Emerging trends in low-migration UV-LED laminating adhesives for flexible packaging

By Catherine Heckman, global industry mgr., Ashland; Jake Staples, technical service & product development chemist, Ashland; and Jennifer Heathcote, global dir.-business development, Phoseon Technology

Introduction

The global flexible-packaging market continues to evolve as shifts in consumer preference lean more toward convenience in single-serve or "grab-and-go" options, extended shelf life and sustainability. In addition to consumers driving innovation in flexible packaging, wide-web and now narrow-web converters are beginning to converge into the packaging space as they see increased opportunity in equipment and coating technologies, thereby lowering the barrier-to-entry. With the advancements of UV-LED (ultraviolet light emitting diodes) curing technology, opportunities in the flexible-packaging space become more available to the converter base.

Flexographic packaging market trends

According to Smithers Pira, the global flexographic-printing industry is forecasted to reach $980 billion this year, primarily driven by growth in packaging and labels. With over 15,000 label converters and almost 500 flexible-packaging converters globally, operating multiple press technologies in multiple plants, there is growing M&A activity that is converging the two market segments, convoluting the packaging space while strengthening a converter's market position. With the label market slated to grow only 2% annually and flexible packaging at a strong 5%, there is even more reason for a company to acquire adjacent technologies or competitors to complement their business strategy.

Many drivers are attributed to the growth in the flexographic packaging market including consumer preferences (particularly from Millennials, who desire convenience and single-serve packaging), the need for increased shelf life, pet-food manufacturers moving away from complex multiwall bags to laminated flexible packaging, and growing interest in moving away from rigid containers to flexible structures.

Flexographic market segments can be divided into three primary categories: narrow-web, mid-web and wide-web with each defined in Table 1. Note: the widths defining each market segment are a general specification and not a stated industry standard.

Due to the significant growth in flexographically printed flexible packaging, the limitations of traditional UV-curing technologies that currently prohibit label and flexible-packaging converters from participating in this segment has been exposed. This is particularly clear in the food and beverage segment, which is more than 50% of the overall flexible-packaging market. One way to eliminate the barrier-to-entry is to fully understand the benefits of new UV-LED technology and the value it brings to the flex-pack market.

Types of UV-LED flexo formulations and technologies

Inks, coatings and adhesives formulated for curing with UV-LED are increasingly gaining traction in the narrow-, mid-, and wide-web markets. While some formulations such as silicone-release and highly functional coatings with smaller overall market demand have seen limited UV-LED development, the broader portfolio of UV-LED-formulated inks, coatings and adhesives already exist commercially for a wide range of converter requirements. In situations where off-the-shelf formulations are not the best match for a particular application, an existing formulation can typically be modified to fit the converter's

TABLE 1. *Flexographic market segments*

Segment	Width	Press Type	Formulations	Applications
Narrow Web	< 30" < 800mm	In Line Flexography	Mostly UV Water, solvent, and solvent-free	Tag and Label
Mid Web	30 to 60" 800 to 1600mm	Central Impression (CI) Stack Gravure	Water, solvent, and solvent-free Some UV coatings	Flexible Packaging (short runs)
Wide Web	> 60" > 1600mm	Central Impression (CI) Gravure	Water, solvent, and solvent- free Some UV coatings	Flexible Packaging (large runs)

TABLE 2. *Advantages of UV curing*

Benefits of Conventional Mercury and UV-LED	Additional Benefits of UV-LED
Viable with inks, coatings, and adhesives	Long source life (+20K hours)
100% solids formulations	Marginal UV degradation over life
Brighter and bolder colors	Superior cured whites, metallics, and fluorescents
Scratch, water, and chemical resistance	Instant On/Off (no shutters)
Fast and complete cure	50% lower energy consumption
No volatile organic compounds (VOC) in exhaust	Reduces heat transfer to media
Eliminates racking or thermal oven	More compact heads with solid-state technology
Increases production speeds	Further increases production speeds
Reduces needed floor space	Further reduces needed floor space
Reduces reject rates	Improves overall process control
Reduces waste	No mercury-filled bulbs
Superior adhesion to media	No ozone or exhaust
Formulations can be left in press	Better adhesion and through cure
Long pot life	Lower maintenance

specific processing, construction or application needs. As a result, generalized claims that most UV-LED formulations do not exist is misleading and detracts from the primary focus which should be on the tremendous operational and economic benefits associated with UV-LED curing.

The greatest commercial use today at press speeds of up to 1,000 fpm are UV-LED-formulated line, process and high-density inks in both general-purpose and low-migration formulations. Metallic and fluorescent UV-LED variations also are being adopted by converters as the use of UV-LED curing sources results in a truer and brighter cured metallic and fluorescent look. In addition, fluorescents have been shown to fade much less when passed under multiple UV-LED lamps on a press than with a similar number of passes under conventional mercury lamps. Recent formulation improvements in clear UV-LED primers, laminating adhesives and protective varnishes are now enabling non-yellowing in the final cure at ever-increasing press speeds that are quickly approaching those of UV-LED cured inks.

Advantages of UV-LED curing

While new narrow-web presses are sometimes sold with hot-air driers for water- and solvent-based formulations, the vast majority are equipped with UV dryers. This is due to the many operational and final product advantages that UV curing offers converters and brands (see Table 2).

> "UV-LED technology…is an innovative, sustainable trend…for those early adopters searching for market differentiation."

For the mid- and wide-web flexo, gravure and coating market segments, presses are generally built to run water-based, solvent-based or solventless inks, coatings and adhesives. Converters often will run a UV-cured, silicone-release coating in nitrogen, a UV-cured protective varnish or a laminating adhesive in combination with these formulations. This commonly is done off-line or at a specified distance from the solvent formulations to comply with appropriate explosion-proofing requirements. It is important to note that due to the electrical design of UV-LED sources and their compactness, UV-LED curing offers the potential to convert many of these

continued on page 40 ▶

◀ continued from page 39

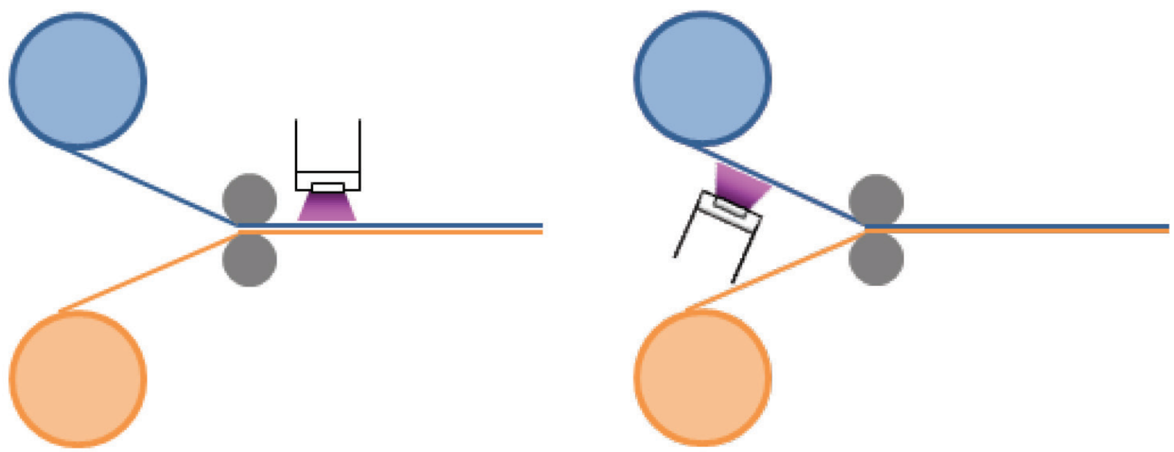

FIGURE 1. *UV-LED laminating adhesive press setup (left); and UV-LED PSA press setup (right).*

mid- and wide-web applications to UV and even run UV-LED technology in-line with solvent formulations.

Regardless of the web width or press configuration, UV-LED curing offers all the advantages associated with conventional mercury lamps as well as a long list of additional environmental, operational and performance benefits possible only with UV-LED systems (see Table 2).

Description of UV-LED laminating process

In flexible-packaging applications, the process of laminating is used to securely bond two or more flexible constructions such as PET, PE, PP, paper and foil together, among others. The two constructions are unwound from their respective rolls. The laminating adhesive is applied to the substrate with lower absorption properties before being nipped or pressed to the second substrate. Formulation application methods include flexography, gravure and various solution coaters. The two substrates combined with the wet adhesive sandwiched between both layers then are passed underneath the UV-LED source for immediate cure (see Figures 1 and 2). Pressure-sensitive adhesives (PSA), on the other hand, are dry-cured because the first construction and PSA are passed over the UV source before being pressed to the second construction.

Because UV-LED has the advantage of transferring less heat to flexible-pouch structures, it expands the range of substrate gauges that can be used in an application. It should be noted that this is not a cold-cure technology as UV-LED wavelengths are still a form of energy. UV-LED basically results in less energy being converted to heat at the substrate surface when compared to other curing sources. For some very heat-sensitive substrates, it is helpful to cure on the outside surface of a chilled drum or roller as a means of managing better substrate and process control, but it is not always necessary.

UV-LED laminating adhesives vs. traditional UV laminating adhesives

In determining the potential value proposition of UV-LED versus traditional UV-mercury technology, one should look to the higher performance of the laminating adhesives in conjunction with UV-

TABLE 3. *Most common flexible-packaging structures*

Laminating Adhesive Technology	Typical Constructions	Typical End Uses
Solvent Free	PET/PE OPP/PE OPP/OPP	Confectionary bags
	OPA/PE	Meat & cheese lidding
	CPA/PE	Base thermoforming webs for vacuum packs of meats & cheese
	PET/Alu/PE	Instant & ground coffee Dried soups & sauces
	MPET/PE	Ketchup, ground coffee
Solvent Based	CPA/PE	Base thermoforming webs for vacuum packs of meats & cheese
	PET/Alu/PE	Instant & ground coffee Dried soups & sauces
	MPET/PE	Ketchup, ground coffee
	PE/MPET/PE	Bag-in-box wine, fruit pulp, tomato paste
	PET/Alu/CPP	Retort wet pet food
	PET/Alu/OPA/CPP	Retort liquid soups & sauces
	PET AlOx or SIOx/OPA/CPP	Microwavable retort rice, ready meals
	Alu/OPA/PVC	Lidding for pharma blister
Water Based	Paper/MPET/HS Coating	Yogurt Lidding
Hot Melt PSA	PET/PE	Reclosure lidding for deli meats & cheeses

continued on page 42 ▶

◀ continued from page 40

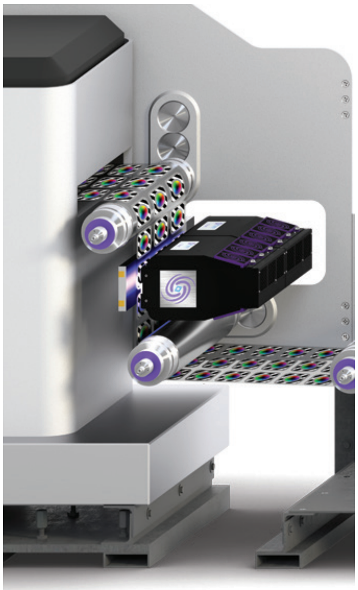

FIGURE 2. *A narrow-web flexible-packaging lamination is cured in-line via a UV-LED system.*

LED curing technology. With UV-LED, the corresponding laminating adhesive provides a longer pot life and immediate cure, as compared to solvent-free laminating adhesives which may take up to five days to fully cure. With the benefit of immediate cure, flexible-packaging rolls can be slit and pouched immediately, offering the converter short runs and quick turnaround to their customers. As well, UV-LED laminating adhesives can be applied with existing flexographic plates or gravure cylinders, and UV-LED stations can easily be retrofitted onto existing equipment, which equals lower total capital investment.

Low-migration regulatory compliance for flexible packaging

In complying with regulations in food safety, particularly when introducing UV-LED laminating adhesives, use of the appropriate regulatory agency (US FDA, EFSA) guidelines for migration and risk assessment is critical. For the US, relying on the FDA's Toxicology and Chemistry guidelines is the most logical starting point. Following these guidelines in developing the needed migration protocol that simulates the foods and conditions of use for food packaging, in addition to determining the risk of exposure to chemical migrants, will protect converters from potential legal implications.

There are three areas that must be understood to evaluate safety in food-packaging applications (see Table 3). First, it is necessary to understand the types of foods and ingredients that are going to be packaged. Table 3 lists the most common flexible-packaging structures matched to typical end-use applications and their corresponding adhesive laminating technology.

Secondly, once the application and type of food that is being packaged have been identified, using the FDA's Toxicology and Chemistry Guidelines (see Table 4), it is necessary to

> "As long as appropriate steps are taken in the risk assessment...UV-LED technology is a viable, efficient, and green method of curing."

determine the recommended simulants that will need to be used in condition testing to determine the migratory properties of the structure.

Lastly, consider the conditions of use the pouch will be subjected to during the processing phase. Using the FDA conditions, testing must be completed per the appropriate condition for the required application.

According to the FDA, the various conditions from A-J to be potentially tested are:

A. High temperature, heat sterilized or retorted (ca. 121º C [250º F])
B. Boiling water sterilized (100º C)
C. Hot filled or pasteurized above 66º C (150º F)
D. Hot filled or pasteurized below 66º C (150º F)
E. Room temperature filled and stored (no thermal treatment in the container)
F. Refrigerated storage (no thermal treatment in the container)
G. Frozen storage (no thermal treatment in the container)
H. Frozen or refrigerated storage: ready prepared foods intended to be reheated in container at time of use
I. Irradiation (ionizing radiation)
J. Cooking at temperatures exceeding 121º C (250º F)

Another key aspect to consider when evaluating the structure is the type of functional barrier being used. The functional barrier prevents a varying degree of migration of the non-food contact material in what is being pouched, particularly if the contents are food. However, there is very little guidance from the FDA or EU that defines performance of an adequate functional barrier and its corresponding acceptable migration levels.

continued on page 44 ▶

◀ continued from page 43

TABLE 4. *US FDA Toxicology and Chemistry Guidelines*

Aqueous & Acidic Foods	Alcoholic Foods	Fatty Foods	Dry foods
Fruits, vegetables, juices, mustard, ketchup, salad, milk, bread	Beer, ale, wine, distilled spirits	Cheese, butter, meats, seafood, ice cream, doughnuts, cookies, potato chips, nuts	Uncooked pasta, cereals, rice cakes, coffee (non-flavored)
			
10% ethanol/ 90% water Note: 3% acetic acid should only be used when food acidity is expected to lead to significantly higher levels of migration than with 10% ethanol.	**10% ethanol/ 90% water** (unless amount of alcohol in final package is >10%, then use actual ethanol wt%)	**95% ethanol/ 5% water (or oil simulant)** Note: Fatty foods represent the majority of the solvent-free laminating adhesive market and have the most challenging simulant standards	**Not specified**

Source: *www.fda.gov/Food/IngredientsPackagingLabeling/PackagingFCS/default.htm*

Ultimately, it is the converter and contract packager's responsibility to determine the needed functional barrier. When testing the structure compliance of the package, ensure the hazard information of the migrants and safe dietary levels are reviewed. Using the FDA default exposure values, determine the exposure level of the package such as percent of diet exposed to the packaging type. This can be calculated by dividing the safe dietary level by the exposure where a detection limit can be derived.

$$\text{Detection limit} = \frac{\text{Safe dietary level}}{\text{Exposure}}$$

The same FDA regulatory requirements that apply to today's packaging standards also are applicable when transitioning from a traditional laminating adhesive such as solvent-free to UV-LED. As long as the appropriate steps are taken in the risk assessment of the packaging (including component migration, toxicological data established limits, and performing tests in all applicable food types, temperatures and conditions), UV-LED technology is a viable, efficient and green method of curing.

"Because UV-LED [transfers] less heat to flexible-pouch structures, it expands the range of substrate gauges that can be used."

Furthermore, UV-LED technology has the advantage of providing a curing process that is reliable, repeatable and extremely controllable. With low-migration and regulatory compliance, it is critical that process variables are monitored and kept within the defined operating window.

Conclusion

UV-LED technology, coupled with UV-LED-formulated laminating adhesives for low-migration applications, is an innovative and sustainable technological trend that will have growing importance in flexible packaging for those early adopters in the narrow-, mid- and wide-web space that are searching for market differentiation. ■

Catherine Heckman, global industry mgr. for Ashland (Dublin, OH), has more than 27 years of experience with labels and flexible packaging in various marketing and business development roles in the PSA and Flexible Packaging industries. She holds a Bachelor of Science in Business (Marketing) from Wright State University and an MBA from John Carroll University. Heckman can be reached at 614-790-3805, email: cmheckman@ashland.com, www.ashland.com.

Jake Staples, technical service and product development chemist for Ashland, specializes in energy-curable products. He has more than 16 years of energy-curable technical expertise, particularly within the development of UV-LED and electron-beam technologies. Staples holds a Bachelor of Arts in Physics from Carthage College and a Master of Science in Mechanical Engineering from the University of Wisconsin-Milwaukee. He can be reached at JAStaples@ashland.com.

Jennifer Heathcote, global dir.-Business Development for Phoseon Technology, has 20 years of UV-curing technical experience encompassing arc, microwave, and UV-LED technologies. She co-authored "The UV-LED Handbook" *and is a current executive board member of RadTech North America. Heathcote holds a Bachelor of Science in Mechanical Engineering from Purdue University and an MBA from The Ohio State University. She can be reached at 503-439-6446, fax: 503-439-6408,* jennifer.heathcote@phoseon.com, www.phoseon.com.