

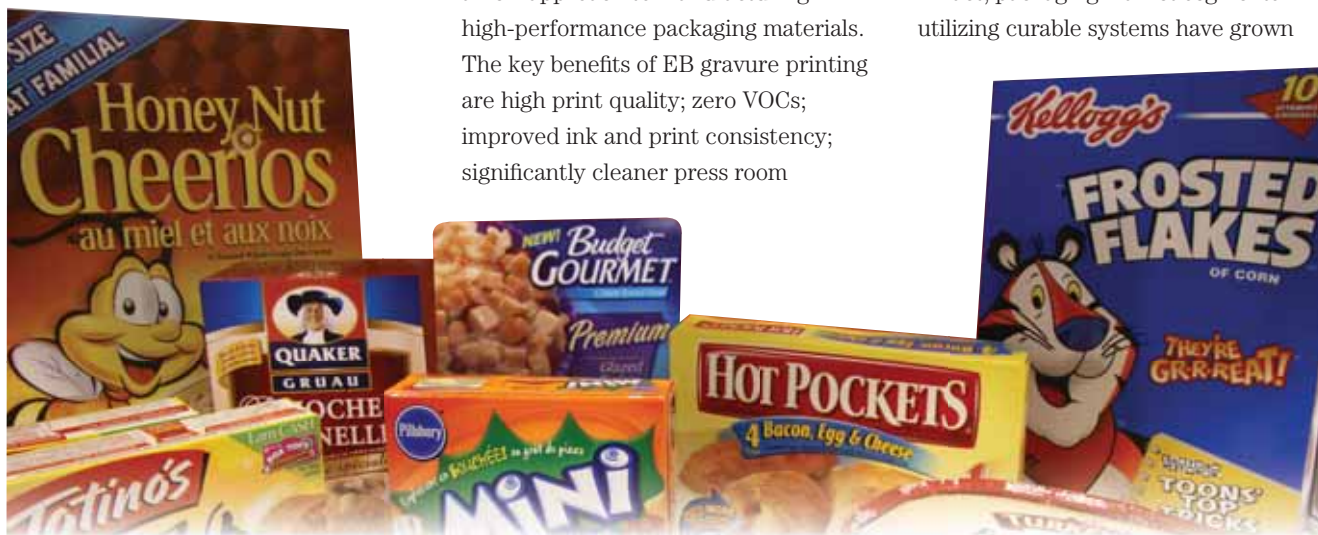
EB Gravure: Novel Printing Concept for Sustainable Packaging

By Mikhail Laksin, Sean Evans, Ken Fontaine and Subh Chatterjee

Packaging and converting industries are under enormous pressure to reduce their carbon footprint while meeting constantly rising functional and aesthetic performance requirements for packaging materials. These ambitious goals must be achieved without a significant increase in the packaging cost. Traditional solvent-based printing technology is giving way to new, low-energy methods of printing and functionalizing packaging materials. Direct gravure is known as one of the highest quality printing technologies available to packaging converters. Combining the benefits of the print fidelity associated with gravure printing and the physical properties achieved with electron beam (EB) chemistry and raw materials, it offers a new approach to manufacturing high-performance packaging materials. The key benefits of EB gravure printing are high print quality; zero VOCs; improved ink and print consistency; significantly cleaner press room

environment; and more. The printing process is also complemented by the in-line application of coatings and/or adhesives which provide packaging materials with outstanding aesthetics as well as chemical, physical and functional properties.

UV/EB-curable inks and coatings have been used in packaging and, specifically, in the food packaging markets for many years, going back to the early 80s. That's when TetraPak and a few smaller converters adapted EB-curing technology for manufacturing of low-odor and low-migration packaging. These original applications—gable-top dairy and fruit juice liquid packaging; frozen food containers; and folding cartons and dry food (cookies) packaging—have not given up their strong market position. In fact, packaging market segments utilizing curable systems have grown



significantly. UV curing joined EB as a technology of choice for several applications, including folding cartons; lids for small containers (yogurt and other dairy products); plastic cups; liquid packaging; outdoor and multiwall bags; and some others. Yet the share of UV/EB-curable systems in the total volume of packaging inks, coatings and adhesives still doesn't exceed 4-5%.

A rapidly changing social and economic landscape with an emphasis on the reduction of a carbon footprint in all areas of industrial activity promotes UV/EB curing to the front line, making it a technology of choice for many packaging and converting applications.

The major challenge is to implement the curing technology within the framework of existing and proven printing methods, such as lithographic, flexographic and gravure printing. UV- and EB-curable inks have been used in lithography; and over the past 20 years they have found their way into some segments of flexography. Gravure printing is the only remaining mainstream printing method that has not been penetrated by this technology. In this paper, we introduce a technical approach to merging gravure printing and EB-curable inks; and discuss the benefits and challenges of this merger for the packaging industry.

EB Gravure—Technical Platform

Gravure printing is a technology utilizing very low viscosity ink systems for direct transfer of an image from the cells of an engraved cylinder onto the printed media. Gravure offers a broad range of gray-scale reproduction due to the dual mechanism of the ink metering via varying cell size and depth. In gravure printing, highlights of the image are reproduced with very small and shallow cells, while very high-density solids are achieved by transferring substantial ink volume

from the large and deep cells. The latter is especially beneficial for special-effect colors (such as metallics), producing strong visual effects unattainable by other printing methods.

The traditional gravure press configuration requires interstation drying of each color, often followed by a drying tunnel at the end of the press for removal of residual solvents or water (which are used to control the viscosity of the inks). Gravure printing is dominated by solvent-based systems that are generally more forgiving in respect to low foaming, re-wettability on the gravure cylinder, and drying speed. Gravure inks are low-solids liquid blends, so the total amount of solvent that has to be evacuated and incinerated during high-speed printing is, by far, the largest in the printing industry. This makes solvent gravure printing the least attractive printing method from the carbon footprint perspective.

Replacement of solvents with water brings new life to gravure printing. However, most of the fast drying, water-based resin systems still contain volatile compounds (such as alcohol and ammonia) to control viscosity. Complete drying of the inks is essential to avoid blocking during storage and to maintain required physical properties of the ink layer.

Introduction of acrylate functionality into the water-dispersible polymer backbone presents an opportunity to eliminate ammonia from the ink composition and expand the performance window for water-based gravure inks. This is achieved by combining air/heat drying with EB curing to obtain desirable physical properties of the printed packaging. Ammonia-free, water-based inks are expected to have better viscosity stability during high-speed printing. Target physical properties are attained immediately after EB curing.

Applying EB coatings is often required as the final step for control of friction and desirable gloss of the finished packaging material. Intercoat adhesion between EB coatings and water-based inks is often limited due to the presence of residual solvents, ammonia or water in the ink layer. Co-polymerization of acrylate functional ink and coating layers under EB irradiation significantly enhances intercoat adhesion.

Resin Chemistry and Ink Properties

Over the last decade, significant progress was made in introducing water-based acrylate functional polymers and oligomers.¹⁻² The primary targeted application for this chemistry has been the wood coating market. In this application, several layers of UV-curable, water-based dispersions are applied over the wood surface via spraying or roller application techniques. Each layer is dried; UV cured; often sanded; and then another layer is applied on top. Several consecutive layers may be applied on the top of each other according to this sequence, depending on the end-use requirement (gloss level, hardness, etc.)

EB flexographic printing was the first attempt to use water-based, EB-curable resins in printing.³⁻⁴ In this application, complete drying of individual ink layers is not required or anticipated because wet trapping is controlled by viscosity gradients generated between consecutive layers due to the partial evaporation of water. The wet layers of ink do not come in contact with the hard surface of turn bars and complete solidification is achieved as a result of UV or EB curing.

The EB gravure printing method is similar to the wood coating model which requires complete drying of individual layers prior to applying the following layers. Unlike wood coating, EB gravure is a very fast process with

web speeds exceeding 800 feet/min. The key criteria for selection of water-based, acrylate-functional dispersion for gravure application are the drying speed and EB-cure response. A number of resins were screened based on these two criteria in a model yellow gravure ink composition. All model blends were prepared by mixing tested polymer dispersion with pigment dispersion, then drawing it down over PET film with #3 Mayer bar and

allowing it to dry prior to testing for five minutes at 60°C. Screening results are presented in Table 1.

It is evident that a broad range of water-based resin dispersions with different polymer backbones is currently available on the market, offering various drying and curing properties.

Gravure inks are generally very low-viscosity liquids with relatively low pigmentation levels. Typical rheological properties of EB gravure

inks determined on a controlled stress rheometer at 25°C are presented in Figure 1.

All process colors have viscosity in the range between 20 and 30 centipoise. Yellow, magenta and cyan have minimum flocculation even at extremely low stress levels under 1 Pascal. Black shows some flocculation tendency that quickly disappears at moderately higher stress levels. Low viscosity and minimal viscosity

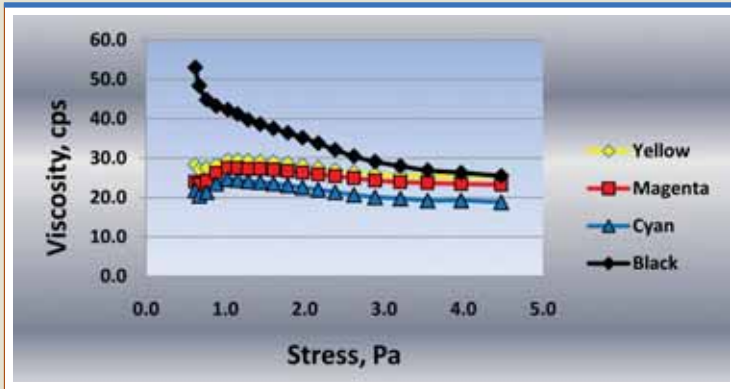
TABLE 1

Screening results

Resin #	Chemistry— described by suppliers	IPA rubs before cure	EB Cure, 30 kGy, IPA rubs	Lay, Scuff, General Appearance
1	Acrylic	2-3	7-8	Fast drying, good lay, some scuffing
2	Aliphatic polyurethane	2	40-45	Fast drying, good lay, minimal scuffing
3	Aliphatic polyurethane	4	40-45	Fast drying, good lay, some scuffing
4	Aliphatic polyurethane and acrylic copolymer	8	7-9	Product is not curable
5	Aliphatic polyurethane	10-11	30-35	Fast drying, good lay, minimal scuffing
6	Aliphatic polyurethane	1	55-58	Tacky before cure, very high gloss, some scuffing
7	Aliphatic polyurethane and acrylic copolymer	2-3	45-50	Fast drying, good lay, some scuffing
8	Polyurethane	3-4	15-16	Fast drying, good lay, some scuffing
9	Polyurethane— acrylic copolymer	12-13	40-45	Fast drying, good lay, some scuffing
10	Aliphatic polyester polyurethane	4-5	10-13	Fast drying, good lay, some scuffing
11	Polyurethane— acrylic copolymer	3-4	55-60	Fast drying, good lay, some scuffing
12	Polyurethane	13-15	95-100	Fast drying, good lay, minimal scuffing
13	Acrylic dispersion	1-2	40-45	Slightly tacky
14	Acrylic emulsion	1-2	55-58	Tacky
15	Aliphatic polyurethane	1-2	3	Tacky, probably not curing
16	Aromatic polyurethane	26	73	Fast drying, good lay, some scuffing
17	Aromatic PU	13-15	over 100	Fast drying, good lay, some scuffing
18	Polyester acrylate emulsion	1	50-55	Poor lay, tacky before cure
19	Polyester acrylate emulsion	1	30-35	Poor lay, tacky before cure

FIGURE 1

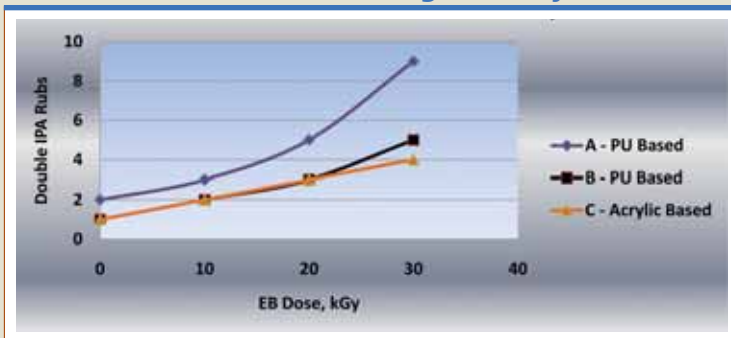
Rheology of EB gravure inks



In this experiment, three model cyan inks were prepared using two different polyurethane-based dispersions (A and B) and one dispersion based on acrylic backbone polymer (C). All inks were applied over the PET film with a #3 Mayer bar; and dried and cured at various EB doses at 100 kV acceleration voltage on the AEB laboratory EB processor. Optical density of the drawdowns was between 1.55 and 1.65. While EB curing response is just one factor in determining the selection of a resin for the ink vehicle, this plot suggests that “ink A” formulation has significantly better cure in the range between 10 and 30 kGy than two other resins.

FIGURE 2

Effect of EB dose on cure—EB gravure cyan



Printing Press Testing

The Graphic Arts Technical Foundation form with multiple color bars and gray scale targets was printed on Rotomec MW-80 Gravure press at Amgraph Packaging. Drying temperature was set at 225°F and EB curing dose was 20 kGy. The color sequence was CMYK or cyan, magenta, yellow and black. A 35# coated paper was used for printing. Print samples were taken at 500 and 750 fpm of press speed.

Print densities for each color have been very consistent at all speeds.

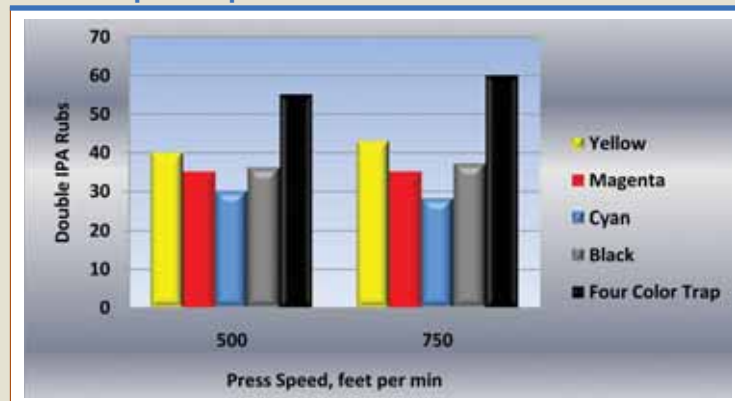
gradients are important for good ink release from the cells and effective transfer at high press speeds.

EB curing of inks requires an EB dose similar to those typically selected in all other EB printing applications. Final crosslinking density of the ink layer is a function of multiple factors, including selection of resin chemistry; pigment-to-binder ratio; and target print density. In many cases the ink layer is cured through a top EB coating.

The graph in Figure 2 illustrates an effect of different EB doses and selection of resin chemistry on crosslinking density of EB gravure cyan ink.

FIGURE 3

Effect of press speed on EB cure



density of each of the four process colors and four color traps are summarized in Figure 3 and 4.

Optical print densities for each color are not affected by the press speed between 500 and 750 fpm. The same is true for solvent resistance of each color. The range for isopropyl alcohol (IPA) rubs is between 30 and 40, which is exceptionally high for EB-curable inks. The four-color trap has an even higher number of double rubs (around 60) due to higher film thickness. While solvent resistance is not necessarily a true measure of crosslinking density, it is a

good indicator of physical properties associated with EB-curable inks.

Considering the fact that typical water-based inks do not offer any significant solvent resistance (IPA rubs are in the range of 1-2), EB gravure inks offer dramatic improvement in the product resistance—even when printed at high press speeds and cured at a moderately low EB dose of 20 kGy.

An illustration of two printing jobs performed with standard water-based gravure inks and EB gravure inks is shown in Figure 5.

While further optimization of the

printing performance is in progress, this image suggests that EB gravure printing technology has its merits and is capable of producing good quality printing.

Conclusions

EB gravure printing represents a novel approach to improving the physical properties of the packaging material, while achieving substantial reduction in the carbon footprint in comparison to a traditional solvent-based gravure printing process. Recent developments in the area of water-based, EB-curable polymers offer good opportunities for developing a broad range of EB gravure inks capable of meeting various end-use performance targets. ▸

Acknowledgments

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FIGURE 4

Effect of press speed on print density

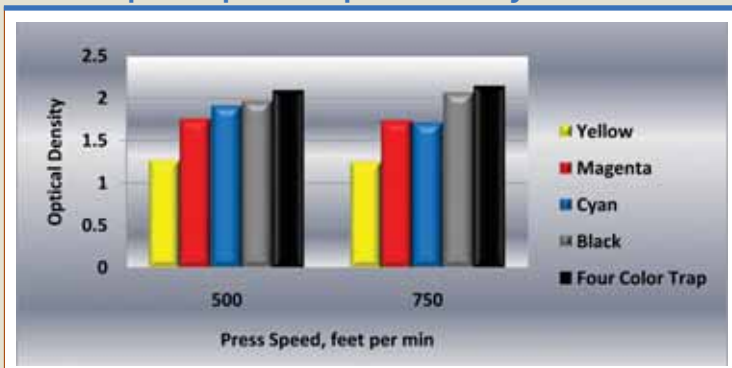


FIGURE 5

Comparison of EB gravure inks with standard water-based inks

