
UV, EB, and Aqueous Coatings: Technical Basics

Packaging specialists have been using coatings for a long time, but more and more general commercial printers are beginning to appreciate the value-added advantages that customers see in coated products—gloss, scuff resistance, and a pleasing touch. The continued impetus toward using coatings comes from other sources as well. Press manufacturers are offering more inline coating options on their new presses, with retrofit options equally available. Aqueous, UV, and EB technologies are also being touted as environmentally friendly as regulations place even greater emphasis on reducing volatile organic compounds (VOCs) and other pollutants.

This article provides an overview of three coating systems—aqueous, ultraviolet, and electron beam—so printers considering coating options can make the right choice.

Coatings are used in both package printing and commercial printing to provide a wide range of value-added functions. On the packaging side consider, for example, folding cartons for golf balls, bacon, trash bags, cereal, ice cream, prepared food mixes, facial tissue, detergent, margarine spreads, beer and beverage cans, bottle multi-packs, toothpaste, and pharmaceutical goods. And there are pouches for salad dressings, multi-wall bags for pet food, blister card packaging, labeled corrugated cartons for bulk wine, paper plates and cups, corrugated point-of-purchase displays, fast food packaging, labels, and credit cards, and more.

Commercial printers use coatings on everything from brochures, annual reports, and flyers to catalogs, sometimes coating just the covers, and sometimes coating every page. All kinds of products are being coated—greeting cards, calendars, sports collector cards, book covers, and labels. In publication printing we can find coatings on magazine covers, telephone directories, and other softback covers.

Virtually all the high-volume printing processes are included, especially litho (web and sheetfed offset), flexo, gravure, letterpress, and silk screen.

Most people who think of coatings immediately think “gloss, gloss, gloss.” But coatings have functional values in addition to gloss, satin, or matte finishes. With blister coating, the added function is an adhesive finish, but coatings can also provide a surface that is not gluable. Other coating functions include increased rub and scuff resistance, slip or anti-skid properties, a higher or lower coefficient of friction, or even grease, alkali, alcohol, block, heat, or water resistance—or combinations of the above. Coatings can offer moisture vapor transmission barriers or gas barriers and, in other cases, permeation for oxygen, which is necessary for drying sheetfed offset inks. There could be a need to foil stamp or laminate to the coating, or the coating may need to offer heat sealability.

Ultraviolet (UV) and electron beam (EB) curable coatings and aqueous coatings also offer such advantages as instant curing or fast drying, no solvent emissions, and increased productivity, but because their functional values differ from each other in many respects, making the best coating decision

depends on knowing something about how and when they work to advantage.

Ultraviolet (UV) and electron beam (EB) processing allow the instantaneous curing of coatings that polymerize (change from a liquid to a solid state) when irradiated with ultraviolet light or accelerated electrons. The term “irradiation” doesn’t mean that either system is associated with radioactivity, but refers to certain energy radiated from the electromagnetic spectrum. For UV this includes the very bright visible light, invisible UV light, and heat-producing infrared (IR) energy emitted by UV lamps used for curing. EB processing equipment produces accelerated electrons for curing and, as a byproduct, also produces secondary radiation in the form of x rays, from which users must be shielded.

Some of the characteristics of EB and UV mechanisms come from their position in the electromagnetic spectrum (and therefore relative energy level). One benefit of EB curing comes from the ability of accelerated electrons to penetrate matter. This property makes it possible for EB systems to cure thick and even opaque wet coating films. It is also possible to cure through opaque substrates. This leads to the practicality of laminating, using EB adhesives. EB is a cold curing process that allows printing, coating, and curing on heat-sensitive substrates.

UV curing involves the interaction of intense UV light with catalyst (photoinitiator) molecules. All UV curing involves a polymer cross-linking (polymerization) reaction to form a solid dry coating film. Curing is fast

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- Instant curing for increased productivity
- Processing can be done in-line
- High gloss
- Abrasion and solvent resistance
- No solvent emissions
- No solvent retention
- Cuts production waste
- Low energy requirements
- Low thermal stress on substrate
- Minimal manufacturing steps, less storage and scrap loss
- Less downtime
- Interstation drying capability
- Minimal floor space required

Except for interstation drying capability, EB offers all the advantages of UV plus:

- Accurate, repeatable control of cure
- Superior coating properties
- Cure of thick pigmented coating and through opaque materials
- Long pot and shelf life
- Cooler curing process
- Capable of high line speeds to increase productivity
- Elimination of all solvents and photoinitiators, and their odors and emissions
- Makes new and unique products possible
- Fastest return on investment (ROI)

and relatively cool, especially when the infrared (IR) component from the UV lamp is shielded, so this process may be used on heat-sensitive substrates.

UV curing is a fast-reacting two-stage chemical process. In the first stage, UV light energy is absorbed by the photoinitiator, which is converted to free radicals. In the second stage, the free radicals attack the acrylic double bonds, causing polymerization. Polymerization is assisted by heat (the IR energy which is part of the UV lamp energy output). Curing occurs instantly, although some post-curing can take place, depending on the coating formulation and the amount of cross-link conversion that took place initially.

UV coatings do not currently have U.S. Food and Drug Administration (FDA) approval for direct food contact, but UV coatings and inks have been used to decorate the outside of food containers and have proven acceptable just as conventional inks and coatings have been. For food packaging and other sensitive products, EB-cured coatings and inks offer a higher safety margin because of the absence of photoinitiators and the much higher cross-link density achieved as a result of curing. The higher energy level of the accelerated electrons in EB curing

acts directly on the oligomers and prepolymers to produce the high degree of polymerization.

EB coatings can be formulated with extremely low extractables for use with sensitive packaged products. Like UV coatings, they do not enjoy U.S. FDA approval for use with direct food contact, although approval may come in the not-too-distant future for both. UV and EB coatings are being used where a physical barrier exists between food and coatings, just as many conventional coatings are used.

Due to their solvent-free, 100% solids formulations, UV and EB coatings produce virtually zero VOC emissions. Because there is no evaporation of solvents to change viscosity, these systems are stable (resistant to chemical change) on press and will not dry or cure until exposed to UV or EB energy. On the other hand, they are reactive systems and will react to heat and certain metals (iron, copper, or their alloys), oxidizing agents, or free radical initiators. Emerging dual-cure and waterborne systems have to be watched to see if any co-solvents add VOC emission potential.

The ultraviolet light source utilized in UV curing is typically a mercury vapor lamp mounted in a focused

reflector module that concentrates the UV energy at the site of curing. The quartz lamp reaches 1800°C and emits IR, UV, and visible light. Safety considerations dictate shielding to prevent exposure to the UV and the intense visible light, and also venting of the ozone generated, particularly at startup.

The number of UV lamps required to cure a UV product is proportional to speed. If a coating is formulated for a cure speed of 50 meters per minute with one lamp, then three lamps will be required to achieve cure speeds of 150 meters per minute, and so on.

An electron beam processor consists of an electron gun mounted in a focused shielded vacuum chamber. The accelerated electrons pass through a thin metallic-foil output window to reach the cure zone. X rays, which can be generated when high-energy electrons penetrate various forms of matter, are the major hazard associated with electron processors. Built-in shielding eliminates any hazard.

Both free-radical UV and EB chemistries are subject to oxygen inhibition (retardation) of the cure. EB curing, especially, is conducted in an inert gas chamber where nitrogen or carbon dioxide flushes the cure zone.

A prescribed amount of EB energy is required to effectively cure EB materials at a rated speed, just as with UV processing. Because EB processors have a variable power supply, it is practical to first determine the optimum curing level and then slave the curing to the line speed.

UV and EB curables are big business worldwide, with sales exceeding one billion dollars (US). Printing inks, coatings, and electronics are said to account for 90% of the market. UV and EB curables appear everywhere imaginable—on such products as fishing rods, golf club heads, automotive wheels, headlights, and windshields—not only in graphic arts products.

One of the major sectors of growth in the graphic arts has been the web offset production of folding cartons. Large production gains have been

demonstrated in printing and coating wide-web-roll paperboard at high speed when it is also possible to diecut, glue, and finish the product for shipment right off the end of the line. UV and EB lines have been built to meet this need, as have aqueous coating lines.

Another concept receiving a great deal of attention is the sheetfed offset press with two (and even three) in-line coaters. Great productivity gains are being achieved by printers who successfully print with conventional inks, prime with an aqueous primer, and follow with a final high-gloss UV topcoat, all in-line.

Aqueous coatings, for the most part, are organic solvent-free products. Most formulations use nonpolluting water as a solvent, although some may still contain alcohol or other co-solvents. Aqueous formulations have historically had an alcohol or other co-solvent component, but today it is perfectly possible to formulate without these solvents to create a low-VOC product. Aqueous coatings have the appearance of a milky white liquid, but they dry water clear, and they are usually about 40% solids.

With aqueous coatings, the dry solid film forms (coalesces) through the evaporation or absorption of the liquid component. Drying is accelerated on press by liberal use of a drying air flow and the exhaust of moisture-laden air. IR energy is commonly used to heat the printed/coated substrate to increase evaporation. IR and hot-air-assisted drying can generally be maintained at low temperatures that do not deform heat-sensitive substrates.

These aqueous coatings, however, are thermoplastic, which means that after drying they may resoften at an

elevated temperature that varies by formulation.

Aqueous coatings are used in all the major printing processes, although adoption by the liquid-ink processes (i.e., gravure and flexo) was easier because the low-viscosity formulations could be run through existing inker application units. The story is different in the paste-ink printing processes, where low-viscosity coating could not be run through inkers, and so coating devices were necessary.

Pioneers looking at sheetfed litho decided that the printing process could be helped if fast drying aqueous coatings could be applied in-line over wet litho inks to produce a mark-free sheet. While the underlying conventional sheetfed offset inks would only be set and not completely dry by the process of oxidation for days, the dry aqueous coating would allow immediate handling and further processing. This is what has happened in sheetfed litho, where productivity gains using this strategy are routine.

The pioneers at first ran aqueous coatings through modified dampening systems. Refined coater-dampeners were quickly developed, followed by blanket coaters, impression cylinder coaters, and the latest type, chambered doctor blade coaters. Today, it is unusual for a sheetfed press with six or

more units to be sold without an OEM or other type of coater installed.

Sheetfed printing's adoption of aqueous coating has virtually eliminated spray powder. While the very lightest powder spray is still recommended when aqueous coatings are used, this minimization has led to a much cleaner pressroom. Additionally, motors and other pressroom equipment are spared the contamination and life shortening that heavy spray powder use brings. Another benefit is the ability to perform off-line UV coating on sheetfed offset litho that is smooth due to the near absence of spray powder, and the adhesion benefit that the aqueous primer coating brings.

Work-and-turn benefits have also come to sheetfed printing. The use of aqueous coatings can eliminate the time-consuming process of racking sheets until inks are dry enough for further handling and finishing. Today, many printers print and aqueous-coat one side of a job in the morning and turn the job in the afternoon.

Off-line calendering of aqueous coatings is also a possibility for those who seek the highest gloss results. An aqueous-coated, printed sheet is brought into contact with a heated polished metal belt or drum. The heat softens the thermoplastic aqueous coating, and its soft surface takes on the smooth highly reflective surface of the metal belt or drum.

Another way to gain the highest gloss with aqueous coatings is to double bump them in-line or apply the second bump of coating off-line. Off-line coating has resulted in a 90% reflectivity range at a 60° angle, rivaling UV coating gloss. In-line double bumping has generally been disappointing, gaining only 5-10 points in gloss.

- Water clarity, nonyellowing
- Offers high gloss, satin, and matte finishes
- Can be a UV primer
- Rub, mar, water, grease, alkali, alcohol, block, heat, and glue resistance
- Breathable or can provide a barrier
- Nonskid and low coefficient of friction slip
- Imprintable, gluable, stampable, and heat-sealable
- Low odor, nontoxic, and nonflammable
- Biodegradable, repulpable, and recyclable
- U.S. FDA conformance
- U.S. EPA-compliant low VOC, including zero alcohol
- Low thermal stress on the substrate

Aqueous Coating Advantages

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Whether a production line is to be equipped to handle aqueous or UV or EB coatings, an investment in drying or curing equipment is necessary. Costs for an aqueous coating dryer running on a high-speed sheetfed line will generally be well under US\$100,000, less for a slower line. A UV dryer comparable in line speed will cost only slightly more. An EB processor will cost 3–5 times more than a comparably speed rated UV dryer system. EB prices have, however, been coming down. EB equipment priced in the \$800,000 range four years ago can now be purchased for between \$500,000 and \$600,000. Some narrow-web (20- to 30-inch) units operating at 125 kV are now available for around \$350,000.

You may have to purchase a coater to apply aqueous coatings. The same type of device may be used to apply UV and EB coatings.

In North America, UV coatings range from a low-end product at \$25 per gallon to over \$40 per gallon for more sophisticated products. EB coatings range from \$30 to \$40 per gallon. Aqueous coatings range from a low of perhaps \$6.50 to more than \$17 per gallon for more sophisticated products.

UV and EB coatings are 100% solids, while thermoplastic aqueous coatings can range much higher in solids, from a high of perhaps 48% solids to a low of 20%, or even less. Nevertheless, it is well to understand that the best performing of these UV, EB, and aqueous coatings are designed to produce optimum properties at coat weights of one pound per thousand square feet wet. This is especially true of high-gloss coatings. Other coatings, such as precoats, may be applied at much lighter coat weights.

UV, EB, and aqueous coatings all provide finishes that are smooth, glossy and protective, and all are in high-volume use throughout the packaging

and commercial segments of the printing industry. UV, EB, and aqueous coatings do, however, have functional and aesthetic differences as well as advantages and limitations to their best use. A coatings decision also needs to take into account capital equipment costs, operation and maintenance costs, consumables costs, storage and handling procedures, and environmental and workplace implications. An upcoming *GATFWorld* article will cover the health and environmental concerns related to UV, EB, and aqueous coating.

There is no question that UV and EB coatings can deliver both a higher and a greater depth of gloss than aqueous coatings. However, while UV and EB coatings achieve gloss readings of above 90% reflectivity at a 60° angle, high-gloss aqueous coatings are not far behind with readings in the 80% range. Because of their cross-linked nature, UV and EB coatings are generally tougher and more abrasion and scuff resistant than aqueous coatings.

EB represents the most in capital equipment costs; coating and inks are expensive as well. On the other hand, the results obtained from an EB-cured coating go unrivaled for applications that can take advantage of its ability to cure thick, opaque coating films at high line speeds even through opaque substrates. Additionally, high gloss toughness along with low taint and odor has led to successful applications in food packaging.

UV has found many applications in the graphic arts because of virtually zero VOCs, instant cure, low energy requirements, comparable capital expense to competing drying systems (except EB), plus a long list of appealing properties. UV coatings are successful in the marketplace, and some markets, like narrow-web label, plastic tube, off-line finishing of litho and screen printing, have almost universally adopted UV. Compared with the conventional system they seek to replace, UV coatings and inks are seemingly expensive, but the high gloss toughness

benefits available from cross-linked UV products and gains in productivity are worthwhile to those who make the right match. Like many chemical products, UV must be handled carefully.

Since their inception, aqueous coatings have enjoyed volume growth. Perhaps the greatest benefit has been the productivity improvements afforded in sheetfed litho. Instead of waiting days for racked inventory printed with conventional oxidizing inks to dry before further finishing, printers can aqueous-coat in-line and work-and-turn or finish almost immediately. Aqueous coatings also perform well for those who have sought a nonpolluting replacement for many traditional solvent coatings applications. Among these would be blister coatings and flexo and gravure overprint varnishes.

I believe that coatings can be used advantageously to add value to printed material no matter what the process. Coatings can provide properties that are unavailable from print alone. However, not all coatings are suitable for all applications. If you do consider a coating system, know something about how it works and match the coating to the application and end use.

FOR FURTHER READING

"The UV Report" by Andy Teng, *Ink World*, October 1997, p. 36–41.

"Electron Beam Processing: It's Come a Long Way" by Ed Maguire, *Paper Film Foil Converter*, January 1998, p. 56–59.

"Aqueous Overprint Coating: A Process and Equipment Primer" by Raymond Siegel, *GATFWorld*, March/April 1997, p. 17–20.

"Aqueous Coatings: A Primer" by Raymond Siegel, *GATFWorld*, January/February 1997, p. 15–16.

"Aqueous Coatings: Dryer Configurations" by Raymond Siegel, *GATFWorld*, July/August 1997, p. 31–32.

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Conclusion

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