Measurement Techniques of Micro Region Discharge Current for Analysis Discharge Mode of Contact Charging Roller

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Abstract

One of the major problems of electrophotography in a contact charging roller system is density nonuniformity of a printed image due to anomalous discharges. To find proper countermeasures to such a problem, characterization of the discharge phenomenon is crucial. We developed a measurement technique for micro region discharge currents using a minute electrode embedded in the surface layer of a photoreceptor drum that is capable of quantifying the time variation of the local discharge current. Using a measurement system that utilizes this technique, dependency of the discharge current mode on charging parameters was clarified. Based on changing the charging parameters, discontinuous changes in the discharge modes that affect the nonuniformity of the image density are observed. In this report, in addition to the measurement technique and results, the relationship between the discharge conditions and the density nonuniformity of the image is discussed.

Introduction

A contact charging roller system is one of the most widely used charging techniques for electrophotographic copiers and printers. In this system, bias voltage is applied between the charging roller and the photoreceptor drum in contact with each other, and the surface potential of the drum is charged by the discharge generated in the minute gap between them. One of the features of this system is that the amount of ozone generation is small because the discharge occurs in close proximity of the photoreceptor drum as compared with the non-contact charging system. Furthermore, because there are fewer components than the non-contact charging system, this system is capable of providing compact and low-cost electrophotographic apparatuses [1].

Recently, demand for smaller and low-cost electrophotographic printers is growing in the production printing market. Even though there is more application of the contact charging roller system to electrophotographic printers in the market, one of the problems of the contact charging roller system in high-speed and high-quality printing machines is the density nonuniformity of printed images due to anomalous discharges [2]. This problem needs to be resolved in order to provide high quality products equipped with this system.

To find proper countermeasures to the problem of density nonuniformity and to achieve high quality of printed images in a stable manner, characterization of discharge phenomenon is crucial. However, measurement techniques for minute discharge distribution patterns were not known in the past. Therefore, to investigate electric discharge at the minute gap between the charging roller and the photoreceptor drum, we developed a measurement technique for micro region discharge currents with a minute electrode embedded in a photoreceptor drum. By using this measurement technique, the time variation of the local discharge current can be quantified.

In this paper, in addition to the measurement technique and results, the relationship between the discharge conditions and the density nonuniformity of the image derived from the results is discussed.

Measurement technique for micro region discharge current

Measurement apparatus

Conventionally, an electric current flowing into the photoreceptor is measured between its base conductor and the source of the power to quantify the electric discharge [3]. However, only the macroscopic state of discharge phenomena can be captured by this method. Therefore, we adopted an approach of measuring an electric current using a minute electrode to capture the variation of discharge current within a micro region. Figure 1 shows the measurement apparatus. A minute electrode is embedded in a hole with a diameter of 1 mm formed through the roll core of a metallic substrate, and the gap between the roll core and the electrode is electrically insulated. The surface of the minute electrode is leveled with the surface of the roll core. Moreover, both surfaces of the minute electrode and the roll core are coated by a charge generation layer and a charge transport layer.

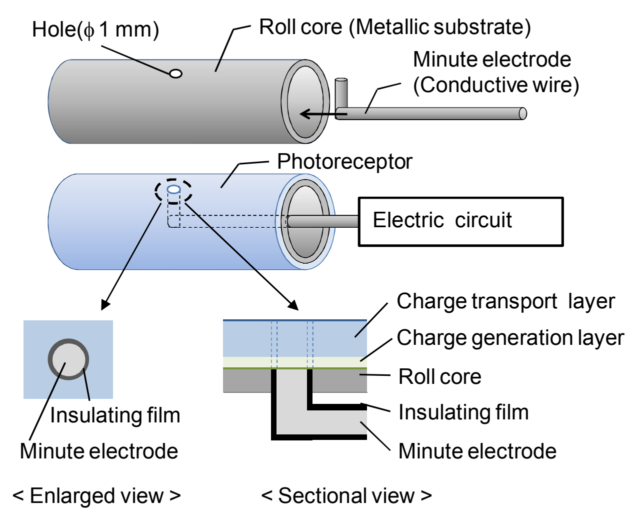


***Figure 1**. Measurement apparatus for micro region discharge*

The minute electrode is connected to a current measurement circuit by a conductive wire to measure discharge current flowing through the minute electrode. As shown in Figure 2, the current measurement circuit consists of an operational amplifier (Op-Amp), a resistor, and a capacitor. These parts are connected in parallel, and the anode side of the Op-Amp is connected to the ground. A discharge current that flows into the input of the electric circuit flows through the resistor and is detected as an output voltage. Based on the configuration described above, the difference in the potential between the microelectrode and the roll core is 0 V because the input of the electric circuit is an imaginary ground. Thus, photoconductive properties at the area around the minute electrode are equivalent to those of the other area. In this manner, only the current of discharge occurring in the area right above the minute electrode can be measured.

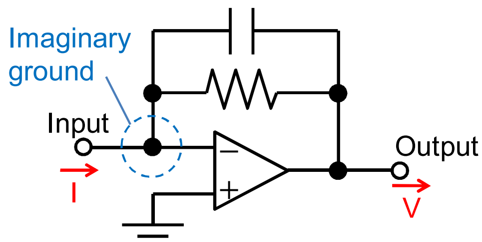


***Figure 2**. The electric circuit to measure discharge current*

Figure 3 shows a measurement system of the micro region discharge current in the gap between the charging roller and the photoreceptor by using the measurement apparatus. A reflective photo-interrupter is used to obtain the rotational position of the minute electrode. Black light-absorptive tape is attached to the photoreceptor drum at the rotational position corresponding to that of the minute electrode, and the reflective photo-interrupter is set to detect the passage of the black light-absorptive tape.

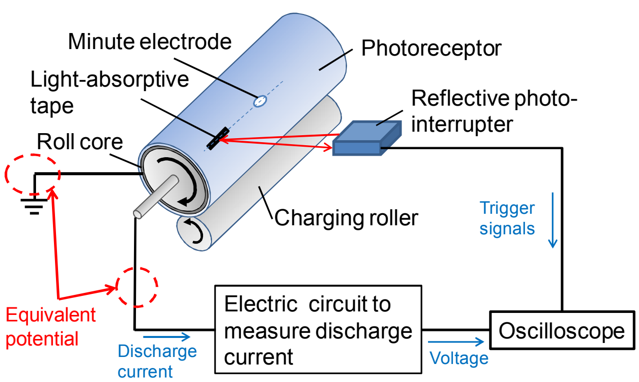
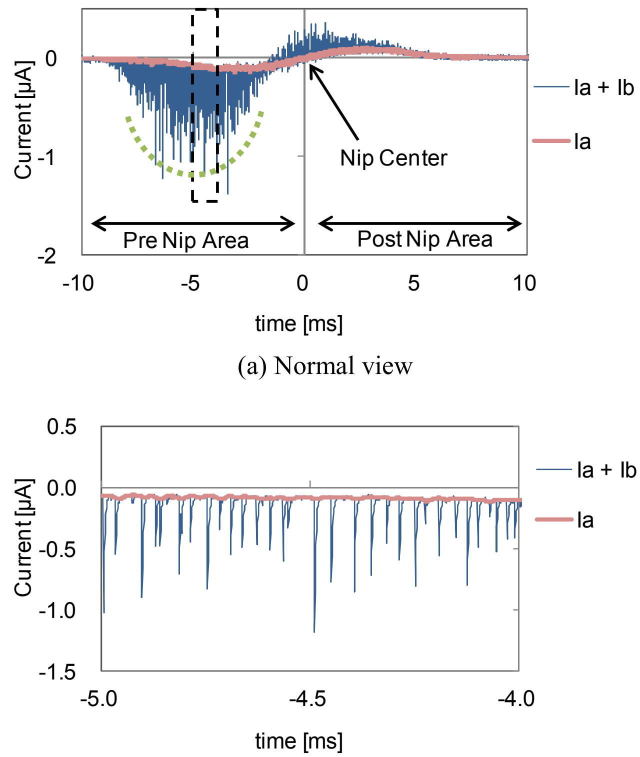


***Figure 3**. Measurement system of micro region discharge current in the contact roller charging system*

Measurement Results

Figure 4 (a) shows the measured time variation of the micro region discharge current under operation with DC bias voltage. The time when the minute electrode passes the center of the nip is taken as the reference time of the measurement. In other words, the minute electrode is located in front of the nip when the time is negative, and it is located after the nip when the time is positive.

The detected current consists of an induced current ("Ia" in Figure 4 (a)) and discharge current ("Ib" in Figure 4 (a)). The waveform of the induced current is S-shaped, coinciding with a time variation of capacitance due to the variation of the gap between the charging roller and the photoreceptor.



(a) Normal view

(b) Enlarged view

***Figure 4**. Time variation of discharge current*

Figure 4 (b) shows an enlarged view of the area indicated by the broken line in Figure 4 (a). In Figure 4 (b), discrete discharge currents are visualized clearly as pulses. Thus, the frequency of the discharge pulses may be identified by counting their number.

As shown in Figure 4 (a), the magnitude of the current per discharge pulse has a mild peak in front of the nip (as indicated by the dotted line). This peak is formed by the relationship between the position of the discharge pulses and the minute electrode. Figure 5 shows a schematic diagram of the overlapping area of the minute electrode and pulsed discharges. If the pulsed discharge occurs near the center of the minute electrode ("(a)" in Figure 5), then the measurement system detects all currents of the pulsed discharge. On the other hand, if the pulsed discharge occurs near the edge of the minute electrode ("(b)" in Figure 5), then the system detects the portion of the pulsed discharge current that is overlapped with the area of the minute electrode. Thus, as the minute electrode approaches the position where the pulsed discharge occurs, the detected discharge current and the frequency of the detected discharge pulse increase. As the minute electrode recedes from that position, the detected discharge current and the frequency of the detected discharge pulse decrease. Therefore, the position of the area where pulsed discharges occur is identified from the position and profile of the distribution.

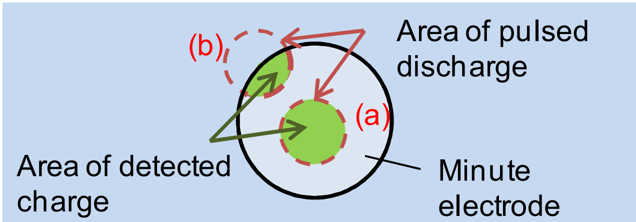


***Figure 5**. Area of detected charge by measurement system of micro region discharge*

Analysis results

Using the measurement system that utilizes this technique, the characteristics of discharge pulses were analyzed. In the analysis, light emission of the pulsed discharges in front of the nip was investigated simultaneously using a highly sensitive camera. Although an eliminating lamp is typically used for static elimination in printers, an anti-static brush was used here to measure only the discharge light emission by the highly sensitive camera.

Characterization of pulsed discharges

Figure 6 shows time variations of the discharge current measured with DC bias voltage of –1010 V and –1210 V. In Figure 6, two different forms of the pulsed discharges are observed depending on the DC bias voltage. When the bias voltage is –1010 V, about 160 pulsed discharges with less than the absolute value of the current 2 μA each occur in front of the nip. These pulsed discharges are denoted as "minute current discharge," and the mode of discharge consisting of only minute current discharges is denoted as "minute current discharge mode" hereinafter. When the bias voltage is –1210 V, large pulsed discharges higher than the absolute value of the current 2 μA occur less frequently. These pulsed discharges are denoted as "large current discharge," and the discharge mode consisting of both minute current discharges and large current discharges is denoted as "large current discharge mode" hereinafter.

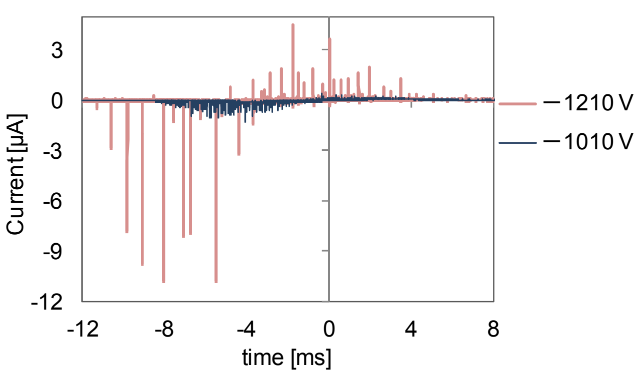
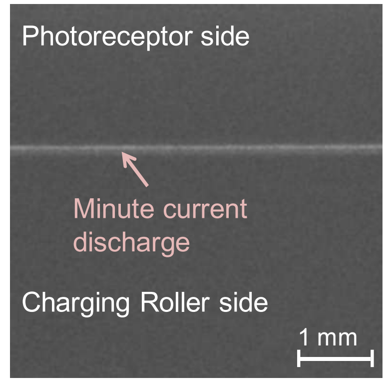
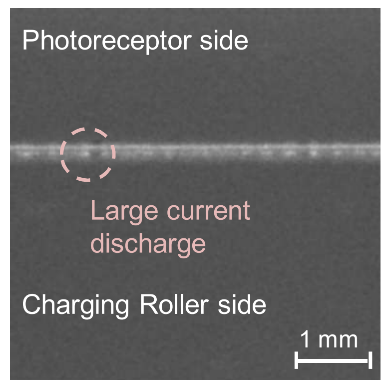


***Figure 6**. Time variation of discharge current*

Figure 7 shows the investigation result of the state of the discharge light emissions in front of the nip for each discharge mode described above. In the minute current discharge mode, a dim discharge light emission is observed as a continuous band. In the large current discharge mode, sparse strong discharge lights are emitted at approximate intervals of 100 µm. From these results, we found that large current discharges occur sparsely as strong discharge light.



(a) Minute current discharge mode



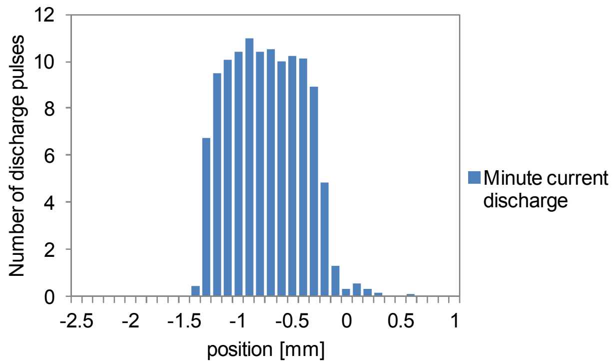
(b) Large current discharge mode

***Figure 7**. Emitting light by discharge in the pre nip area*

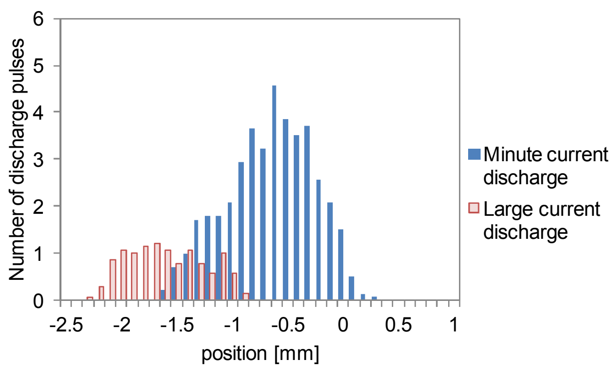
Figure 8 shows a frequency distribution of the detected discharge pulses for each position. In this figure, the horizontal axis corresponds to the relative position between the center of the minute electrode and the center of the nip. The number of detected discharge pulses for each position was obtained by averaging measured data from 14 repeated experiments. When the bias voltage is –1010 V, the minute current discharges are detected within the range from –1.4 mm to –0.1 mm as shown in Figure 8 (a). In addition, the frequency distribution is square-shaped, with the width roughly equal to the diameter of the minute electrode (1 mm). From these results, we infer that minute current discharges occur mainly at a position –0.8 mm from the center of the nip, and the size of the minute current discharge is much smaller than the diameter of the minute electrode.

Figure 8 (b) shows the frequency distribution of the discharge pulses under the bias voltage of –1210 V. Since the distribution of the large current discharges range from –2.2 mm to –1 mm and is also nearly flat, it is deduced that the discharge pulse is much narrower than the electrode and occurs mainly at –1.6 mm. On the other hand, the frequency distribution of the minute current discharges in this case is wider than that of the case of –1010 V.

Based on this, the minute current discharges under the large current discharge mode appear to be dispersed widely compared to those under the minute current discharge mode.



(a) Bias voltage −1010 V



(b) Bias voltage −1210 V

***Figure 8**. Frequency distribution of the detected discharge pulses for each position*

From these results, we conclude that a surface potential is created by the minute current discharges occurring in a very narrow area in the case of the minute current discharge mode. On the other hand, in the case of the large current discharge mode,-the large current discharges occur in front of the position where the minute current discharges occur and the minute current discharge pulses are dispersed. This dispersion of the minute current discharge pulses is presumably induced by a nonuniform electric field due to the prior large current discharges.

Analysis of discharge mode transition

Figure 9 shows a variation of the maximum current of pulsed discharge against the bias voltage for several thicknesses of charge transport layer. Here, the maximum current of pulsed discharge is defined as the absolute value of the current of the largest discharge pulse. In the minute current discharge mode, the maximum discharge current pulse increases gradually as the bias voltage rises. As the bias voltage is raised further, the maximum current of pulsed discharge increases discontinuously when the bias voltage exceeds a threshold voltage. Moreover, when the charge transport layer becomes thick, the threshold voltage becomes lower. Based on additional experiments with varying factors, the threshold voltage was found to be dependent on other system parameters such as load between the contact discharging roller and the photoreceptor, as well as surface roughness of the contact charging roller.

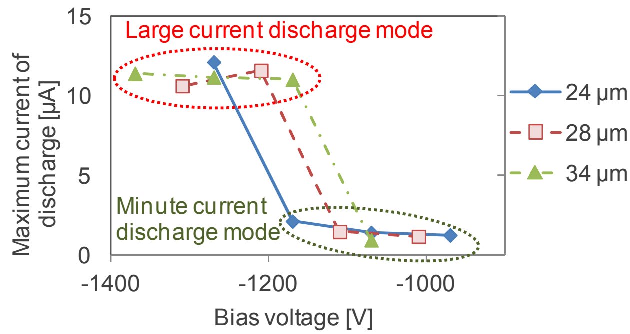


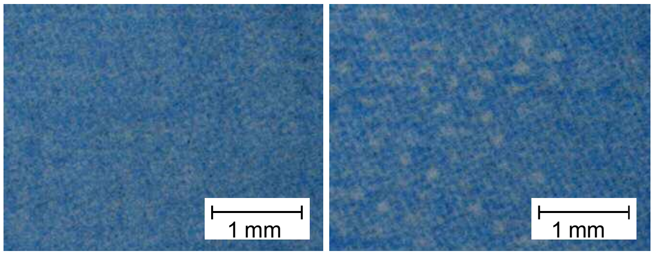
***Figure 9**. Minimum current of pulsed discharge for thicknesses of charge transport layer*

These results indicate that the state of discharge is discontinuously switched between the two modes, depending on the condition of the charging.

Mechanism of the density nonuniformity of a printed image

The relationship between the image quality of output prints and discharge modes was investigated. Figure 10 shows printed solid images produced by a printer using contact roller charging. To create the printed image as a solid image, the exposure process is disabled. Thus, the image density distribution is considered as being a surface potential distribution of the photoreceptor after the discharge process. To adjust average densities among the printed images, the developing bias voltage was calibrated. To visualize the difference in the density nonuniformity of each printed image, the contrast of the printed images was enhanced by using digital image processing.

When the bias voltage was −1010 V, the image density distribution was uniform. "White dots" were observed when the bias voltage was −1210 V. The surface potential in the area of the white dots is higher than that in the other areas of the printed image. By analyzing the frequency distribution of the white dots in the printed image, the number of white dots per area of minute electrode was found to be roughly equal to the number of large current discharge pulses detected by the measurement system. From the investigation above, it was clarified that the white dots correspond to the areas that are excessively charged by the large current discharges.



(a) Bias voltage −1010 V (b) Bias voltage −1210 V

Figure 10*. Output image by roller charging with DC voltage*

Based on the analysis results above, the mechanism behind density nonuniformity of the printed image by pulsed discharges is presumed as follows: In the minute current discharge mode, uniform surface potential is created by successive superposition of dense pulsed discharges with minute currents. In the large current discharge mode, nonuniform surface potential is created by superposition of the pulsed discharges with the large current and minute current. First, sparse excessively high potential dots are created by the large current discharges. Next, the minute current discharges charge the yet low potential area. Even though reverse discharges are needed at the excessively high potential areas in order to make the potential distribution uniform, they do not occur because sufficiently high electric fields are not created there.

Summary

A measurement technique for micro region discharge currents that is capable of analyzing the position of the area where discharge occurs, intensity of discrete discharge pulses, and frequency of pulses was developed. Upon applying the measurement technique to a contact charging roller system, the following mechanisms ware clarified.

1. Stage of discharge mode changes discontinuously from minute current discharge to large current discharge as the bias voltage exceeds a threshold value.
2. Large current discharges occur in front of the position where minute current discharges occur in the large current discharge mode.
3. The density nonuniformity of the printed image is created based on excessive discharge by large current discharge pulses.

References

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Author Biography

Minoru Ohshima received his MS in Information Science from the Japan Advanced Institute of Science and Technology in 2004. He joined Fuji Xerox Co., Ltd. in 2004 and has since been engaged in the development of mechatronics and simulation technologies of paper handling and electrophotography. He is a member of the Imaging Society of Japan.