A New Printing Method with Transfer of Toners by Flash Light

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Abstract

A new printing method of direct toner transfer by irradiation of high-intensity light is proposed. Two-dimensional patterns are generated with a flash of light. Uniformly attached toner on a transparent sheet is exposed through a pattern mask located between the flash lamp and the transparent sheet. Negative patterns of the mask are generated only by transferring toners in the exposed portions from the transparent sheet to the paper. Toner transfer is investigated and the main cause is considered to be toner ablation with the strong flash of light. We evaluated the amount of toner transferred and the image resolution. By applying an electric field to the charged toner particles, the amount transferred was increased and the image resolution was improved. The basic pattern generation experiment was performed and the resolution was found to more than 300 dpi.

Introduction

The electrophotographic process is used in many kinds of image forming machines such as copy machines and laser printers. It has the advantages of high resolution and high printing speed, but has complicated processes such as charging, exposure, developing, transfer, fixing and cleaning. Several new processes have been proposed to eliminate these complications.[1,2] Recently, we proposed a new method for image pattern generation with toner transfer.[3] In this method, particles of toner are transferred by the direct irradiation of high-intensity light through a mask. A new type of printer can be designed with a printing process which uses this pattern generation method, rendering unnecessary photoconductive members and complicated printing processes such as charging or discharging of photoconductive members.

This paper presents the new printing process and evaluates the printing method. The process of toner transfer is also explained.

Image Forming Processes

Figure 1 shows the configuration of the apparatus used to form the image.[3] A toner layer was distributed uniformly on a transparent plastic sheet. To form an image pattern, a pattern mask was sandwiched between a glass substrate and the transparent plastic sheet. We used a xenon flash lamp as a light source. The light image was irradiated to the toner layer through the sheet. Part of the irradiated toner was transferred to a piece of paper facing the toner layer and formed a negative image pattern of the mask on it. We can make a new type of printing system if we use a transparent endless belt or drum on which toner is carried and a controllable spatial modulator such as an LCD panel in place of the pattern mask. The new printing process is as follows: (1) a toner layer is distributed uniformly on a transparent belt or drum; (2) the toner layer is exposed to the high-power light image pattern formed by the controllable spatial modulator. Part of the toner exposed to light is transferred to the paper and forms a negative image pattern of the mask; (3) the image pattern is fixed to the paper. The light energy that forms image patterns is high enough to melt toner, so the light can also be used to fix the toner by irradiating again. This printer principle has many advantages. A photoconductive member is unnecessary since toner is exposed directly to the light modulated on the image information through the transparent belt or drum. Charging and transfer devices are also unnecessary. In addition, the exposure, developing, and transfer processes of conventional electrophotography can be done simultaneously since the toner moves only by the irradiation to a light image pattern. As a result, the image forming process is drastically simplified. The light energy that forms image patterns also fixes the toner, replacing a fixing device such as a heat roller in the conventional electrophotographic printer. There is also the advantage that the toner layer can be regenerated cyclically, compared with the thermal transfer printer which uses an ink ribbon.

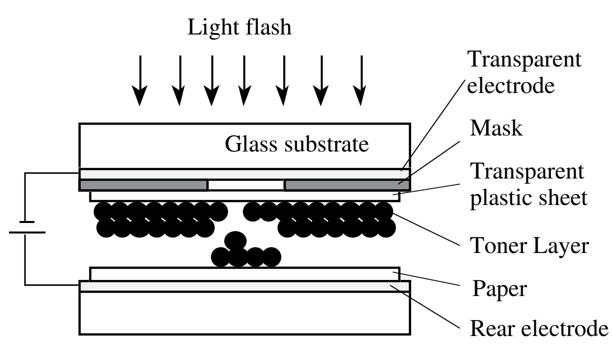

Figure 1. Experimental setup

The Process of Toner Transfer

We investigated an irradiated part of a toner layer with a high-speed video camera (maximum recording speed: 1000 frame/sec). In this experiment, we used a laser diode with a wavelength of 830 nm as a light source. A pulsed laser beam was focused on the toner layer. The side view of the irradiated part of the toner layer was observed with a microscope and recorded on the high-speed video tape,. The beam diameter at the irradiated part was about 50 μm (the average power density was about 2.5 x 10^3 W/cm^2).

Figure 2 shows photographs recorded on the high-speed video tape. The white particles to the right are toner particles. The laser pulse was irradiated from the right side through the transparent sheet. We observed a jet of smoke-like matter given off from the toner layer by irradiating a laser pulse onto it (Figure 2(b)). After irradiation, toner particles at the irradiated part disappeared (Figure 2(c)). We think that the toner particles were pushed by this jet from the toner layer. It seems that toner ablation was the main cause of the movement.[2] We observed that there was a time interval between the toner removed and the start of laser irradiation. These intervals became longer as the irradiation power was lowered. We thought that the intervals showed to the time to heat the toner up to the temperature at which ablation occurs. The maximum inside temperature of a toner particle was calculated when the particle was irradiated by the flash lamp. When one particle was irradiated in air at 0.73 J/cm^2 for 0.4 msec, the maximum temperature in the particle increased more than 600°C. Using the same flash lamp, Mitsuya et al.[4] measured the time-dependence profile of the surface temperature of the toner layer when directly irradiated from the air side, and showed that the peak surface temperature of toner irradiated by the light from the flash lamp supplying 440 J of electric power was over 300°C. This temperature is much higher than the melting point of the toner's base plastic material (e.g., polystyrene, polyethylene), so we concluded that the toner was transferred by ablation.

Printing Characteristics

Evaluation of the Transferred Amount

We examined the printing characteristics of the new printing process. First, we measured the amount of toner transferred by the irradiating flash of light. The experimental setup is shown in Figure 1. A glass substrate with a transparent electrode was used to support a transparent plastic sheet on which a toner layer had been deposited. This toner layer was formed using a conventional copy machine from which we had removed the fixing device. A black copy machine toner was used. A piece of paper or a plastic sheet was placed on the rear electrode at a distance of about 100 μm from the toner layer surface. A xenon flash lamp was used as a light source. The flash lamp (emission efficiency: 0.3) was supplied with 200 ~ 440 J of electrical energy. The irradiation area was 180 cm^2, so the optical energy density was 0.32 ~ 0.73 J/cm^2. The exposure time was 0.43 msec full width at half maximum. Toner was exposed to light from the flash lamp through the substrate and the transparent sheet.

Figure 3 shows the amount of transferred toner as a function of the irradiated energy density. In this experiment, the toner layer was irradiated uniformly without a mask. The transferred amount increased linearly with irradiation energy density. The initial amount of toner applied was 0.76 mg/cm^2, so the maximum transfer toner ratio was about 15% at 0.73 J/cm^2. Since the transferred amount increases linearly with the irradiation energy density, the gradation of images can be made by changing the irradiation energy density. This figure also shows that toner is not transferred until an energy density threshold of 0.22 J/cm^2 is exceeded. Although toner was transferred by irradiation of high-power light, the amount of transferred toner was too small to form a high optical density pattern. Toner particles can be transferred by overcoming the adhesive force with the flash of light. The adhesive force of toner particles to the plastic sheet and neighboring toner particles was stronger than that acting on the irradiated toner, so the amount of transferred toner was small. To increase the amount transferred, an electrostatic force was introduced to weaken the adhesive force to toner particles. We therefore supplied a voltage between the transparent electrode and the rear electrode to attract charged toner particles to the paper, as shown in Figure 1. Figure 4 shows the amount of transferred toner as a function of supplied voltage between the two electrodes. By supplying a higher voltage, more toner was transferred during irradiation. The maximum transferred toner amount was 68% of the initial amount of toner

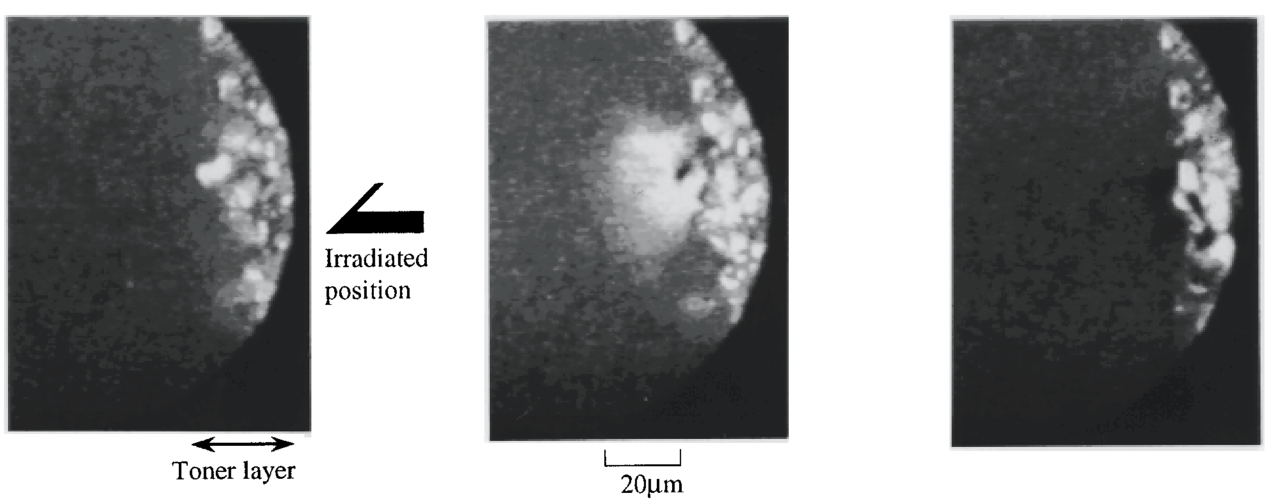

Figure 2. Pictures of irradiated part of toner layer

applied. In applying an electric field without flash light irradiation, weakly adhered toner would also be transferred. Thus, Figure 4 also shows the amount of transferred toner without flash light irradiation. The amount of toner transferred by the electric field alone was much less than that transferred by flash light irradiation. We concluded that the increase in the amount transferred was caused by the electrostatic attraction weakening the toner's adhesive force.

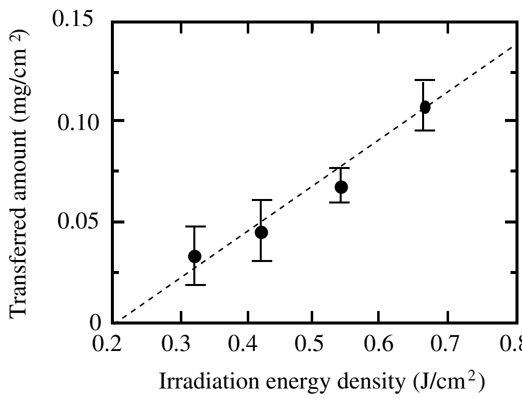

Figure 3. The amount of transferred toner as a function of the irradiation energy density.

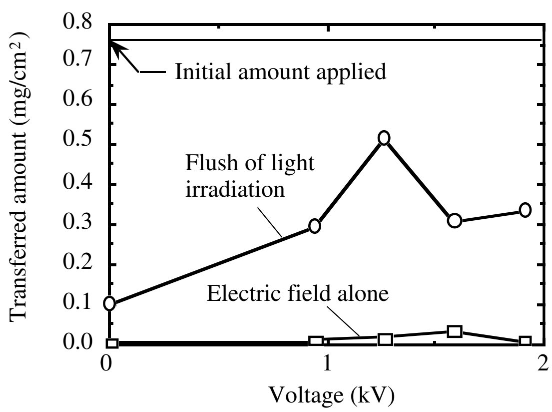

Figure 4. The amount of transferred toner as a function of the voltage supplied to parallel electrodes.

Evaluation of the Resolution of Images

Next, we evaluated the resolution of this printing method using the mask of the positive resolution test pattern. We found that the resolution of images formed by irradiation alone was only about 180 dpi. There are two main causes of this low resolution. One was that the toner particles were pushed into various directions by the light irradiation because the light of the flash lamp used in the present study was not collimated. The second was that toner particles were pushed by the flash of light, so the direction of motion was determined by the irradiated positons of toner particles. We therefore applied the electric field to the toner particles to improve the poor resolution caused by this second point. Toner particles separated from the transparent sheet were attracted to the paper by the electric field, and thus reduced the dispersion of toner particles.

Figure 5 shows the resolution of images formed as a function of the supplied voltage between the transparent electrode and the rear electrode. The resolution was improved by applying an electric field. The resolution improved to more than 300 dpi at around 1 kV, with a maximum resolution of 360 dpi. On supplying more than 1.4 kV, blooming occurred and the resolution was degraded.

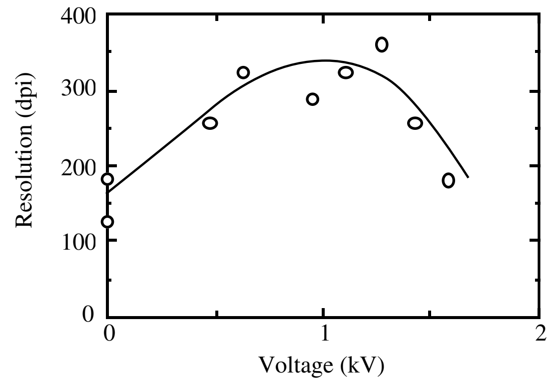

Figure 5. The resolution as a function of the voltage supplied to parallel electrodes.

(a) Without Electric Field (b) With Electric Field

Figure 6. Image samples.

Image Samples

Figure 6 shows two image pattern samples formed on plastic sheets. One image was made without the electric field and the other was made with it. After the image pattern was formed, the image parts of toner were fixed by irradiating a flash of light through the same mask used to form pattern. Comparing the two images, it is apparent that the optical image density was increased by applying the electric field.

Conclusion

A new printing method of direct toner transfer by a flash of light was proposed. Image patterns were generated by directly irradiating uniformly distributed toners on the transparent sheet to the strong flash of light through a pattern mask. Using this printing method, the image forming process was considerably simplified. The toner transfer process was carried out mainly by toner ablation with the high-power flash of light. By applying the electric field to the charged toner particles, the amount of toner transferred was increased and the image resolution of was improved to more than 300 dpi.

References

1. J. Johnson and O. Larsson, *Proceedings of t he Ninth Int'l. Congress on Advances in Non-Impact Printing Technologies*, 509 (1993).
2. I. Y. S. Lee, W. A. Tolbert, D. D. Dlott, M. M. Doxtader, D. M. Foley, D. R. Arnold and E. W. Ellis, *J. Imag. Sci. Tech.* **36**, 180 (1992).
3. T. Sugita, A. Arimoto, T. Mitsuya, Y. Takuma and N. Hoshi, *Opt. Lett*. **20**, 1224 (1995).
4. T. Mitsuya, T. Kumasaka, S. Fujiwara and S. Nishino, *Opt. Engineering*, **30**, 111 (1991).