A High Definition and Continuous Tone Color Image in Dye Thermal Transfer Printing by Laser Heating

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Abstract

A high quality image with both properties of a high definition and good continuous tone can be obtained easily by a laser thermal transfer printing using dye sublimation type medium because a laser light is focused to small spot and heat energy can be controlled by the pulse width modulation of laser light. The ink donor sheet is composed of the laser light absorbing layer and the color dye donor layer. We have investigated on an image resolution and effect of a light-heat conversion efficiency of IR light absorbing materials on tone reproduction curve. A high definition image with an image resolution of over 8000 dpi was printed by laser thermal dye transfer. Carbon black and metal-phthalocyanine pigment were used as a light-heat conversion material. As experimental results of dye transfer from the ink donor layer to the receiving sheet by laser heating, each sample exhibits different dye transfer characteristics according to kind of light-heat conversion materials. By the measurement of absorption spectra of laser light absorbing layers after laser heating, it was cleared that IR absorbing dye was decomposed by thermal reaction and the crystal phase of phthalocyanine pigment was transformed by laser heating.

Introduction

In a dye sublimation transfer printing by laser heating, it is possible to obtain a high definition and continuous tone image easily because a focused laser light is used as heat source and transfer amount of dye can be controlled by changing the energy of laser light. A double layered ink donor sheet for laser dye thermal transfer printing is composed of a laser light absorbing layer that converts laser light into heat, and an ink donor layer that transfers dye to a receiving sheet.[1] In the previous paper, we have studied on the dye transfer mechanism from an ink dye layer of double layered ink donor sheet.[2,3] In this report, we focus on a high definition and an effect of a light-heat conversion efficiency of IR light absorbing materials on a continuos tone reproduction. Converting the light energy of laser light into the heat energy is requested to the laser light absorbing layer. In order to compare light-heat conversion efficiency for several IR light absorbing materials, we have discussed tone reproduction curves depending on changes of the light-heat conversion material in the laser light absorbing layer of the ink donor sheet. Absorption spectra of laser light absorbing layers before and after laser heating were measured because there were possibilities that physical properties of light-heat conversion materials were changed by laser heating under a condition of high exposure energy.

Experimental

Principle of Laser Dye Thermal Transfer Printing

A principle of laser dye thermal transfer printing is shown in Figure 1. An ink donor sheet is composed of a laser light absorbing layer and color dye layer. A laser light absorbing layer is exposed to a laser light that is focused by an optical lens, and then a laser light energy is converted into heat energy and heats color dye layer. By this energy conversion process, a sublimation dye of ink layer is transferred to a receiving sheet, and dye image is formed on a receiving sheet.

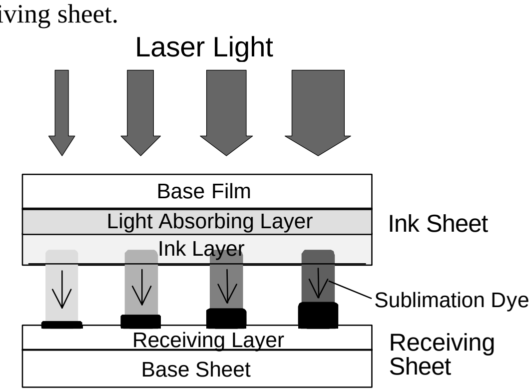

Figure 1. The principle of laser dye thermal transfer printing.

Preparation of Ink Sheet

A double layered ink donor sheet for laser dye thermal transfer printing is composed of a laser light absorbing and an ink donor layer as is shown in Figure 2. The laser light absorbing layer was coated on the transparent polymer base film by a wire bar coating. Carbon black, titanyl phthalocyanine pigment (TiOPc), and three kinds of near-IR absorbing dyes: metal complex organic compound (Mitsui Chemical Co., Ltd., PA-1006), cyanine dye (Nippon Kankoh-Shikiso Kenkyusho Co., Ltd., NK-2204) and vanadyl phthalocyanine dye (VOPc(S-Naph)$_{16}$, Yamamoto Chemicals, Inc.) were used as light-heat conversion material. These materials have a good optical absorption in the infrared wavelength of 825 nm at which the laser diode radiate infrared light. Polycarbonate polymer (PC, Teijin Kasei Co., Ltd., Panlite K1300) was used as the binder polymer for the laser light absorbing layer. The pigment was dispersed using an ultrasonic dispersion technique and near-IR dye was dissolved in PC polymer. we have prepared laser light absorbing layers to have an almost similar absorbance and thickness by adjusting the mixture ratio of light-heat conversion materials to PC polymer in order to compare laser light absorbing layers under the same condition apparently.

A magenta sublimation dye was coated as an ink donor layer on the laser light absorbing layers by vacuum evaporation. The thickness of ink donor layer is 1.5 µm.

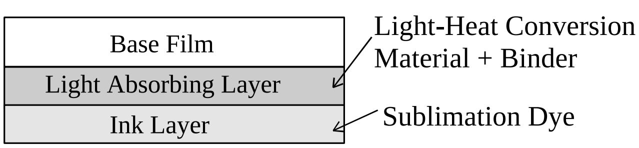

Figure 2. A double layered ink donor sheet for laser dye thermal transfer printing.

Printing and Measurement

A schematic diagram of the laser thermal dye transfer printing system is shown in Figure 3. There are three main sections: an optical head which includes the laser diode with power of 100mW and wavelength of 825 nm, a printing drum which performs the main scanning, and a sub-scanning section which moves the optical head using a micro-stage. The laser diode is operated according to the image signals, and the drum rotation and micro-stage movement are controlled by a microcomputer. The ink donor sheets in contact with the receiving sheet were set on the printing drum, and continuous tone images (grayscale data) with resolution of 2540 dpi were recorded by modulating pulse width of laser light under the recording condition which a laser power is 40 mW and recording speed is 156 mm/s. A spot size of laser light is selected on 3 µm which is a possible minimum spot size at this printing system. The characteristics of continuous tone reproduction were obtained by the measurement of average optical density at each pulse width using optical densitometer.

To observe the change of physical properties of light-heat conversion materials by laser irradiation, absorption spectra of laser light absorbing layers (without ink donor layer) before and after laser irradiation were measured by a spectrophotometer using a integrating sphere attachment.

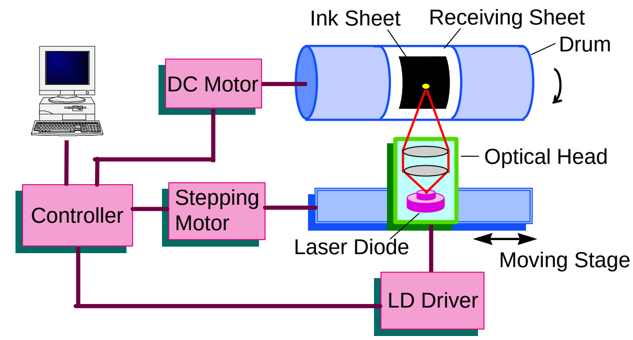

Figure 3. A schematic diagram of the laser thermal dye transfer printing system.

Results and Discussion

High Resolution Character Image

Characters were printed at resolution of 8470 dpi by laser thermal dye transfer. Magnified views of printed sample are shown in Figure 4. A good image was obtained at a high pixel resolution. We have reported that the maximum pixel resolution is 10,160 dpi in laser thermal dye transfer.[4]

Although it is generally easy for dye sublimation dots to spread on the receiving sheet, the resolution is improved significantly by laser printing. This is cause that a laser spot is very small and ink donor layer is contact with receiving sheet by thermal expansion.

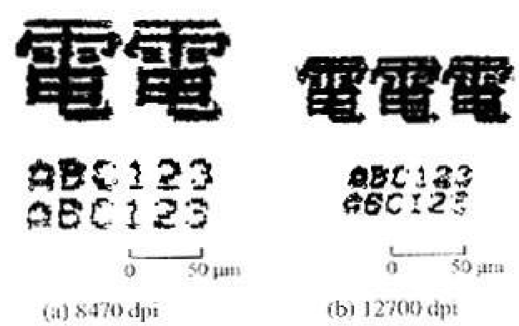

Figure 4. Magnified views of printed laser thermal transfer character image.

Tone Reproduction Curves

Figure 5 shows the relationship between pulse width of laser light and optical density of transferred dye using 3 µm spot size of laser beam (on focus) width. For the printing condition using focused laser beam, the sublimation dye was transferred in response to pulse width from the range of short pulse width for all light-heat conversion materials. However, the optical density for carbon black and VOPc dye is clearly higher than that for the other materials, and goes to the saturated optical density quickly. After all, the experimental result indicates that the laser light absorbing layers using carbon black and VOPc dye have a high heat generation efficiency.

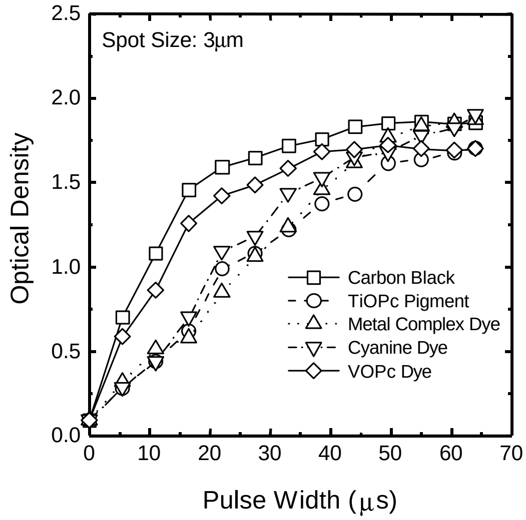

Figure 5. Relationship between optical density and pulse width. Spot size of laser light is 3 μm.[5]

A light-heat conversion efficiency of IR material was checked using a direct thermal transparent film. After the IR absorbing layer contacted with the direct thermal film was exposed to laser light, the optical density of colored image area on the film by chemical reaction was measured. Figure 6 shows the relationship between an optical density and the pulse width. The laser light absorbing layer consisted of carbon black powder and binder polymer exhibited good light-heat conversion property as is shown in this figure.

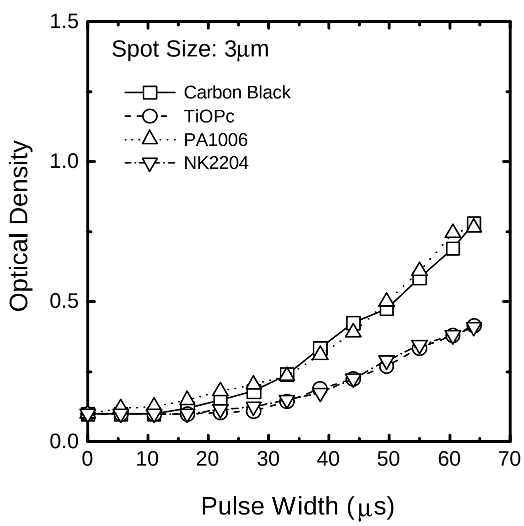

Figure 6. Relationship between an optical density and the pulse width on a direct thermal transparent film printed by laser heating.

Absorption Spectra for Laser Light Absorbing Layers

Figure 7 shows absorption spectra of laser light absorbing layers (without ink donor layer) before and after laser irradiation. Spectra changes by laser irradiation are little for carbon black. It is considered that absorbed laser light is converted into heat efficiently with little damage by laser irradiation due to the high heat stability of carbon black. The phthalocyanine dye exceeds the cyanine dye in heat and light stabilities, and can convert light into heat with a situation that a damage such as a decomposition is little in comparison with the other dyes under the printing condition of high exposure energy using focused laser light. For the TiOPc pigment, the crystal phase transformation by laser irradiation was observed as shown in Figure 7(B), though the phthalocyanine has high heat and light stabilities, and an absorbance at the wavelength of laser light was decreased. On the other hand, there was no problem of the crystal phase transformation for the VOPc dye because of the dye molecule was dissolved in the polymer matrix compared with that existed in the crystal state for the TiOPc pigment. If a speed of the dye decomposition or crystal phase transformation is faster than the pulse width of laser light, the absorbance at the wavelength of laser light will be decreased during the pulse duration, and so a decrease of heat generation will be expected.

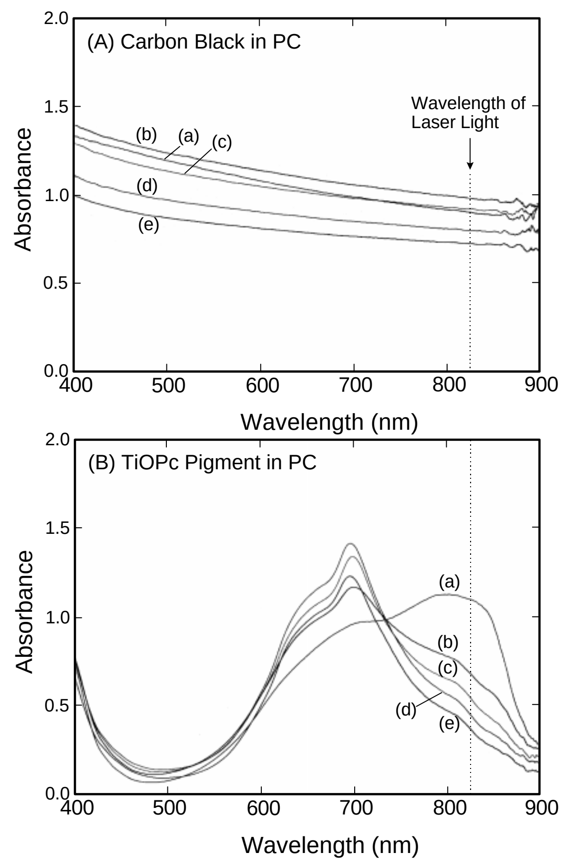

Figure 7 Absorption spectra for laser light absorbing layers at different irradiation times (a) 0 [non-irradiation], (b) 16, (c) 32, (d) 48 and (e) 64 μs. Spot size of laser light is 3μm.

Conclusions

It is concluded that a high definition and good continuous tone image can be obtained by laser thermal dye transfer. A high definition image with an image resolution of over 8000 dpi was printed by laser thermal dye transfer.

The heat generation of two light-heat conversion materials such as carbon black and TiOPc pigment for the laser light absorbing layers was discussed on the basis of the amount of dye transferred from the ink donor sheet and the absorption spectra of laser light absorbing layers after laser irradiation.

It was confirmed that the different heat generation was affected with the decrease level of laser light absorption by the decomposition reaction or the crystal phase transformation of the materials during laser irradiation.

References

1. M. Kinoshita, Y. Odai and T. Kitamura, *Proceedings of 5th International Conference on High Technology, World Techno Fair in Chiba '96*, 298 (1996).
2. T. Kitamura, M. Kinoshita and Y. Odai, *Proceedings of 12th International Conference on Digital Printing Technologies*, 258 (1996).
3. M. Kinoshita and T. Kitamura, *Proceedings of 13th International Conference on Digital Printing Technologies*, 765 (1997).
4. Y. Odai, M. Katoh, T. Kitamura and H. Kokado, *J. Imaging Science and Technology*, **40** (3), 271 (1996).
5. M. Kinoshita, K. Hoshino and T. Kitamura, *Proceedings of Pan-Pacific Imaging Conference / Japan Hardcopy 98*, 338 (1998).