Development of a UV Inkjet System for Printing Flexible Packaging

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Abstract

Technologies for printing small lots on flexible packaging are advancing. The demand for the using digital printing for small lots has increased. Fujifilm is developing a digital printing system using a UV inkjet system. We discovered three issues: odor, safety, and adhesion of ink films. We solved these issues by introducing three technologies: a nitrogen-purge UV-exposure system, multi-functional monomers, and an undercoating.

1. Introduction

Printed flexible packages are widely used for food, toiletries and pharmaceuticals. The global flexible packaging market is said to be an over-60-trillion-yen market. The market is expected to grow. Photogravure and flexography have been mainly used for printing flexible packaging materials. Those analog printing methods, which use printing plates, now need to meet demanding requirements on cost and delivery time as customer needs are changing. Customers are requiring high-mix, low-volume printing, printing on small lots of packages for diversified products.

Unlike analog printing, digital printing does not require a printing plate. It is better than analog printing in cost and delivery time. Digital printing is considered to suit high-mix, low-volume printing, the present market trend.

FUJIFILM has developed a digital inkjet printer for flexible packaging. We have incorporated our UV inkjet printing technology developed in the wide format printing business into the inkjet printer MJP20W manufactured by Miyakoshi Printing Machinery, Co., Ltd.

The purpose of this paper is to describe this inkjet system and report problems of the use of the system for flexible packaging and their solutions.

2. Flexible packaging

A flexible packaging material is flexible, as its name suggests, and forms into a shape to suit the contents. The materials include polypropylene, polyethylene and other plastic films.

Flexible packaging fulfills three major functions: protection (e.g., barrier function), handiness (e.g., transport) and information (e.g., advertisement). They are mainly used for food (Fig. 1).

Many flexible packaging materials are laminated. A laminate is used for two main purposes. One of the purposes is to make a material into a bag. It is melted by heat and easily bonded to make a bag. The other purpose is to minimize the amount of ink that transfers to the food in the bag. However, it is possible ink passes through the laminate layers (Fig. 2).

Especially when flexible packaging material is used for food, food manufacturers not only in Japan but also in the US and European countries set limits on the amount of ink or the amount of a specified chemical substance that infiltrates...
into the package for food safety (Table 1). To introduce a new printing system in the flexible packaging field, it is critical to comply with those safety regulations.

3. UV inkjet printer for flexible packaging MJP20W

Overview of the UV inkjet printer for flexible packaging MJP20W is provided below (Fig. 3 and Table 2).

Ink used for the printer is high-sensitivity radical polymerization UV ink developed by FUJIFILM. The printing method is not the shuttle scanning employed for home printers but the single pass method in which the ink head is fixed and printing is made in one go. Thanks to the use of the method, a high throughput of 50 m/min is enabled (Fig. 4).

The MJP20W prints in the procedure below (Fig. 5). The procedure is roughly divided into four steps.

1. Corona treatment
   The material is surface-treated with a corona discharge. The treatment makes it easy to apply the undercoat in the next step. It is used for materials that repel an undercoat, like OPP.

2. Undercoating
   The undercoat is applied using an anilox roll. Combining pinning with undercoating drastically enhances the adhesion and print quality. (See below for details.)

3. Inkjet printing
   The material is printed with the inkjet printer in black (K), cyan (C), magenta (M), yellow (Y) and white (W) in this order.

Table 1 Compliance with food packaging legislation

<table>
<thead>
<tr>
<th>Country, region or manufacturer</th>
<th>Food regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>Ministry of Health and Welfare Notification No. 370</td>
</tr>
<tr>
<td>USA</td>
<td>FDA</td>
</tr>
<tr>
<td>EU</td>
<td>EuPIA</td>
</tr>
<tr>
<td>Switzerland</td>
<td>Swiss Ordinance</td>
</tr>
<tr>
<td>Nestle</td>
<td>Nestle Guidance</td>
</tr>
</tbody>
</table>

Table 2 Outline of MJP20W

<table>
<thead>
<tr>
<th>Ink</th>
<th>Ultraviolet curing ink (UV ink)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Cyan, magenta, yellow, black, white</td>
</tr>
<tr>
<td>Printing speed</td>
<td>50 m/min</td>
</tr>
<tr>
<td>Resolution</td>
<td>600 dpi × 600 dpi</td>
</tr>
<tr>
<td>Suitable material</td>
<td>PET, OPP (polypropylene), NY (nylon)</td>
</tr>
<tr>
<td>Material thickness</td>
<td>12 μm ~ 100 μm</td>
</tr>
<tr>
<td>Maximum printing width</td>
<td>541 mm</td>
</tr>
<tr>
<td>Printer dimensions</td>
<td>1.8 m high × 8.6 m long × 1.9 m wide</td>
</tr>
</tbody>
</table>

※1 Pinning: The process of applying a dose of low intensity ultraviolet light to pre-cure or gel the undercoat and the ink.
(4) Nitrogen-purge UV-exposure system
The nitrogen-purge UV-exposure system purges with nitrogen to lower the oxygen level. UV-LED light is shed in a low oxygen environment and the ink is fully cured. Printing is complete.

4. Technical problems
This section describes problems likely to occur when the printing system above is introduced in the flexible packaging business and suggests solutions to them.

4.1 Measures for food safety
As mentioned above, flexible packages are mainly used for food. Enhancement of food safety is a top priority issue. To solve this problem, FUJIFILM has taken measures in terms of its UV ink technology and the system technology.

As radical polymerization UV ink is used, polymerization is easily inhibited by oxygen and unreacted monomers are likely to remain in the ink. The monomers can transfer to food (Fig. 6).

As a measure on UV ink, we have reduced the amount of unreacted monomers by using multi-functional monomers (Fig. 7). We have also changed the initiator to the one high in safety and sensitivity to cure the ink with only a small dose added.

![Fig. 5 Process of MJP20W](image)

![Fig. 6 Process of polymerization inhibition caused by oxygen](image)

![Fig. 7 Result of residual monomers in ink films](image)
As a measure on the system, we have used a nitrogen-purge exposure process to perform UV exposure with a low level of oxygen, which inhibits radical polymerization. That facilitates the effective polymerization reaction and drastically reduces unreacted monomers (Fig. 7).

Those measures on the ink and the system have made it possible to form ink films that meet the Notification No. 370, Japan’s food safety standard.

4.2 Side effect from the enhancement of food safety — Measures against reduction in adhesion

While safety was enhanced, the use of multi-functional monomers increased cure shrinkage and that stress reduced the adhesion of ink films to the material. To solve the problem, we employed the “undercoating technology” and the adhesion was significantly improved.

The undercoating technology consists of an “undercoat agent containing a high-adhesion material” and the “undercoat pre-cure system” that pre-cures the undercoat, immediately after it is applied, by exposing it to low intensity UV light (pinning).

This undercoat pre-cure system forms an undercoat layer containing a high-adhesion component (Fig. 8) and strong intermolecular force is generated between the layer and the material. The adhesion to the flexible packaging material

Fig. 8  Cross-section of ink films containing an undercoating with/without pre-cure system

Fig. 9  Image figure of exhibiting adhesion

Fig. 10  Result of adhesion

Fig. 11  Result of adhesion by pre-cure system

※2 Ministry of Health and Welfare Notification No. 370: Standards for food and additives the Japanese government established in 1959. They include the total amount of transfer when the print on flexible packaging is extracted using a specified solution.
is drastically improved. In addition, a mixed layer formed between the undercoat layer and the ink layer produces an anchoring effect. Coupled with the undercoat, the anchoring effect helps increase the adhesion to the target level (Fig. 9 and Fig. 10).

As shown in Fig. 11, as the intensity of pinning light increases, an undercoat layer is formed and the adhesion to the material is improved.

### 4.3 Improvement in print quality by having an undercoat layer

Forming an undercoat layer enables control of the ink dot diameter and reduction of blurring and improves the print quality (Fig. 12 and Fig. 13).

Ink droplets placed on an uncured undercoat layer sink into the layer. When the undercoat is pre-cured, the viscosity increases. Ink droplets are kept from spreading and as a result the dot diameter is controlled (Fig. 14). Similarly to the adhesion, the spread of ink droplets varies with the curing condition of the undercoat layer. The dot diameter can be controlled to the optimum for covering the unit area by adjusting the pinning light intensity (Fig. 15). The undercoat pre-cure system using pinning is important technology for improvement in the adhesion and the print quality.

### 5. Conclusion

We have completed a UV inkjet ink system suitable for flexible packaging and high in food safety by making the most of our technologies. We expect that the system contributes to cost reduction in high-mix, low-volume printing and reduction in delivery time.

We also expect that this system will spark creation of a new printing business in the diversified printing industry. We will make continued R&D efforts to further improve the performance.

### References


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