Development of Printing Method to Produce High-glossy Images with UV Inkjet Printer

Takuya Yamashita[1], Masaru Ohnishi[2] Hironori Hashizume[2] and Takao Abe[1]
(1)Division of Science and Technology, Shinshu University, Ueda City, Nagano Prefecture, Japan
(2) R & D Division, Mimaki Engineering CO., LTD. Tomi City, Nagano Prefecture, Japan

Abstract

While UV-curable inkjet printers have come into wide use, these printing systems have a few problems to be solved. We took notice that the printed images showed relatively low gloss. The decrease in gloss is known to be caused by the fact that UV-curable ink changes into solid before leveling off under irradiation of UV light. We have been trying to develop the new application of UV-curable inkjet printing to obtain high glossy images on the surface of various articles. We had already presented a prototype as one of such trials at ICJ2012, the annual conference of the Imaging Society of Japan in 2012. The process was called DVT which was the decompression transfer printing process with a UV-curable inkjet printer and a vacuum chamber. The DVT had some problems such as low image quality and troublesome process with manual operation. The first improved process which was called DVT-I was proposed at ICJ2013 held in Tokyo last June. However there still remained a few problems, so that we have continued our study and then developed an automated machine in this study. High image gloss has been obtained by excluding air bubbles during the decompression process. Thus we have been able to create products with high quality and glossy images on the surface of various articles.

Introduction

We proposed the decompression transfer printing process with a UV-curable inkjet printer and a vacuum chamber, which was named DVT, for the first time at ICJ2012, the annual conference of the Imaging Society of Japan in 2012 [1]. The DVT had the problem about the distortion in images. It resulted from the fact that a silicone rubber sheet stretched easily during the image-transfer process, where the silicone rubber sheet was used as an intermediate printed-image acceptor to transfer the image to the final object to be decorated. The object to be decorated is called printing media hereafter in this paper.

Considering this fact, we tried to use a polyethylene film for an intermediate image acceptor instead of a silicone rubber sheet. In this case, the silicone rubber sheet was placed onto the backside of the polyethylene film to press it to the object at the image transfer stage in a vacuum chamber. We called this improved process DVT-I. We proposed two kinds of DVT-I procedures, that is to say, DVT-I1 and DVT-I2 at ICJ2013 in last June [2]. The difference in DVT-I1 and I2 was the absence and the presence of a UV-curable clear ink layer, respectively. The clear ink means that the ink does not contain colorants. The clear ink layer was placed on the printed color images to play a role as an adhesive layer between a polyethylene film and the printing media. The DVT-I1 and I2 had a few problems for practical usage. It needed troublesome manual operation in a series of its workflow. This was a serious problem from the industrial point of view. There was also a serious problem about the quality of images finally formed on the printing media. There were lots of small circled image voids those were produced by air bubbles remaining between the polyethylene film and the printing media.

We have tried to solve the problems described above in this study. This paper describes the following matters: Details of the process of DVT-I, comparison of the image samples between DVT-I1 and DVT-I2, and the development of an automated machine for DVT-I. It is also mentioned that the automated decompression method has brought to reduce air bubbles under a polyethylene film in a vacuum chamber, and as a result we have been able to obtain high image quality.

Process of DVT-I1 and I2

The DVT-I is classified into I1 and I2 [2]. They are almost the same as each other. Only one difference is that a solid pattern is printed with UV-curable clear ink after the color image printing in DVT-I2, while such the printing is not applied to DVT-I1.

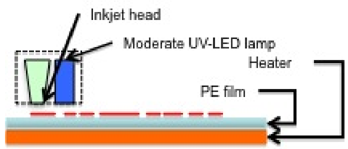
A series of the stages of DVT-I1 procedures is as follows.

(1) As shown in Fig. 1(a), color image printing is carried out by an inkjet printer with UV-curable colored ink containing organic solvent. UV-curable inkjet printer UJF-3042 has been used through this study, which is manufactured by MIMAKI ENGINEERING CO., LTD. Polyethylene (PE) film is selected for an intermediate printed-image acceptor, because adhesion of UV-curable ink to PE film is relatively weak and PE film has the property of low elasticity. These facts are important at the stage of image transfer in a vacuum chamber. To make the viscosity of printed ink slightly higher, the solvent in the ink is evaporated by heating after image printing, and then moderate UV light is irradiated (9.2 mJ/cm^2). By these treatments the ink becomes not to spread out of the printed area. Then, the residual solvent in the ink is evaporated by a high-temperature heater.

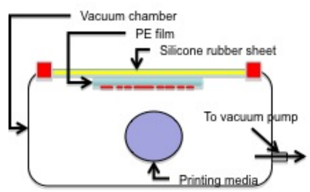
(2) The PE film as an intermediate printed-image acceptor is set in a vacuum chamber as shown in Fig. 1(b), where the printed ink surface faces the printing media.

(3) As shown in Fig. 1(c), the inside of a vacuum chamber is decompressed. Enough UV light is irradiated to solidify completely the color ink of printed images (1780 mJ/cm^2). A silicone rubber sheet works here to press and wrap the PE film and results in the effective image transfer from the PE film to the surface of the printing media.

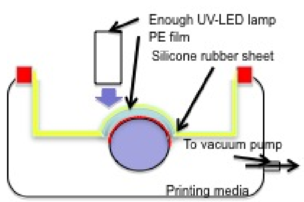
Figures 2(a)-2(d) show the process of DVT-I2. During image printing, UV light irradiation is carried out to make the ink hard completely. Then, a solid pattern is printed to cover the whole printed images by an inkjet printer with UV-curable clear ink which works as adhesive agent between the PE film and the printing media in a vacuum chamber. A UV lamp is not applied when printing the clear ink, while a heater is used to evaporate the organic solvent in the clear ink after the printing (65°C). The image transfer stage is the same as DVT-I1.



(a) Printing color image, where curing of the images is not enough.



(b) Setting PE film.



(c) Decompressing.

Figure 1. *Process of DVT-I1.*

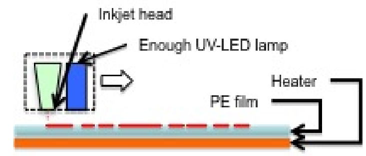
Problems of DVT-I

Figure 3(a) shows the result of DVT-I1. There are many image voids those have been brought by air bubbles remaining between the PE film and the printing media in a vacuum chamber (Fig. 1(c)). Figure 3(b) is a photograph of the result of DVT-I2, where a smear like a patch of damp is seen in a circled area. Figure 3(c) is an enlarged photograph of it. The smear seems to be caused by the clear ink which has spilled out from the primary image area at the image transfer stage. (Fig. 2(d)). Figure 4 shows the result of another experiment, where we can see the clear ink spilled out from the image part. As described above, both of DVT-I1 and I2 have the problems of the image quality of their final products.

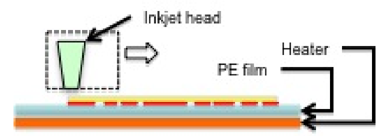
Experimental

We have used the printer and materials described below. Inkjet printer: "UJF-3042FX" manufactured by MIMAKI ENGINEERING CO., LTD. Silicone rubber sheets and PE film are supplied by TIGERS POLYMER CORPORATION and Shin-Kobe Electric Machinery Co., Ltd, respectively.

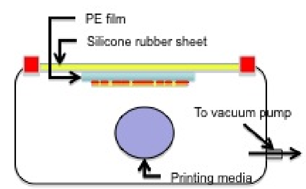
All of the UV-curable inks used in this study contain a low-boiling-point organic solvent. We have called this kind of ink SUV ink.



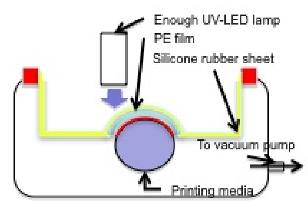
(a) Printing color images with enough curing.



(b) Solid pattern printing with clear ink.



(c) Setting PE film.

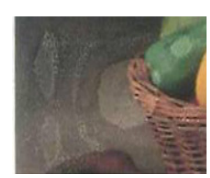


(d) Decompressing and UV irradiation.

Figure 2. *Process of DVT-I2.*

(a) Result of DVT-I1.

(b) Result of DVT-I2.



(c) Enlarged photograph of wholed part Fig. 3 (b).

Figure 3. *Results of Manual DVT-I.*

Results and Discussion

We have tried to solve the above problems at the image transfer stage, that is, the phenomenon of ink spilling out and the air bubbles remaining under the PE film in a vacuum chamber.

Figure 5 shows the absorption spectra of materials and the radiation spectra of the UV-LED used in this study. UV light can transmit both of silicone rubber sheet and PE film. However, it seems to be difficult to transmit the printed image part. Especially black ink does not transmit UV light as seen in Fig. 4. Consequently the clear ink is not cured sufficiently under the color images and spills out from the image area.

Figure 4. Smear caused by clear ink spilled out from printed image area.

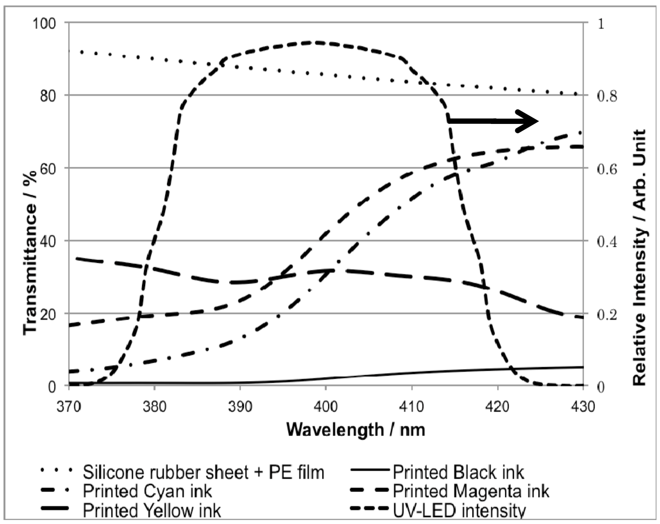


***Figure 5.** Relation among Wavelength, transmittance of black ink and silicone rubber sheet + PE film and relative intensity of UV-LED emission.*

The SUV ink can control the viscosity in wider range than the conventional UV-curable ink by evaporating its solvent. Since the fluidity of the ink decreases with increasing its viscosity, we have evaporated the organic solvent to prevent the unnecessary ink spill out. Figure 6(a) shows the relation between the distance of clear ink spilling out of the printed area and heating time on a heater with the temperature at 65°C. When the heating time exceeds 420 seconds, the clear ink spill out is not seen. This fact suggests strongly that the clear ink is confined to the print area. Furthermore, to obtain a clearer insight into viscosity control, we measured the viscosity of the ink with evaporating an organic solvent by heating. Figure 6(b) shows the relation among the decrement of clear ink (%), change in the viscosity, and the heating time. For example, the result of this figure indicates the amount of ink has decreased by 30% and the ink viscosity has increased to 61 mPas by heating for 420 seconds. Such the relation suggests that the control of the ink viscosity is important to improve the quality of transferred images.

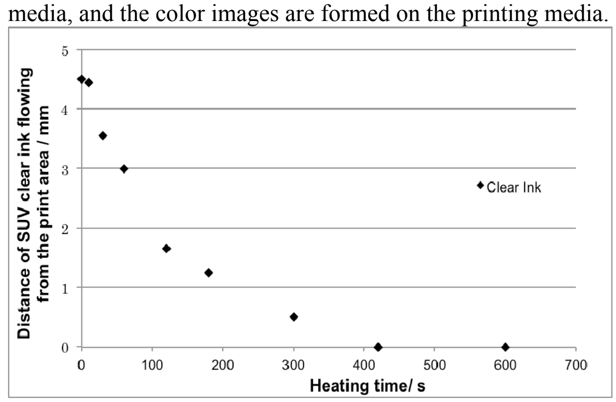
To solve the problem of image voids, we have made some improvement at the image transfer stage by introducing an automatic mechanism. Figure 7 shows conceptually the automated decompression transfer printing setup. Image transferring procedures are as follows:

(1) PE film with printed images is placed under a silicone rubber sheet by adhering lightly. They are hold with a silicone rubber holder as shown in Fig. 7(a). The side of printed images is downward.

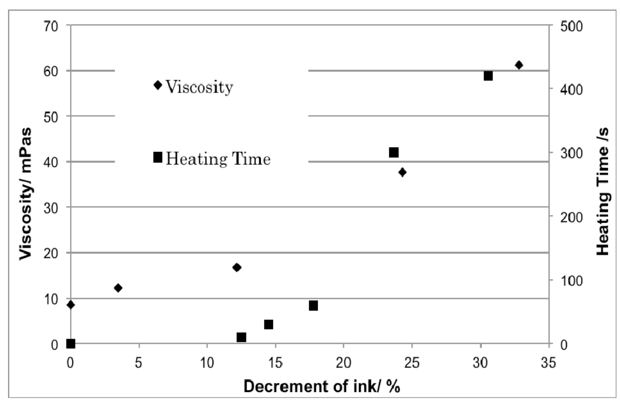
(2) Printing media is placed in room B. The upper lid is then lowered so as to create rooms A and B. Those are separated by the silicone rubber sheet as shown in Fig. 7 (b). Both rooms are then decompressed to very low air pressure. The amount of decompression is over 70 kPa.

(3) Then, air pressure of room A is returned to the atmospheric level. Based on the air pressure difference between rooms A and B, the silicone rubber sheet which is holding the PE film is pressed firmly to the printing media as shown in Fig. 7 (c). UV light is irradiated at this time. This process ensures that enough pressure can be applied to the surface to which the images are to be transferred.

(4) Finally, the silicone rubber sheet is removed from the printing media, and the color images are formed on the printing media.



(a) Distance of SUV clear ink spilling out of the printed area.

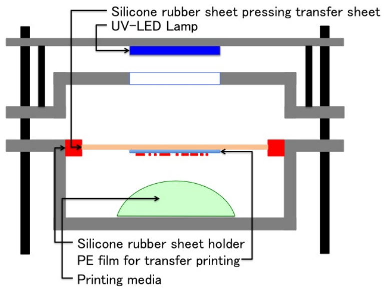


(b) Relation among decrement of clear ink, viscosity and heating time.

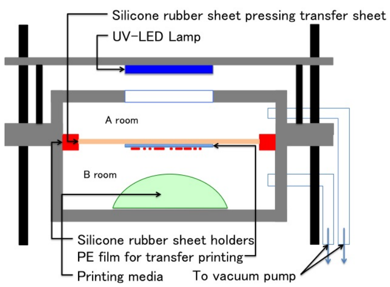
***Figure 6.** Change in viscosity of clear ink.*

Figure 8 shows the result by the improved process of DVT-I2. Sharp and glossy images have been obtained on the surface of the object to be decorated.

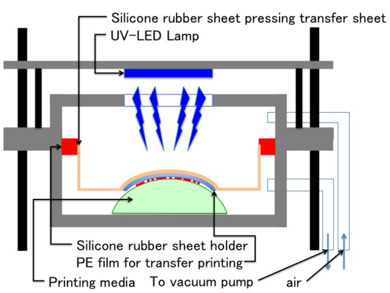
The comparison of the values of glossiness is shown in Table 1. As seen in this table, the process of DVT-I can produce highly glossy images.



(a) PE film is held in place by the silicone rubber holders.



(b) Upper lid is lowered to create room A and room B.



(c) With pressure inside room A returned to atmospheric level, a UV light is irradiated.

Figure 7. *Process of automated DVT-I Process.*

Figure 8. *Printed images with optimum viscosity*

Table 1. Value of Glossiness by each transfer process

Process	*Glossiness(60°)*
Automated DVT-I2	*79.8*
Manual DVT-I2	*75.4*
Manual DVT-I1	*74.3*
IJ Direct Print	*27.5*

Summary

The following matters have been found in this study.

1. The viscosity of the clear ink affects the quality of transferred image directly. So the heating condition of the clear ink should be severe. The time for DVT-I process may be shortened if more effective heating condition is applied.
2. We have created a prototype of an automated decompressing machine that can bring the effective decompression, and as a result succeeded to remove air bubbles between the PE film and the printing media. Under the previous experimental condition, we could reach only 16% reduction of air pressure in a vacuum chamber. However, 69% reduction of air pressure has been achieved in this study. As a result, air bubbles have reduced at the image transfer stage and image voids have drastically disappeared on the surface of products.
3. It took about 5 minutes at the image transfer process of the previous manual treatments in a vacuum chamber. On the other hand, the automated DVT-I process has decreased the time to less than 2 minutes.

Although the automated transfer process requires careful consideration of various conditions that can affect the final result of the transfer process, this transfer process has the potential to be established as an innovative transfer printing technique. It can be used to print clear images on the surface of various articles.

References

[1] Hironori Hashizume and Masaru Ohnishi; Development of Digital Transfer Printing Processes with Inkjet Printer ICJ2012, A-12, pp77-80.

[2] Takuya Yamashita, Masaru Ohnishi, Hironori Hashizume and Takao Abe; Improvement of Digital Transfer Printing Method in Decompressed Atmosphere Using UV curable inkjet printer ICJ2013, A-13, pp141-144.

Author Biography

Mr. Takuya Yamashita is a graduate student, Division of Science and Technology, Shinshu University, japan. His major is material and chemical engineering.