Cleanerless Electrophotographic Process Using Magnetic Polymerized Toner

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Abstract

The magnetic toner using an emulsion polymerization technique exhibits a high transfer efficiency and is suitable for cleanerless electrophotography. Also, we used a two-component development system using small iron carriers with low resistivity to completely recover the residual toners from the photoreceptor surface to the developer. Our improvements allow compact page printers to be designed without conventional cleaner units and magnetic sensors controlling the toner concentration.

Introduction

A cleanerless electrophotographic process is important because it is compact and waste-toner-free.[1] In this process, a developing unit simultaneously develops an electric latent image and cleans the photoreceptor surface. Toners remaining on the photoreceptor surface may cause a background noise if the cleaning is not sufficiently thorough. Therefore it is important to reduce the residual toner on the photoreceptor after the transfer process. It is also required to completely recover the residual toner from the photoreceptor surface to the developer. Another aim is to realize a simple and compact developing unit which does not require exact control of toner concentration. These aims have been achieved by our new developer consisting of magnetic polymerized toners and small iron carriers. We will report the transfer efficiency of the magnetic toner using an emulsion polymerization technique,[2] the recovering characteristics of the developer with a high toner concentration, and its application in a compact page printer.

Experiment

The transfer efficiency, η, of the magnetic toner using an emulsion polymerization technique was compared with that of the conventional toner using a pulverization technique. The average sizes and magnetic properties of these toner samples are shown in Table 1. Figure 1 shows a SEM image of the magnetic polymerized toner. Each toner consisted mainly of 40 wt% magnetite particles and styrene-acrylic binder resin. Transfer properties were measured for a laser printer with a two-component developing unit and a corona transfer charger. The two-component developers were prepared by mixing each toner with a plate-shaped iron carrier approximately 30 μm in diameter. The applied voltage for the corona transfer charger was 5 kV, which gave the highest η to each sample. Then η of a solid image was estimated using the equation

$$\eta = [OD1/(OD1 + OD2)] \cdot 100.$$

OD1 is the optical density of the toner image transferred to paper, and OD2 is that of residual toners on a photoreceptor. η is expressed as a percentage.

Table 1. Magnetic toner sample

Production method	Average size (μm)	Magnetic property σs (emu/g)	Hc(Oe)
Polymerization	7.4	20	188
Pulverization	8.0	21	163

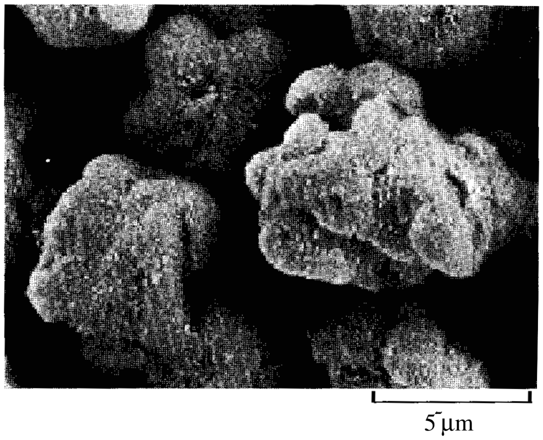

Figure 1. SEM image of magnetic polymerized toner.

The charge-to-mass ratio, q/m, of each toner was measured by a developing method using a compact developing setup, as shown in Figure 2. Each toner was developed using the plate-shaped iron carrier. The amount of electrostatic charge and the weight of a developed toner layer was measured, and then q/m was calculated.

The ability of developers to recover residual toners was measured using the same compact developing setup, as shown in Figure 2. Firstly, magnetic polymerized toner was developed to an aluminum roller using a magnetite carrier (step-1). The layer of toner on the aluminum roller was approximately 60 μm thick (3 mg/cm^2) and the q/m of the developed toner was approximately -7 μC/g. Secondly, after replacing the developer-1 with developer-2 for measurement, the aluminum roller was rotated once and then part of the toner layer was recovered to developer-2 from the aluminum roller (step-2). A spherical ferrite carrier, spherical magnetite carriers, an irregularly shaped iron carrier and plate-shaped iron carriers, as shown in Table 2, were used for developer-2. All the carriers, except for the ferrite carrier, were coated with resin. The potential difference between the aluminum roller and the developing roller was zero. The peripheral velocities of the aluminum roller and the developing roller were 25 mm/s and 75 mm/s, respectively. The width of contact between the aluminum roller and the developing roller was approximately 0.5 mm and the blade gap was 0.35 mm. Finally the amount of recovered toners was weighed.

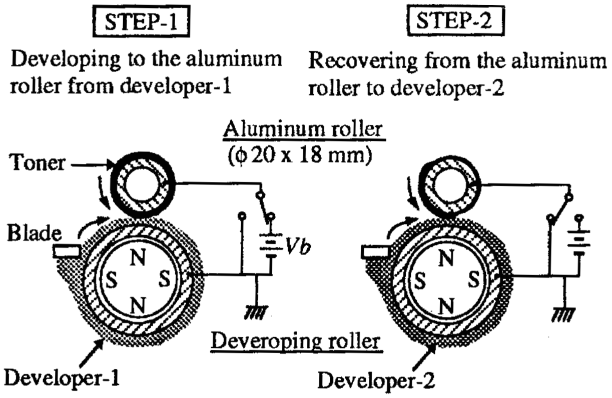

Figure 2. Measurement setup for q/m by a developing method and recovery characteristics.

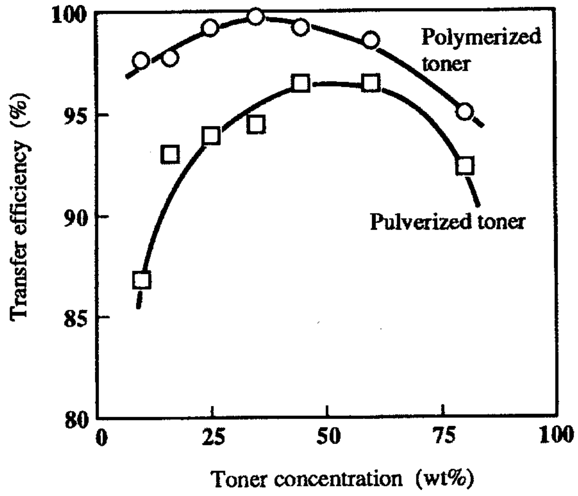

Figure 3. Toner concentration and transfer efficiency. Carrier was a plate-shaped iron particle with 30 μm in diameter.

Results and Discussion

1. Transfer Efficiency

Figure 3 shows the relationship between the toner concentration, Tc, and the transfer efficiency, η, of two toner samples. The magnetic polymerized toner exhibits a high η from low to high Tc, and the maximum η is nearly 100 %. Figure 4 shows the Tc dependence on q/m measured by the developing method. At concentrations above 40 wt%, Tc does not drastically change q/m and both toners exhibit a fairly high q/m. The reason magnetic toners exhibit high η at a high Tc seems to be because highly charged toners are developed selectively.

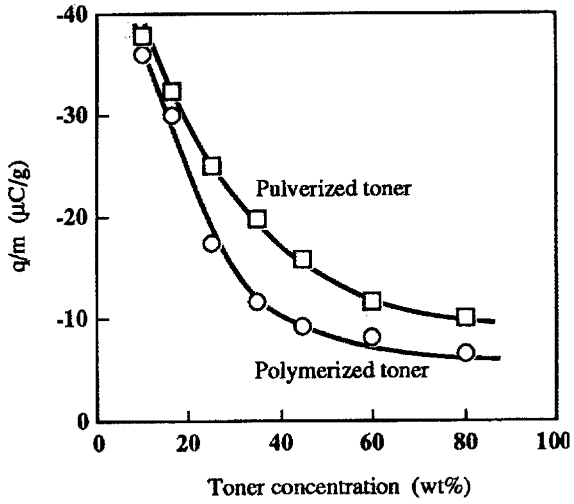

Figure 4. Toner concentration and the charge-to-mass ratio, q/m, by a developing method. A plate-shaped iron carrier was used.

Figure 5 shows the relationship between q/m and η. Each toner exhibits a similar q/m dependence on η, although η of the polymerized toner is higher than that of pulverized toners for the same q/m. It is well known that η depends mainly on q/m and the adhesive force of toner particles.[3] Therefore it seems that the polymerized toner exhibits a high η because of its weak adhesion with other toner particles and the photoreceptor surface.

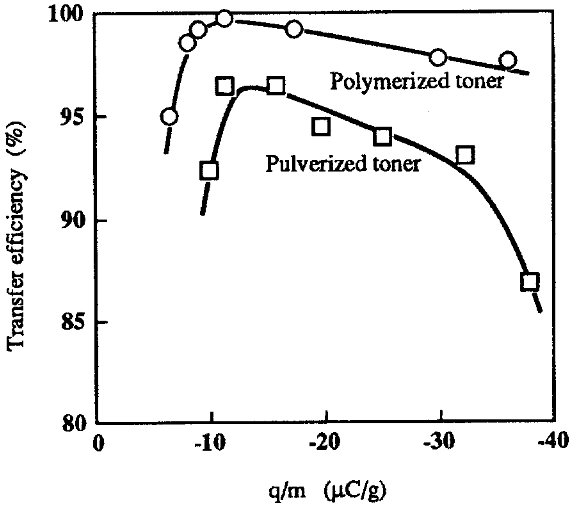

Figure 5. Charge-to-mass ratio and transfer efficiency.

2. Recovery Characteristics

Table 2 shows the carriers for measurement and the amount of recovered toner. The ability of iron carriers to recover the residual toner is 1.3-1.4 times better than the ferrite or the magnetite carriers. The size of the carrier makes little difference, although the increased surface area of the carrier seems to enhance the ability to recover. Figure 6 shows the relationship between the volume resistivity of the plate-shaped iron carrier and the amount of recovered toner. The lower the resistivity is, the higher the ability to recover is. It indicates that the electrostatic recovering force is enhanced by a near-electrode effect. In this case, the electrostatic force working on the residual toner layer is the image force due to its own charge because the potential difference between the aluminum roller and the developing roller was zero. Therefore, the carrier for a cleanerless process using a magnetic toner must have high magnetization and low resistivity. Moreover, an increased carrier surface area is need to give toners a sufficient triboelectric charge at a high Tc. Then a small iron carrier with low resistivity is suitable for a cleanerless process.

Table 2. Carrier and recovery efficiency

Carrier			Amount of recovered toner
Core	Shape	Size (μm)	(mg/cm^2)
Ferrite	Spherical	30	0.84
		30	0.86
Magnetite	Spherical	45	0.85
		60	0.74
Iron	Irregular	30	1.19
Iron	Plate-like	30	1.13

The volume resistivity of carrier with a 30 μm diameter was more than 10^{12} Ω*cm. Tc was 25 wt%.*

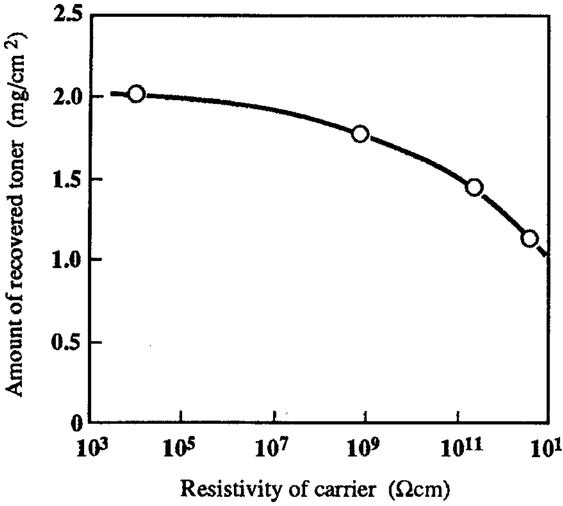

Figure 6. The volume resistivity of plate-shaped iron carrier and the amount of recovered toner. The volume resistivity was measured at 100 V/cm.

Figure 7 shows the relationship between toner concentration expressed as a volume percent, Tc', and the amount of residual toner, M. M decreases in proportion to Tc'. In other words, M increases in proportion to carrier concentration. The recovering ability of the plate-shaped iron carrier is higher than that of the other carriers from low to high Tc', although Tc' changes it drastically. The reason the plate-shaped iron carrier with low resistivity has a strong Tc' dependence on M seems to be because Tc' changes the resistivity of the developer drastically. Moreover the dependence of Tc' on M at low concentrations is weaker than that above 70 or 80 volume percent. We guess that, at low concentrations, parts of toners separated from carriers are held near the surface of the developing roller by magnetic force. Therefore Tc' in the magnetic brush is lower than the average Tc' in the whole developer. Tc' should be lower than about 70 volume percent, that is approximately 40 wt%.

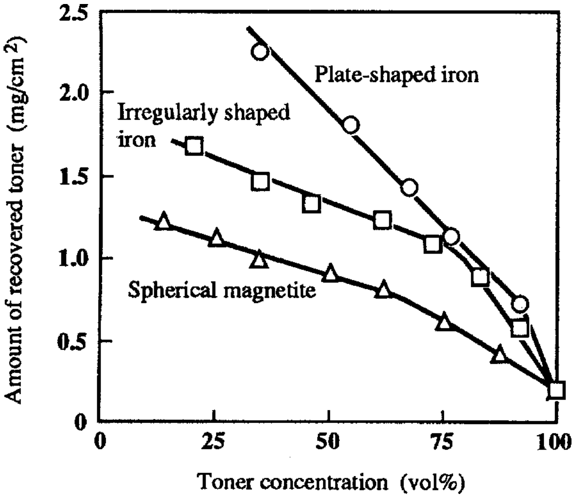

Figure 7. Toner concentration expressed as a volume percentage and the amount of residual toner. The volume resistivity of the plate-shaped iron carrier was approximated 10^{12} Ω*cm.*

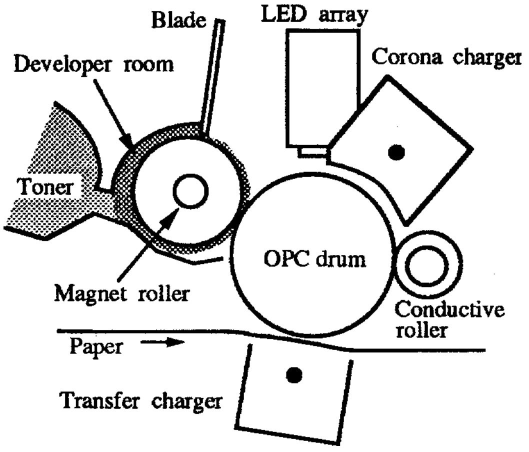

Figure 8. The configuration of a cleanerless process.

3. Application in a Page Pringer

Figure 8 shows the configuration of a cleanerless process that is designed without a conventional cleaner unit and a magnetic sensor controlling Tc. This simple developing unit is realized by using the new two-component developer that exhibits a high η and a high ability to recover the residual toner. Also, the developer room at the rear of a developing roller is important. The carriers packed in this room prevent toner from being supplied excessively. Then

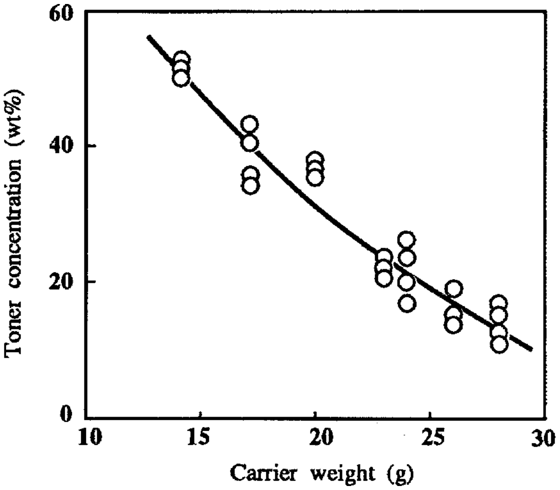

Figure 9. Carrier weight and toner concentration. The capacity of the developer room was approximately 17 cm^3.

Tc is automatically controlled in it. Figure 9 shows the relationship between the amount of carrier and Tc when the capacity of the developing room is approximately 17 cm^3. It is possible to control Tc with the width of roughly 10 wt%. A conductive roller between the transfer and charger units aids in recovering the residual toner and erases the surface charge of the photoreceptor. We achieved excellent print quality when Tc was controlled between 20 wt% and 30 wt%.

Summary

We studied a two-component developer consisting of a magnetic toner and a magnetic carrier for a cleanerless electrophotographic process. The magnetic toner by the emulsion polymerization technique exhibits a high transfer efficiency η and the maximum η is nearly 100 %. Also, the small iron carrier with low resistivity has a good ability to recover the residual toner. Finally the new two-component developer allows compact page printers to be designed without conventional cleaner units and magnetic sensors for controlling toner concentration.

References

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3. J. Nakajima, et al., *Electrophotography—Bases and Applications,* 1st ed., Corona Publishing Co., Ltd., 1988, p. 171.