Dot Formation Condition from the Conductive Toner Cloud by Aperture Electrodes

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Abstract

The printing by controlling conductive cloud has a possibility of realizing simple printing mechanism. Electric field activated jumping toner is confined by using dented electrode and the confined toner generates toner cloud. In the experiment, 4 electrodes of pulling electrode, a pair of control electrode and dented base electrode are arranged. When the control electric field between the pair of control electrodes is forward to toner motion to the pulling electrode, toner can pass the control electrodes to the pulling electrode and form a toner dot. The dependence of the toner dot size on the electric field is measured. The toner dot size starts to increase from the certain electric field. It is obtained that the dot size depends also on the electric field outside of the aperture electrodes.

Introduction

In non-impact printing process, control of toning material is important point. Main evaluation items of the printing process are: print quality, printing speed and simplicity of printing mechanism. The print quality is controlled by the precision of position where a toner particle is attached to a paper and the controllability of amount of attaching toner particles.

Although the electrophotographic printing is relatively complex, its print quality and its speed are excellent. To maintain good printing condition need efforts because printing mechanism is complicated. This disadvantage leads to seeking efforts for realizing new printing technologies, which have characteristics of a simpler printing mechanism, higher printing quality, higher printing speed, and/or better stability and maintainability.[1-4] Array Printers AB in Sweden have developed a direct printing method using insulating toner, TonerJet®, since 1986, express purpose to be faster than inkjet and lower in manufacturing cost than electrophoto-graphy.[5,6] In 1999, we propose new dot formation method using conductive toner called "Toner Cloud Beam (TCB)".[7]

In TCB printing method, the toner beam is extracted from toner cloud generated by electric field applied between electrodes. Then, the toner beam is projected to paper to form dots by such a simple printing mechanism.

The conductive toners start to move up and down between the electrodes because the conductive toners are charged by conduction from the electrodes under the electric field applied and electric force (toner charge × electric field) works on the toners.[8-11] The conductive toners can be confined between electrodes using the dented electrode and generate toner cloud.[7-10] This confinement is realized by electric field toward central axis of the dent of the electrode. We reported transport characteristics of toner by dented shape.[12,13] The toner beam is extracted from toner cloud generated by electric field applied between electrodes. Then, the toner beam is projected to paper to form dots by such a simple printing mechanism. The experimental setup for this method, includes the dented electrode, lower control electrode, upper control electrode and pulling electrode being placed parallel. It is confirmed that dot is formed on paper by this method. In this paper, we reported it is possible that toner dot formation is controlled by controlling application voltage of each electrode.

Experimental

The schematics of experimental system is shown in Figure 1. The bottom electrode has dent and is called dented electrode. There is a pair of electrodes above dented electrode. They have aperture and are called aperture electrode or control electrode. In this study, lower control electrode is electrically ground. We call a lower one lower control electrode and upper one upper control electrode. From the dented electrode, conductive toner moves upward and downward by electric force under the electric field. It forms toner cloud and is confined between control electrode and dented electrode. When the voltage of upper electrode is less than the lower electrode, the toner can not pass the control electrode; it is "off" state. But, when the voltage of upper control electrode is higher than the lower control electrode; it is "on" state.

Materials

The toner used is conductive one and its average diameter is around 10 μm.

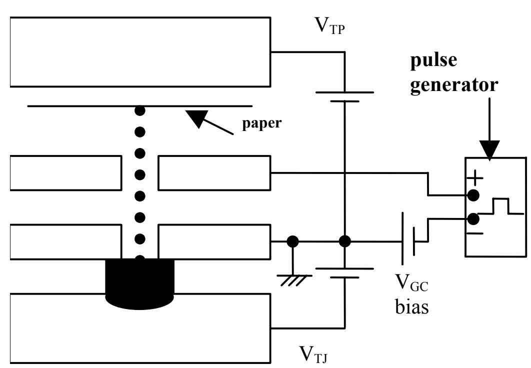


Figure 1. Schematics of experimental apparatus.

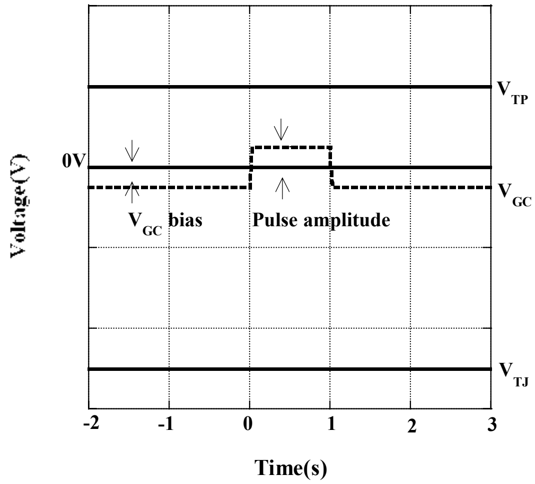


Figure 2. Time sequences of applied voltage to electrodes.

Electrode

Dented electrode is of copper, size of electrode plate is 10 cm × 10 cm and its thickness is 2 mm, diameter of dented area is 9 mm and its depth is 0.2 mm.

Control electrodes are of stainless steel, its size is 5 cm × 5 cm, diameter of aperture in this experimental is 0.5 mm, and its thickness is 0.1 mm. Pulling electrode is of copper and size is 5 cm × 5 cm.

The insulation board was made with plastic, its size is 5 cm × 5 cm and its thickness is about 0.93 mm.

In this study, experiment are carried out by two steps. At first, off condition is obtained.

Experimental Procedure is as Follow

Toner of weight 5mg is supplied to the dented area of the electrode. Each electrode is put and paper is set on the pulling electrode. Then the voltages are applied to each electrodes and dented electrode is added the voltage of -550V. Time duration of voltage application is 15 second. It is recognized it is control electrode off state even if the pulling voltage is no matter how high, paper can not appear dot. We thought it off state to dented electrode voltage of -550V and upper control electrode of -25V.

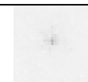
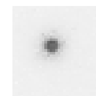
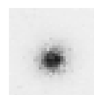
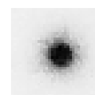
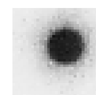
Experimental Procedure is as Follow

After each electrode is put, dented electrode is applied -550V and upper control electrode is applied -25V, pulling electrode is applied, too. Then the upper control electrode is applied to "on" pulse voltage by 1 second with controlling of digital function generator. Time sequence of the applied voltage is shown Figure 2.

Results and Discussion

Figure 3 shows the enlarged photos of the dots. The experiments are carried out at the condition that the voltage difference between the pulling electrode and the upper control electrode is constant 400V. The voltage of the upper control electrode is increased from 0 to 400V. It is found that the dot size increases as the voltage of the upper electrode increases.

In the Figure 4, when voltage of control electrode was less than 100V, very few toner would attach on paper and formed dots, but the number were very few and dots were hard to be seen with human eyes, and we could consider that dot size was almost zero. When voltage of control electrode was above 100V, dots can be seen clearly and that result had a high probability in repeating tests.

TP(V)	400	500	600
GC(V)	0	100	200
Dot Samples			
TP(V)	700	750	800
GC(V)	300	350	400
Dot Samples			

0 10 mm

Figure 3. Photo of dots of various voltage condition.

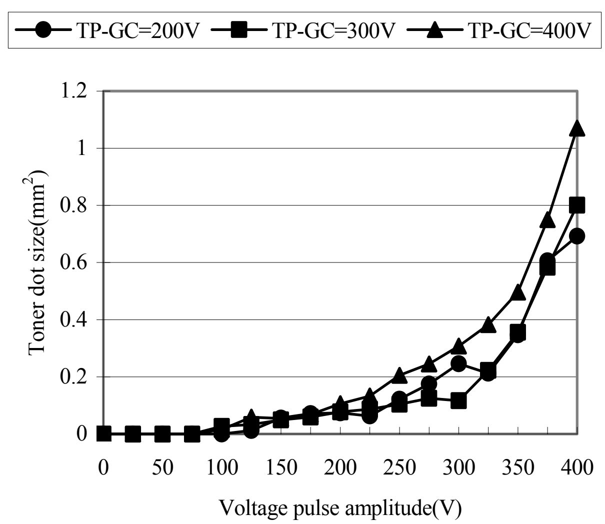


Figure 4. Toner dot size dependence on voltage pulse amplitude with the three conditions of V_{TP}-V_{GC}=200,300,400.

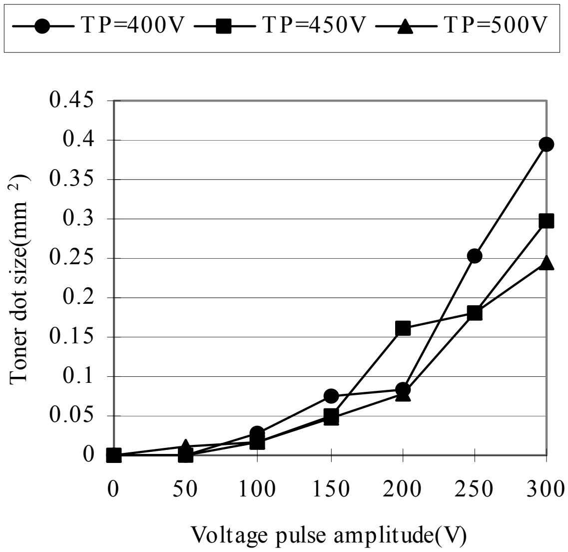


Figure 5. Dot size dependence on voltage pulse amplitude with the three conditions of V_{TP}=400,500,600.

When voltage of control electrode was more than 100V, dots' size was increasing as voltage of upper control electrode increasing. Experimental results displayed that dot size was nearly same at the voltage of control electrode both TP-GC=200 and TP-GC=300. But at TP-GC=400 condition, dot size was obviously larger than above two conditions.

Figure 5 shows how toner dot size changed when voltage of control electrode was changing but the voltage of pulling electrode kept on a fixed value. We also found that dot size was increasing with voltage's increasing of control electrode. According to Figure 5, dot size is almost same when voltage of control electrode was same; even voltage of pulling electrode was changing. It was difficult to know if dot size depended on voltage of pulling electrode from these experimental results. So it's necessary to discuss dependence between higher voltages of pulling and higher voltage of control electrode in future.

The relations between voltage pulse time (ON time) and dot size are studied next. We set the voltage of upper control electrode was 300V and the voltage of pulling electrode is 700V. The result of dot size with various pulse condition is shown in Table 1 and Figure 6 shows the photos of typical toner dots of various voltage pulse condition. Figure 6 shows that the dot size increase in the pulse width of 0.01~0.02S and the dot size becomes saturated over 0.02S.

Table 1: Dot Size Dependence on Voltage Pulse Width

ON time(s)	0.01	0.02	0.1
Dot size (mm^2)	0.085	0.14	0.22
ON time(s)	0.5	1	10
Dot size	0.26	0.30	0.27

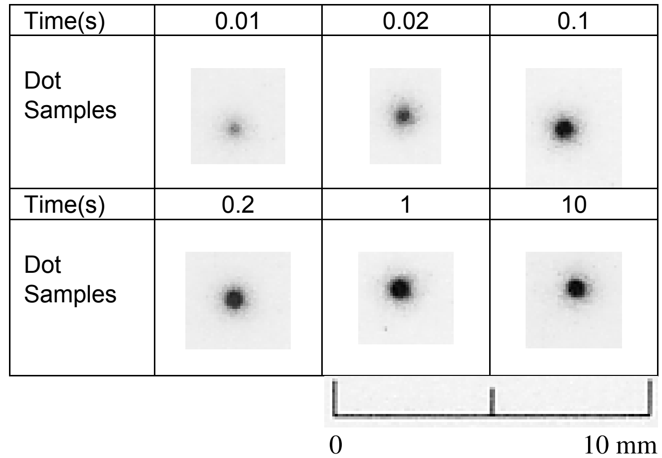


Figure 6. Photos of dots of various voltage pulse width.

Conclusions

Dot formation method by TCB is expected as simple mechanism. In this paper, it was confirmed that TCB is possible and dot is formed on paper by controlling voltages. TCB mechanism include 4 electrode and the upper control electrode is very important to toner dot formation. Dot size was increasing as increasing the voltage of control electrode. For example, On the condition that V_{TJ} is -550V, V_{TP} is 700V and V_{GC} is 300V with 1 second of ON time, toner dot size is about from 0.28 mm^2 to 0.32 mm^2 and mean value is 0.30 mm^2. In addition, small and clear dot is provided. For example, toner dot size is about 0.00074 mm^2 on -550V of V_{TJ}, 700V of V_{TP} and 300V of V_{GC}. If a smaller aperture size of control is applied smaller and clear toner dot size is expected to be provided.

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Author Biographies

Ye Zhou got Bachelor Degree of Applied Chemistry from Chinese Central South University of Technology in 1996.He got Master Degree of Systems Engineering from Nippon Institute of Technology in 2003. Since 2004, began to study for Doctor Degree in Nippon Institute of Technology and his major is Hard Copy Technology.

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