M. The toner layer properties before and after developing step were evaluated. M/A and Q/M of the toner layer were measured by tape stripping method and suction type Faraday-cage, respectively. Surface potential of the toner layer, Vt was also measured by non-contact type surface potential meter.

All the measurement were made under 18•21• and 30•50%RH.

3. Results and Discussion

3.1. Development Characteristics

Figure 2 shows the development characteristics in this developing unit. The development characteristics calculated by the following equation are also given in this Figure.8)

$$m_C = (m_0/2) \times (1 - V_{PD}/V_t) \qquad (1)$$

where m_c and m_0 are developed toner mass per unit area and toner mass per unit area of the toner layer formed on the developing roller. By this equation, the developing characteristics can be calculated under the condition of the uniform charge distribution within the toner layer formed onto the developing roller. This equation shows also that a half of the toner layer formed onto the developing roller is transferred to the metal plate at VPD=0V.

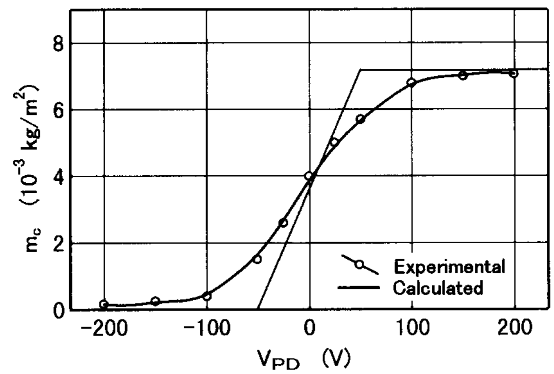

Figure 2. Developing characteristics of the developing unit.

The experimental characteristic indicated a curve similar to the characteristic calculated by equation (1). At VPD=0V, however, the toner mass transferred to the metal plate was more than a half of m0. This result was indicated that the charge distribution within the toner layer was not uniform.

3.2. Toner Layer Properties

Charging behavior was studied by measuring the properties of the toner layer before and after the developing step. First, the toner layer properties at VPD=0V were measured. Next, charge characteristics under the condition that VPD was not 0V were measured. Finally, influence of toner electrical resistivity in the developing method was studied by using the lower resistivity toner.

3.2.1. At V_{PD} = 0V

Table 1 shows the toner layer properties before and after the developing step under the condition of VPD = 0V. In regarding of to the properties after the developing step, the properties both on the metal and on the developing roller are shown at this table.

Table 1. Toner layer properties before and after the developing step. The development was carried out at V_{PD}=0V.

	Before the developing step	After the developing step	
		On the metal plate	On the developing roller
Q/M (-µC/g)	19.1	17.1	21.0
M/A (10^{-3} kg/m^2)	7.20	4.03	3.17
Q/A (-µC /m^2)	137	68.9	66.6

M/A transferred onto the metal plate was larger than a half of the toner mass before the developing step as mentioned above. However, the charge level of the toner transferred onto the metal plate was lower than that of the toner remained on the developing roller. This result indicates that the toner near the bottom side of the toner layer formed on the developing roller have higher charge level compared with the toner near the surface side. On the other hand, in regarding of the toner layer charge, Q/A, the toner layers on the metal plate and on the developing roller was almost equal. Sum of these was also equal to that of the toner layer before the developing step.

These results show that Q/A was not changed between before and after the developing step and that Q/A of the toner layer formed on the developing roller was divided equally by the developing step. Equation (1) indicates that if Q/M are uniform, then the toner mass of the toner layer formed on the developing roller was divided into two equal parts by the developing step. This insists also that Q/A is divided equally by this developing step. The experimental results indicate that bisection of Q/A is realized though Q/M within the toner layer are not uniform and M/A are not divided into halves.

3.2.2. At $V_{PD} \neq 0V$

The toner charge level at various VPD conditions are shown in Figure 3. The toner charge both on the metal plate at VPD < 0V and on the developing roller at VPD > 0V were not able to measured because the toner mass were a small quantity.

The toner charge on the developing roller increased with a decrease in VPD. At VPD = –200V, that is, when the toner mass were almost remained on the developing roller, the toner charge increased 1.7μC/g compared with the toner charge on the developing roller at VPD = 0V. This value was also 3.6μC/g higher level than the toner charge before the developing step. On the other hand, the toner charge on the metal plate increased with an increase in VPD. However, even then at VPD = 200V, the value was lower than the toner charge level before the developing step.

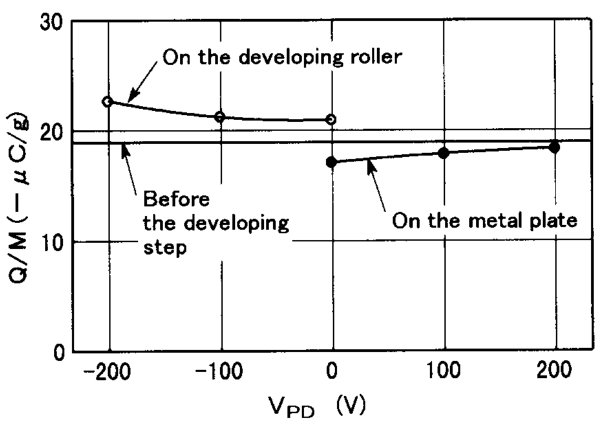

Figure 3. The toner charge per unit mass before and after the contact developing step.

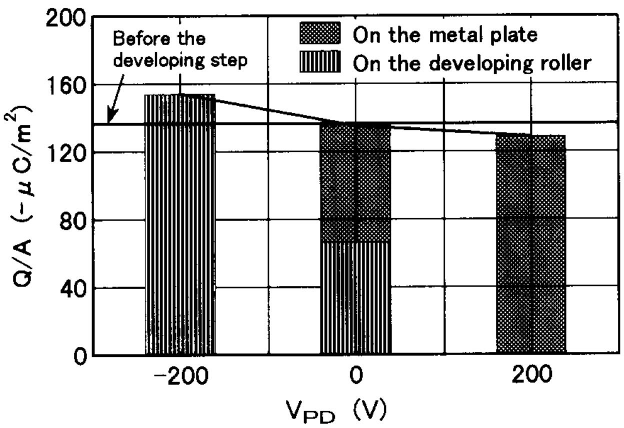

Figure 4. The toner layer charge after the contact developing step.

Figure 4 shows the toner layer charge Q/A after the contact developing step. Q/A at VPD = –200V was calculated on the assumption that the all toner mass was remained on the developing roller after the developing step. Q/A at VPD=200V was calculated on the assumption that the all toner mass was transferred to the metal plate after the developing step. This figure indicates that total Q/A is changed between before and after the developing step at VPD ≠0V in the contact developing process.

In order to clarify the reason of the change of Q/A associated with the change in VPD, current flowing into the developing unit and the metal plate during the contact developing step were measured. The measurement result as difference to the value at VPD=0V is shown in Figure 5. Sum of the current flow into the developing roller, the toner supply roller and the regulating blade is represented by It, the current flow into the metal plate is Ip.

Total current flow, (I_t + *Ip*) increased with an increase in V_{PD}. This indicates that, for example, positive current flow in the toner layer composed of negative charge type toners at VPD = 200V. In this result, it is studied that Q/A at VPD = 200V decrease compared with Q/A at VPD = 0V.

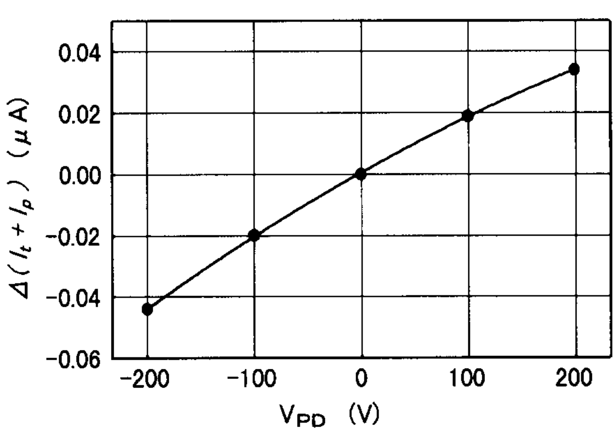

Figure 5. Total current flowing into the developing unit and the metal plate as a function of VPD.

From above discussion, it was conformed that the amount of the toner charge changed largely due to charge injection in the developing step at $V_{PD} \neq 0V$.

3.2.3. Toner Electrical Resistivity

Influence of toner electrical resistivity on the toner charge behavior in the contact developing process was studied by using the lower electrical resistivity toner. Figure 6 shows the toner charge of the lower resistivity toner before and after the contact developing step as a function of VPD.

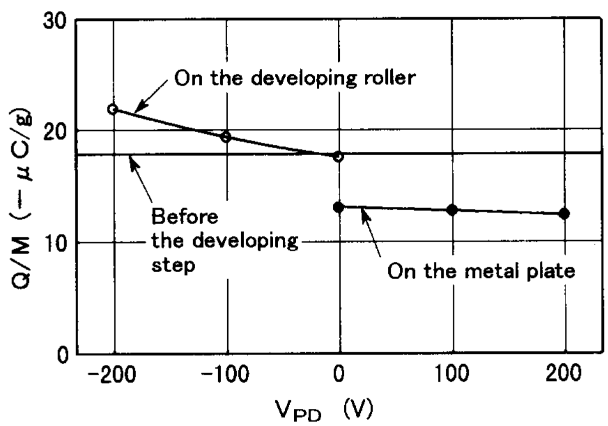

Figure 6. The toner charge of the lower resistivity toner before and after the contact developing step.

The toner charge on the developing roller at VPD=0V was an amount about equal to the toner charge before the developing step. The toner charge on the developing roller increased with a decrease in VPD. The toner charge at VPD = –200V was 4.3μC/g higher than before the developing step. On the other hand, the toner charge on the metal plate decreased with an increase in VPD. These tendencies were different from the charging behavior of the toner layer consisting of the normal toner.

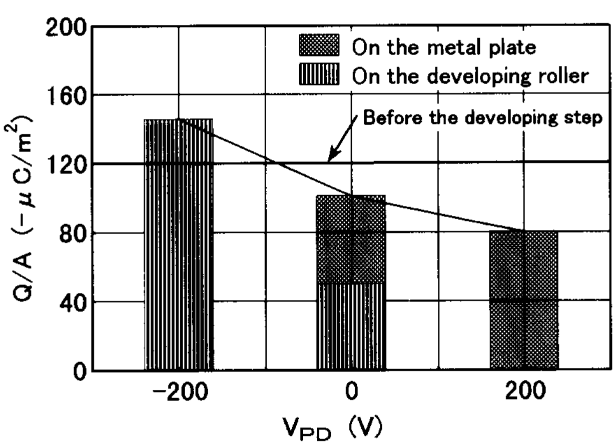

Figure 7. The toner layer charge consisting of the lower resistivity toner after the contact developing step.

Figure 7 shows Q/A of the toner layer consisting of the lower resistivity toner after the contact developing step.

At VPD=0V, Q/A on the developing roller was equal to that on the metal plate. Sum of these, however, was lower than Q/A of the toner layer before the developing step. It was conformed that the amount of the toner charge of the toner layer consisting of the lower resistivity toner did not keep after the contact developing step even at VPD=0V. In addition, the change rate of Q/A associated with the change in VPD was large compared with the change rate under the condition of the toner layer consisting of the normal toner. In the same manner as the normal toner, the current flowing into the developing unit and the metal plate during the contact developing step were measured. The change rate of (It+Ip) associated with the change in VPD was larger than that of the normal toner.

4. Conclusion

The toner layers formed on the developing roller were transferred to the metal plate under the various developing electrical fields in contact-type non-magnetic single component developing process. Charging behavior of the toner layer in this process were studied by measuring the properties of the toner layer before and after the developing step. The Following conclusions were obtained.

1. When developing electrical field was zero, amount of toner charge of toner layer formed on the developing roller was divided equally by this developing step.
2. When the developing electrical field was not zero, the toner charge changed by charge injection.
3. In the toner layer consisting of the lower electrical resistivity toner, amount of the toner charge decreased after this developing step even when the developing electrical field was zero.
4. The amount of toner charge changed by charge injection, which depended on the developing electrical field and electrical resistivity of the toner in the contact developing step.

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Biography

Chiseki Yamaguchi received his BS degree in Applied Physics from Tokyo University of Agriculture and Technology in 1978 and a Ph.D. in Material Science from Ibaraki University in 1998, respectively. He joined NEC Corporation in 1992 and has been developing electro-photography process. From 1995, he has been as manager of imaging process engineering in PPC E&P Division, NEC Niigata, Ltd. His research interests includes also advanced novel printing and electrostatics properties of polymer particles. He is a member of The Society of Imaging Science & Technology, The Imaging Society of Japan, the Institute of Electrostatics of Japan and the Japan Society of Applied Physics. He is also a consulting engineer authorized by the Japanese Government.