EB-Cured Adhesive Lamination: Hurdles for the Industry in Flexible Packaging

By Duncan Darby and Tom Dunn

This article considers the challenges for flexible packaging converters when using electron beam (EB) cured adhesive laminations to make packaging for food and pharmaceutical products.

First, it briefly addresses the advantages of EB-cured laminating compared to EB coating. Then, it reviews specific hurdles converters must overcome to make EB-cured adhesive laminations a commercial reality.

EB-cured adhesive laminations are used for food product packaging.

Advantages

Coating

EB-cured coatings can achieve film-quality gloss without using a reverse-printed film. Such coatings can in fact provide better gloss than the so-called catalytic overlacquers that converters have historically used for high-gloss product requirements.

The instant cure of EB coatings offers process advantages for converting. These include confidence about the acceptability of structures immediately off-line and reduction of embargoed inventories waiting for shippable gloss levels.

Two clear environmental advantages for EB coatings have been recognized. First, they do not release polluting solvents into the atmosphere.

The other factor, often overlooked, is the extremely wasteful use of solvents. Industry mines fossil fuels, produces solvents from them, dissolves polymers into those solvents, applies the coatings, then evaporates the solvents, and typically oxidizes them. In many cases, the energy value from the oxidation is not recovered. Such material and energy waste does not occur in the case of 100% solids EB coatings.

The gloss and environmental advantages also contribute to cost benefits by layer replacement and removal of drying cost. This, of course, assumes that the glossy EB coating can eliminate a layer of film (as is the case if this film contributes nothing but gloss) and that the converter can eliminate the cost of solvent drying and oxidation.

Adhesives

In contrast with coatings, EB-cured adhesives do not contribute high gloss because adhesives are used between layers, and not on a surface. The instant cure and environmental benefits still exist. Potential savings through drying and oxidation cost reduction remain, but not through layer replacement.

Hurdles for Adhesives

The hurdles to commercializing EB-adhesive laminations fall into six categories: adhesive performance, structural performance, regulatory status, capital cost and competition from competing technologies, especially other 100% solids technologies.

Adhesive Performance

Performance gaps between conventional two-component polyurethane systems and EB systems have been seen:

- lower bond strengths
- lower temperature resistance
- lower water resistance.

In some cases higher cost films, particularly chemically treated oriented polyester (OPET) rather than corona treated OPET, may be required to get good lamination bonds. In many applications, these two kinds of OPET would be considered interchangeable using conventional adhesives, but they do not appear to be so using the currently available EB adhesives.

The industry can probably prevail over this hurdle. The incumbent adhesives are based on polyurethane chemistry that has been available to the packaging converting industry for at least 30 years. Manufacturers of this chemistry have had the advantage of growing up with the rest of the industry, so each new advance was incremental. EB formulators have the unenviable position of being compared to strong, well-established product lines. However, they may catch up, especially considering that many of them are also formulators of polyurethane chemistry. Already there has been a rapid advance in the chemistry for EB adhesives from suppliers.

Structural Performance

This refers to whether or not the EB-curing energy negatively affects the performance of the non-adhesive layers. In some instances, the high-energy electrons do in fact modify polyethylene and polypropylene films. In particular, heat seal characteristics of these layers change for the worse after exposure. Seal range and hot tack decrease, and seal strength at a given temperature falls. In some applications, these effects might be desirable, but if the sealability of these materials is adversely affected, then their most common applications are compromised. Other polymers may also be affected, although little effect has been seen on OPET at the dosage levels used even in laminations.

The effect of electron EB on inks may be beneficial. Inks are often the weak point in a lamination. If the effect of the electrons increases adhesion of this important layer, it could benefit both converters and end-users.

EB adhesives may only partially overcome such structural limitations. High-energy electrons modify polyethylene and polypropylene at the molecular level, diminishing associated seal performance. While additive

technology may appear to minimize the effect, the prospects of more chemical additives in direct food contact layers of packages may encounter resistance. Structural interaction with inks may well become a positive factor for EB adhesives as inks optimized for this combination are developed.

Regulatory Issues

The industry needs to consider the safety and migration of original monomers and oligomers, cross-linked polymers, and any by-products formed in the coating material itself and from EB interaction with other materials present in the packaging.

The industry has indeed addressed these needs. Interim findings of the Food Packaging Alliance of RadTech North America in 2004 indicate no unacceptable toxicity from a set of “work horse” pre-polymer chemicals. Similarly, if the EB curing of the adhesive occurs with the packaging material in an oxygen-free atmosphere, no chemical by-products result. When the group documents these findings, regulatory issues associated with the use of EB adhesives for food packaging will be essentially resolved.

Material Cost Issues

Consumer packaged goods companies have one consistent message to their packaging material suppliers—

provide regular cost reductions. To this end, the question: "Will EB-cured laminations cost less than current alternatives?" must be answered. If total system costs do not decrease, the industry has little or no stimulus for this work to go forward.

EB-cured adhesives can eliminate operating costs for drying current coatings and oxidizing evaporated solvents during converting operations. These savings will typically account for about 10% of the non-material operating costs of a laminator. Even with the operating savings, three issues that must be considered could offset these savings:

1. Do the EB adhesives carry a demanding premium over conventional adhesives? EB-curable adhesives carry premiums sufficient to offset the operational savings.
2. Does the substrate cost increase? There have been cases in which the substrates required to get acceptable results with EB adhesives offset operational savings.
3. Will operating speeds decrease? This could also offset the savings. Experience sufficient to assess this factor must await commercial deployment of EB adhesives lines.

These issues will probably be overcome. The ultimate adhesive cost comparison of conventional adhesives and EB adhesives will probably depend on the polyurethane market, the acrylate market, and economies of scale to be achieved at the formulator level. Converters generally do not know the dynamics of these markets well enough to comment.

If the EB laminating volume grows, adhesive and substrate manufacturers will improve their products to work together more effectively in the process.

The processing speeds that converters enjoy today are as yet unproven for EB lamination, but adhesive and equipment providers project success.

Capital Cost Issues

The installed base of dryers and oxidizers serving industry laminators presents a significant hurdle to adoption of EB laminating. These increase total system costs to the extent that they represent an annual non-cash depreciation expense.

Such assets are currently on the books of converters and they have long depreciation times. Even if switching to an EB operation would reduce operating cost, the depreciation costs of the assets remain. The alternative, to take a one-time write-off of the book value of these assets, makes no good business sense unless those operating cost savings provide an exceptional return on the new investment!

As dryers become obsolete, retrofitting lines with EB is a possibility, although additional changes required for the coating and laminating stations may make this option all the more expensive.

Additionally, note that oxidizers are often shared between multiple pieces of equipment. This would mean that the converter might not be able to save on the operating cost of this equipment because of other equipment in the plant that uses it.

Customers of a consumer food company may be quick to say "Those capital costs are your problem, Mr. Converter, I want EB now." However, to be sustainable, technology change for the packaging industry must reside in reduced total system costs, not from forcing one part of the supply chain to write-off invested capital
that is productive, but no longer state-of-the-art.

This hurdle can probably be overcome, but it will take some time. Investment cycles within the converting industry will continue and as new laminating equipment is evaluated, EB curing will be considered, especially if the chemistry and polymer operating costs look attractive! On high-end equipment costing millions of dollars, an EB unit could be considered an incremental cost. However, on current low-end 100% solids laminators, the EB-curing units cost as much as the laminator itself.

Alternatively, replacing a working dryer with an EB unit may not make sense as it will not save cost of capital, although it could save operating costs.

Competitive Technology

The final hurdle for commercialization of EB-laminating technology is the overlooked competition. The operating cost savings usually suggested (and indeed earlier in this paper), compare EB technology to solvent-based or water-based adhesive laminating. The real competitor though is "100% solids" adhesive laminating.

When you compare these EB and 100% solids systems (see Table 1), it is immediately evident that, with respect to solvents, dryers and oxidizers, the

Table 1

Comparison of other 100% solids systems

EB-cured	Solvent-free PU
• No solvents	• No solvents
• No dryer	• No dryer
• No oxidizer	• No oxidizer
• ***EB unit cost***	• ***No EB unit***
• ***Instant cure***	• ***Delayed cure***

TABLE 2

Hurdle summary

Barrier to remove	Prediction
Adhesion	Overcome with chemistry
Structural	Overcome partially
Regulatory	Very doable
Cost	Probably overcome
Investment	Time needed to recapitalize
Competition	Partial

two technologies offer the same savings. EB lamination requires an EB unit, so its capital cost would be somewhat higher than that of 100% solids lamination. The question then becomes "What is the value of instant cure?"

There is a one-time cost savings from lower in-process inventory and ongoing savings of interest expense on this lowered inventory value. (This asset account would decrease and—assumedly—revenues eventually increase). If a company wants a one-year payback on an investment, then a tremendous amount of inventory would have to be reduced to offset an installed unit costs of $300,000 for the EB unit.

In other words, at 15% carrying costs, inventory value reduction of $3 million would generate $300,000 for a one-year payback. Even with a seven-day curing period, such a large amount of in-process inventory is very unlikely.

Then there is the "sleep factor." This is defined as the ability to sleep because you do not have to wait for material to cure before you know that it is good. Virtually every converter who has used 100% solids polyurethane adhesives has a horror story to tell about this type of failure.

Unfortunately, when this is applied to financial measures, most stockholders of converters place little value on sleep. Instead, the expectation is one of learning from these mistakes and designing improvements in process control and monitoring procedures even if direct product quality cannot be measured in real time.

Can EB adhesives overcome 100% solids polyurethane adhesives? The answer is, it depends! The business volume, cost of capital, the risk profile of a company and so on affect the decision. Certainly, EB would be more attractive to large pieces of business and more sensitive applications where the risk is less tolerable.

Summary

To conclude, there are a number of hurdles to overcome (Table 2).

- Most of them can be overcome.
- Savings can be offset by other factors.
- The capital base of dryers and oxidizers must be considered as part of the total system cost.
- Finally, EB-cured adhesives must compete with the 100% solids polyurethane laminating alternatives.

The future of EB-cured laminating is more complicated than bleak. There is room for optimism about the process over the coming years. Converters will continue to invest in EB evaluation, because the environmental and operating cost factors are now or will soon become compelling.

A prediction—by 2015, converters should not be buying a lot of dryers and oxidizers.

When the research demonstrates that adhesive systems work, converters will buy EB-curing laminators. When conventional dryers become obsolete, EB may or may not be a retrofit option to otherwise working equipment.

—Duncan Darby, Ph.D., is associate professor, department of packaging science, Clemson University, Clemson, S.C. Tom Dunn is director of product development, Printpack Inc., Atlanta, Ga.