

Ghost Mechanism of Single-Component Contact Development

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Abstract

Ghost-free image is significant in single-component development system. A low resistance development roller can exclude the ghost due to the charge accumulation on the surface of development roller, but it is not sufficient to achieve the ghost free image.

To explain the ghost mechanism, it is effective to calculate and study the relation between development characteristics and major parameters, such as toner mass per unit area and toner charge per unit mass.

We have experimentally found out the relation between the ghost and the toner particle diameter transition on the development roller, and theoretically explained the ghost mechanism. On the basis of these results we propose the ghost-free development system by using a reset member which restricts the toner particle diameter transition.

Introduction

Regarding the ghost mechanism, several analyses have been reported in the past few years. Among them are the ghost mechanism caused by charge accumulation on the surface of high resistance development roller[1], and the report on importance of the dielectric relaxation times for ghost-free image[2].

To exclude these ghost phenomena, we used a low resistance development roller, but the ghost still remained unexpectedly. In the theory section, we summarize fundamental development characteristics mathematically, and presume several patterns of ghost mechanism. In the experiment section, we show the results of the toner particle diameter transition on the development roller, and explain the mechanism of the ghost. Further we propose the ghost-free development system.

Theory

Resistance of Development Roller

The relation between the development characteristics and the resistance of development roller has been studied in detail[3]. Fig. 1 shows this characteristics. The slope of development curve becomes lower with the increase of roller resistance R_{dev}, which is caused by development voltage decrease by development current. When R_{dev} is smaller than 10^6, the variation of the curve slope is very little.

For the stability of development characteristics, we select $10^5 \sim 10^6\ \Omega$ resistance roller. Using this roller, we can also exclude the ghost caused by charge accumulation on the development roller surface.

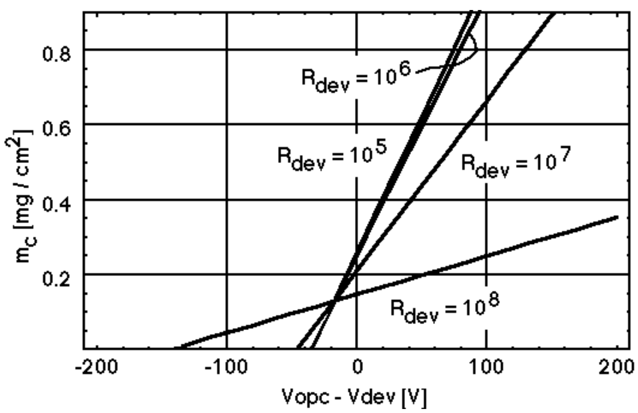

Figure 1. Effect of development roller resistance on development characteristics

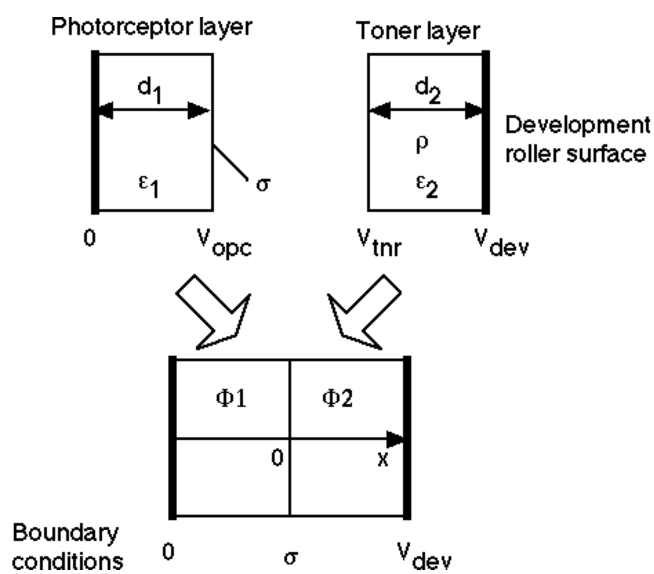

Figure 2. Schematic of mathematical model

Mathematical Model and Fundamental Characteristics

Photoreceptor layer and the toner layer before development zone are shown schematically in Fig. 2. Also these layers at the development zone are shown in Fig. 2. The toner layer assumes the uniform charge density per volume. The parameters used are summarized in Table 1.

Laplace's equation is applied to photoreceptor layer and Poisson's equation is applied to toner layer.

$$\frac{\partial^2 \phi_1}{\partial x^2} = 0 \tag{1}$$

$$\frac{\partial^2 \phi_2}{\partial x^2} = -\frac{\rho}{\varepsilon_2} \tag{2}$$

Table 1. Parameters and Standard Values for Simulation

Photoreceptor		
thickness	d_1	20μm
dielectric constant	ε_1	$3\ \varepsilon_0$
charge per unit area	σ	
Toner layer		
thickness	d_2	15μm
dielectric constant	ε_2	$(1 + p(\varepsilon_r - 1))\ \varepsilon_0$
charge-to-mass ratio	q/m	12 μC / g
mass per unit surface area	m_0	0.6 mg / cm^2
packing ratio	p	0.4
Toner		
mass per unit volume	δ	1 g / cm^3
relative dielectric constant	ε_r	3

Before development zone, the surface potential of toner layer V_{tnr} is given by Eq. 3. And charge density per volume ρ and the thickness of toner layer d_2 are given by Eq. 4 and Eq. 5, respectively. So V_{tnr} is given by Eq. 6 using q/m and m_0. According to this equation, the fundamental characteristics are obvious that V_{tnr} is proportional to q/m and to m_0^2.

$$V_{tnr} = \frac{\rho \cdot d_2^2}{2\varepsilon_2} \tag{3}$$

$$\rho = \frac{q/m \cdot m_0}{d_2} \tag{4}$$

$$d_2 = \frac{m_0}{\delta \cdot p} \tag{5}$$

$$V_{tnr} = \frac{q/m \cdot m_0^2}{2\varepsilon_2 \cdot \delta \cdot p} \tag{6}$$

At the development zone, datum of coordinates is the contacting surface of photoreceptor layer and toner layer as is shown in Fig. 2. And boundary conditions are as follows;

$$\varepsilon_2 \frac{\partial \phi_2(0)}{\partial x} - \varepsilon_1 \frac{\partial \phi_1(0)}{\partial x} = -\sigma \tag{7}$$

$$\phi_1(-d_1) = 0 \tag{8}$$

$$\phi_1(0) = \phi_2(0) \tag{9}$$

$$\phi_2(d_2) = V_{dev} \tag{10}$$

By solving these equations, electric field in the toner layer is given by Eq. 11. The toner layer is divided at the plane x = X_{div}, where the electric field becomes zero. So, development thickness X_{div} is given by Eq. 12, using V_{opc} and V_{tnr} instead of σ and ρ, where the surface potential of photoreceptor V_{opc} is given by Eq. 13.

$$E_2 = \frac{\rho}{\varepsilon_2} x - \frac{\frac{d_1 \cdot \sigma}{\varepsilon_1} - V_{dev} - \frac{\rho \cdot d_2^2}{2\varepsilon_2}}{d_2 + \frac{\varepsilon_2}{\varepsilon_1} d_1} \tag{11}$$

$$X_{div} = \frac{-1}{\frac{d_1}{\varepsilon_1} + \frac{d_2}{\varepsilon_2}} \frac{d_2^2}{2\varepsilon_2} \left(\frac{V_{opc} - V_{dev}}{V_{tnr}} - 1 \right) \tag{12}$$

$$V_{opc} = \frac{d_1 \cdot \sigma}{\varepsilon_1} \tag{13}$$

By substituting X_{div} = 0 for Eq. 12, development starting voltage is given by Eq. 14. Similarly, by substituting $X_{div} = d_2$ for Eq. 12, development ending voltage V_{end} is given by Eq. 15. And by differentiating Eq. 12 with respect to (V_{opc} - V_{dev}), relation between bias voltage and slope of development is given by Eq. 16. According to these equations, the fundamental characteristics are obvious that V_{sta} is completely equal to V_{tnr} , and V_{end} is slightly larger than $-V_{tnr}$. Consequently V_{sta} and V_{end} are approximately proportional to q/m and to m_0^2, and the slope of the development curve is approximately proportional to q/m and to m_0.

$$V_{sta} = V_{tnr} \tag{14}$$

$$V_{end} = -V_{tnr} \left(1 + 2 \frac{\frac{d_1}{\varepsilon_1}}{\frac{d_2}{\varepsilon_2}} \right) \tag{15}$$

$$\frac{\partial X_{div}}{\partial\left(V_{opc} - V_{dev}\right)} = \frac{1}{\frac{d_1}{\varepsilon_1} + \frac{d_2}{\varepsilon_2}} \frac{1}{\rho} \qquad (16)$$

Sensitivity Analysis and Ghost Mechanism

Based on the Eq. 12, we show the results of simulation of development characteristics. The following figure, development volume is shown by m_c instead of X_{div}, where m_c is given by Eq. 17. And velocity ratio between photoreceptor and development roller is set 1.5. Table 1 shows standard values of parameters for simulation.

$$m_c = X_{div} \cdot \delta \cdot p \qquad (17)$$

Fig. 3 shows the effect of toner q/m on development characteristics. As q/m increases, V_{sta} decreases, V_{end} increases and the slope of curve becomes lower in proportion to q/m described above.

Under the assumption of toner particle diameter being in proportion to surface charge density of toner surface, q/m is inversely proportional to toner diameter. So, the effect of toner diameter on development characteristics is similar to Fig. 3; that is, as toner diameter decrease, V_{sta} decreases, V_{end} increases and the slope of the curve becomes lower.

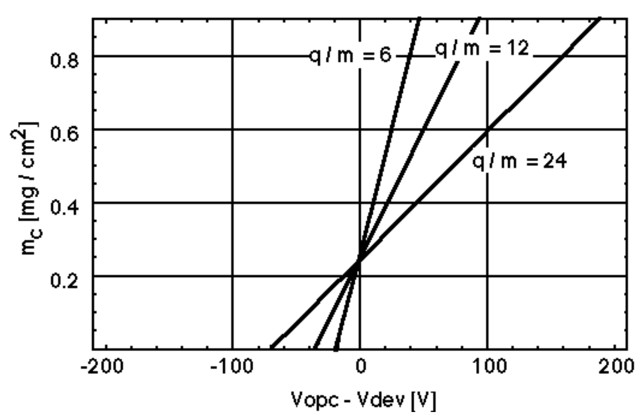

Figure 3. Effect of toner charge on development characteristics

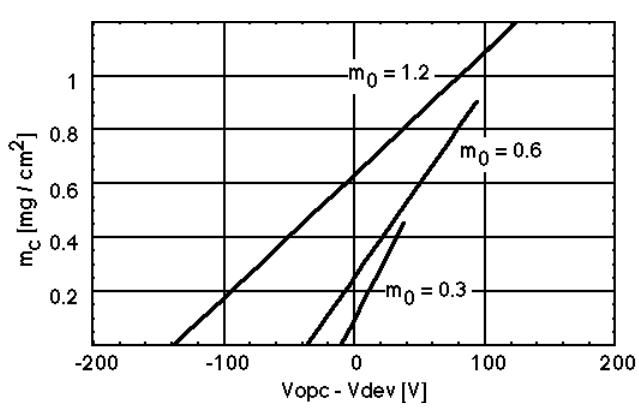

Figure 4. Effect of toner mass on development characteristics

In case of toner charging time being long, or toner diameter getting smaller, q/m becomes higher. So, the slope of development curve becomes lower. If the q/m at the area of development roller where white image is developed was not equal to the q/m of black image area, the ghost phenomenon would be produced.

Fig. 4 shows the effect of m_0 on development characteristics. As m_0 increases, V_{sta} decreases, V_{end} increases and the slope of the curve becomes lower in the proportion described above.

If the toner supply capacity was not sufficient, at the area of the development roller where black image was developed, m_0 would decrease and m_c would decrease. Thus, negative ghost would be produced.

Fig. 5 shows the effect of surface voltage variation of development roller ΔV on development characteristics. Corresponding to the ΔV decrease, the development curve shifts to the left side. If the surface potential at the area of development roller where white image is developed was not equal to the surface potential of black image area, the ghost phenomenon would be produced.

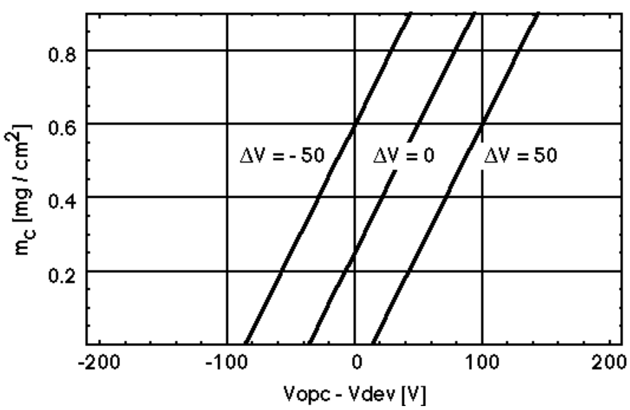

Figure 5. Effect of ΔV on development characteristics

Experiment

Experimental Condition

The essential components of development apparatus used in this experiment are a elastic development roller with the resistance of 10^6 Ω, an urethane-foam-made supply roller which contacts with development roller, and a conductive resilient blade for forming a uniform toner layer on the development roller. The toner in this experiment is made by pulverization method, and its charging time is sufficiently fast. The image pattern for evaluating ghost has checker pattern at the top position and halftone at the next position.

Toner Diameter and Ghost

By using above-mentioned low resistance development roller, we excluded several ghost phenomena, but unexpectedly the ghost still remained.

We have found out that a transition of toner particle diameter is significant as a clue to elucidate the residual ghost mechanism. Fig. 6 shows the distribution of toner particle diameter on development roller. It was measured with a Coulter Multisizer. The toner average diameter at the black area is 7.6 μm which is approximately equal to the toner diameter in hopper. By contrast, the toner average diameter at the white area is 4.8 μm. It became evident that the toner diameter at the area of development roller where white image is developed becomes extremely smaller. Corresponding to the transition of toner diameter, the toner q/m was changed; q/m of black area is -10μC/g and q/m of white area is -14 μC/g.

We conclude from the theory and the experiment described above that the ghost of low resistance development roller is explained as following; the toner diameter at the area of development roller where white image is developed becomes smaller, so q/m of white area becomes higher, ultimately development volume m_c becomes smaller and positive ghost is produced.

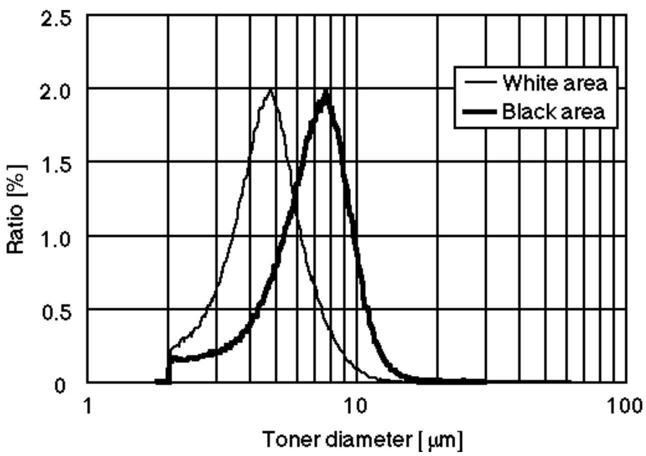

Figure 6. Distribution of toner diameter not using reset member

Method for Ghost Free

We supposed the reason of toner diameter transition due to the insufficiency of mechanical force of toner supply roller which remove the residual toner from development roller. So we tried removing the residual toner by electrically using the reset member. The reset member contacting with the development roller below the development zone, is made of conductive sheet, and is biased.

Fig. 7 shows the distribution of toner particle diameter using the reset member. In this case, the average toner diameter at the white area is 6.1 μm. The transition of toner diameter is decreased, and the positive ghost is excluded. The extent of decrease corresponds to the bias voltage of reset member. The reset member was proved to be effective for decreasing the transition of toner diameter and excluding the ghost.

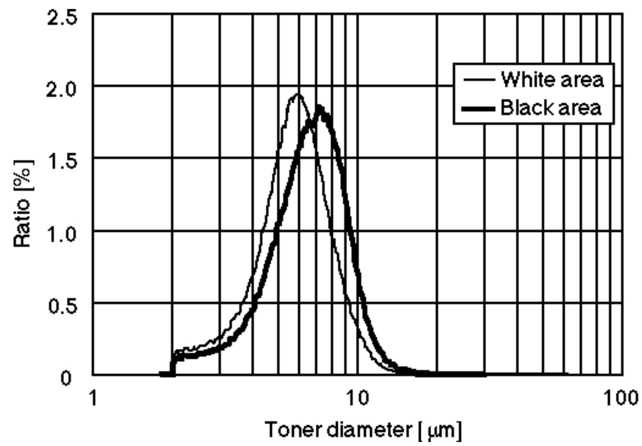

Figure 7. Distribution of toner diameter using reset member

Conclusion

1. We have calculated the relation between development characteristics and major parameters, and presumed the ghost mechanism.

2. We have found out the toner diameter decrease in the white image area and explained the ghost mechanism under the condition of using a low resistance development roller.

3. We have confirmed the reset member is effective for decreasing the transition of toner diameter and excluding the ghost.

References

1. M. Hosoya and M. Saito et al., *J. Imaging Sci. and Tech.*, **37**, 223, (1993).
2. K. Aoki et al., *J. Imaging Sci. and Tech.*, **40**, 359, (1996).
3. I. Chen, *J. Imaging Sci. and Tech.*, **41**, 611, (1997).

Biography

Tadashi Iwamatsu received his B.S. in mechanical engineering from Kyoto University in 1986. He joined Sharp Corporation in 1986. He was engaged in design of servomechanism and optical design of hologram scanner. He belongs to Precision Technology Development Center. His current interest is simulation of electrophotography.

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