The Changing Economics of EB Curing

By Mikhail Laksin and Joshua Epstein

The value proposition for electron beam (EB) curing in the food-packaging industry is dramatically increasing as evolving market requirements are being met by a broad range of innovations in EB technology. While EB curing has been a viable curing alternative for decades, it has been relegated to only niche applications where the advantages of EB curing (Figure 1) were absolutely required. Although many applications could have benefited from the unique capabilities of EB curing (for instance, operational cost reduction and product differentiation) such benefits were outweighed by high acquisition and maintenance costs, as well as the difficulties posed by limited EB ink, coating and adhesive formulation research.

Circumstances are changing. The food-packaging markets are in a state of rapid transition as a result of rising operating costs, tightening VOC emission regulation, and a heightened focus on food-packaging safety. Converters of food-packaging are turning to alternative package materials and new production technologies while striving for competitive differentiation by adding more value to their products. At the same time, there has been a rapid pace of innovation for both EB systems, EB-curable formulations and EB-friendly printing technologies.

The combination of growing market demand and more practical EB solutions has significantly increased the value proposition of EB curing. As a result, the economics of EB curing are becoming increasingly attractive.

Figure 1

Key advantages of EB curing

- No VOCs
- Energy efficient
- High consistency
- High resistance
- Ability to penetrate
- Low extractables

Advances in Flexible-Package Printing Technology Open Up New Options for EB Curing

Converters are responding to customer preferences for lighter, more functional, less expensive packaging materials while simultaneously striving to minimize operating costs. To stay competitive, they need to deliver novel, eye-catching visual effects while continuing to optimize overall product resistance (i.e., thermal, UV and scratch resistance). At the same time, in order to become more efficient, converters are seeking to simplify their operations by eliminating converting steps or moving complex finishing tasks in-line. EB is energy efficient and delivers complete, instantaneous curing and a high-quality finish that addresses visual and surface characteristics required by packaging markets.

With flexible packaging becoming the format of choice for many applications, new approaches to flexible material converting are being deployed. Flexible packaging converters are investigating new printing technologies such as wet-on-wet flexo printing or offset-based flexible package printing, both of which eliminate the need for interstation curing. EB-curable ink systems such as Sun Chemical's WetFlex technology enable a single curing station at the end of a central impression flexo press.[1] Likewise, new advancements in offset-based printing press technologies like that from Drent Goebel, allow for wet-on-wet printing on flexible substrates.[2] Both of these flexible package printing technologies allow for a single EB-curing station at the end of the print line. While it is typically not economical to have multiple EB-curing stations in a print line, a single EB-curing station can be more competitive to multiple UV or IR interstation curing stations. Furthermore, the low heat of EB curing typically does not require a chill drum to cool the substrate. A single EB-curing station and the elimination of the chill drum reduces the overall capital cost economics for EB. The EB-operating cost economics are enhanced by the energy efficiency of a single EB-curing station and the energy savings from avoiding chill drum.

In concert with evaluating new printing technologies, converters are taking a fresh look at packaging material technologies. The need to control raw material costs has lead packaging technologists to explore innovative approaches to using both less expensive materials as well as less overall material. The typical flexible packaging film substrates used today [e.g., polyethylene (PE), biaxially oriented polypropylene (BOPP), polyethylene terephthalate (PET), polyethylene terephthalate glycol (PETG)] carry specific printing, curing and converting challenges. EB curing is an appropriate technology for heat sensitive film substrates because it generates very little heat.

FIGURE 2

Trends in packaging technology

- Lighter packaging materials
- Simplification of converting process
- Shorter runs
- Emphasis on reducing/ eliminating migration risk

FIGURE 3

Comparison of formulation components

Managing Migration Risk Is a Key Factor in Evaluating Different Curing Technologies

For many years, food-packaging markets have successfully avoided any serious scrutiny of packaging material compliance with regulatory requirements established by the Food and Drug Administration in the U.S. and similar regulatory agencies in Europe. This is no longer true. While most flexible packaging converters have well-established protocols for controlling residual solvents in the ink, increasing regulatory attention is being paid to the possibility that converting process by-products such as ink and coating are being introduced into packaged products. All types of food packaging—labels, flexible packaging, folding cartons and rigid plastics—are coming under increased scrutiny. With the introduction of energy-curable technologies (i.e., UV&EB), there is a new set of options for and challenges to controlling migration risk.

An ink chemistry may be in compliance with migration related regulations if the levels of any ink components found in the packaged food are no more than Threshold of Regulation (TOR) in the U.S. or Overall Migration Limits (OML) in Europe. (This rule only applies to components of inks that have not been toxicologically tested.) In general, there are only two key factors relating to ink chemistry and mechanisms of drying or curing that are critical for migration:

1. Total amount of ink components and impurities available for migration into food or food stimulant after drying/curing.
2. Physical structure (flexibility, density, etc.) of the ink polymer network that will impact migration of the residuals.

Figure 3 shows the basic components of conventional ink systems (solvent and water), UV-ink systems, and EB-ink systems.

Solvent-Based

Most of the polymeric resins used in solvent-based system (nitrocellulose being the most common for flexo and gravure systems) do not present a major concern from the regulatory perspective. However, they do not offer adequate protection against the migration of the rest of the ink components, including pigments. In extraction tests typically conducted with different solvents, it is always possible to dissolve and extract base resin along with the more soluble additives. In light of the new European Food Safety regulations, conventional packaging ink systems will likely come under renewed scrutiny.

Water-Based

Water-based flexo and gravure inks represent a relatively modest fraction of the printing market due to limited print quality and press stability. Aqueous printing inks are typically based on polymer dispersions and emulsions, neutralized for better water solubility. To ensure adequate stability and press performance of aqueous printing inks, additives are required-emulsion stabilizers, antimicrobial additives, defoamers and wetting agents. Many of these additives are prone to migration and can be easily solubilized and extracted in the food simulating solvents.

UV

Incomplete cure of low-molecular weight monomers and by-products of photoinitiators, formed as a result of photodecomposition, are the main concerns in UV curing. Additionally, since some pigments such as phthalo-blue used in cyan, carbon black and different violet pigments (carbazole violet, methyl violet, etc.) absorb light in the UV region, competing with photoinitiators for available UV energy, the curing process itself must be carefully constructed to avoid migration problems due to incomplete curing.

UV&EB Hybrid

UV&EB hybrid approaches can minimize some of the problems presented by UV curing alone. UV&EB hybrid approaches can be effective to ensure complete end-of-line curing of ink systems cured interstation with UV. In addition, final EB curing of UV formulations can enhance adhesion to different plastic substrates. Though it is impossible to eliminate the migration risk associated with UV photoinitiators, a UV&EB combination may allow reducing amount of photoinitiator, increasing overall conversion rate and eventually lessen migration.

EB-Curable Formulations Are an Effective Strategy for Minimizing Migration Risk

The chemistry of EB-curable inks and coatings is very similar to UV-curable inks, but they do not require photoinitiators for curing. High EB energy attacks the double bond of acrylate functional groups, inducing rapid free-radical polymerization similar to UV. While EB systems are not completely "color blind," correct selection of pigments makes cure rate practically independent from ink color. The lack of additives or catalysts combined with a complete cure gives EB-ink and coating systems an advantage in addressing food regulation requirements regarding migration.

EB technology is not new—EB-curable lithographic inks and coatings have been used in food-packaging for more than 30 years. However, the use of EB-curing technology for food-packaging has been significantly advanced over the last several years with the introduction of EB-curable coatings approved for direct food contact and wet trapping flexo printing technology.[3,4,5] Continued research and development of EB-printing inks, EB coatings, and EB-curable adhesives are focused on simplifying the printing/converting process while addressing food-packaging regulatory requirements.

In addition to basic ink and coating applications, EB-cured coatings are often used to deliver a high-gloss finish and protect the printed surface, offering an alternative to more expensive laminating structures. EB-curable coatings can be used with solvent, water or UV-based inks. There are certain EB-coating formulations with low-migration levels in compliance for direct food contact.[5]

For applications requiring a protective laminate layer, in line EB curing of laminate adhesives can be an attractive approach. EB energy has the ability to penetrate through the laminate structure, regardless of laminate color or reflectivity. EB adhesives cure instantaneously while maintaining high clarity of the laminated structure. Low-migration EB-curable adhesives are available for food-packaging applications.[6]

EB curing offers significant performance advantages desirable for the food-packaging industry while addressing the industry's migration concerns. The rapid advancement in EB formulations optimized for food-packaging have made EB-curing a more desirable alternative—directly improving the value proposition and overall economics of EB curing.

Electron Beam Technology Is Advancing at an Unprecedented Pace

While EB-curing systems have been in operation for decades, the technology is rapidly evolving away from complex, custom-engineered solutions toward streamlined, standardized product offerings. EB equipment is benefiting from continued technology innovation, increased competition, and the growth in low-voltage (80-150kV) electron beam technology options optimized for surface treatment applications like curing. Across most EB technology vendors' product lines, system prices are coming down, machine sizes are smaller, and maintenance complexity has been drastically reduced. In this way, the overall cost of ownership of EB equipment has dropped.

In addition to overall price reduction, the entry price point for EB-curing systems is now much lower. While EB curing historically has not been a practical alternative for narrow- or mid-web printers, new alternatives exist for appropriately sized EB-curing systems at scaled down price points. These options allow narrow-web converters to participate in the food labeling or flexible-packaging markets while taking advantage of the same curing technologies traditionally reserved for wide-web printers. With the overall growth in flexible packaging demand, there is a need for narrow- or mid-web printing formats that are more economical for shorter run lengths. A new generation of compact EB technology makes end-of-line curing of inks and coatings more practical for webs of any width.

Overall system size has also decreased, opening up new options for integration into both new and retrofit print lines. Leveraging a more compact footprint and the complete, instantaneous curing capability of EB, converters can move many complex finishing tasks in-line. As the form factor of EB changes and new inline applications become practical, converters are able to differentiate their product offerings, further improving the value proposition of EB.

Finally, the standardization of EB-product offerings has lead to greater system reliability and simpler system maintenance schemes. Minimized curing system downtime coupled with the curing consistency inherent in EB technology means that use of EB technology enables substantially greater production efficiency.

Summary

The economics of EB curing are changing as a result of evolving customer preferences and regulatory requirements with respect to food-packaging as well as technological advancement in the EB industry. The food-packaging industry is under pressure to reduce use of raw material, cut operating costs, improve product line offerings, and respond to tightening food-packaging regulations. EB curing is an increasingly attractive option as EB-curable formulations advance and the total cost of ownership of EB equipment comes down. This convergence of factors is leading food-packaging converters to more carefully consider investing in EB-curing capability as a practical way to control costs, meet regulatory requirements and gain a competitive advantage.

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