An Innovative Way to Print: Ultra Violet and Electron Beam Curing

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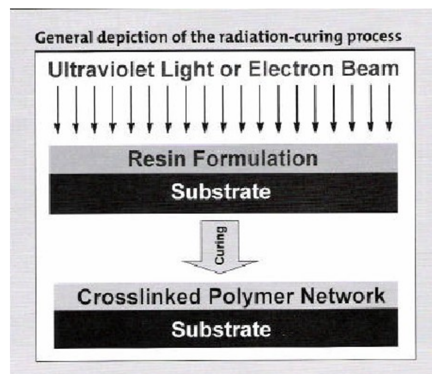
Introduction

Printing is widely used in our society to pass on information and to decorate objects. This has resulted in printing being used on many different packaging surfaces ranging from aluminum cans and plastic bottles to flexible plastic and paper. Special inks have been developed to provide optimal print quality in all of these surfaces. In this time of rapid change in technology, manufacturers are examining processes which are environmentally friendly, cost effective, and energy efficient. One such technology that has become more popular and more economically feasible around the world is Ultraviolet (UV) and Electron Beam (EB) curing technology. Among experts, UV and EB ink curing have been discussed in the same conversation as the terms sustainable, flexible manufacturing, energy efficiency, increased ROI, higher quality products, lower greenhouse gas and VOC emissions.



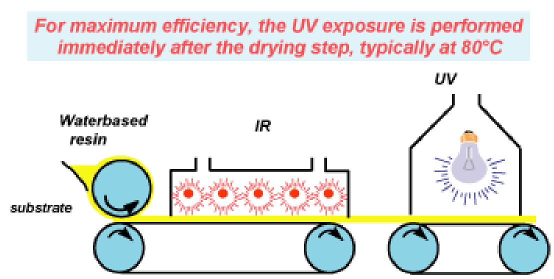
Radiation-Curing Process (Miller, 2005).

Before divulging the world of radiation technology, it is important to understand the basic process. UV and EB curing technology is often referred to as radiation curing "radcure" because both systems use radiant energy sources: ultraviolet rays and electron beams. Radiation curing is typically describes as ultraviolet light and electron beams polymerizing a combination of monomers and oligomers in the form of ink into a substrate (RadTech International North America, 2005).

Manufacturing Equipment and Process

Radiation curing and UV/EB inks have been around since the 1960's. However, they have only recently become widely accepted, they are therefore still considered "new" technology. Most conventional ink systems need to go through a drying process by either absorbing or evaporating excessive ink and solvent or water, or a combination of both. UV/EB inks go through a different process called "curing." Utschig (2004) describes curing as the chemical reaction that a material goes through to get from the wet to the dry stage. Ultraviolet and electron beam cure via different modes of energy and ink compositions.

The primary difference between UV and EB radiation technologies is the type of energy used. During the UV process the photon is used, which is known to have both particle and wave-like characteristics. The photon emitters used for UV cure are typically medium pressure mercury lamps, pulsed xenon lamps, LEDs or lasers. The photons of light are absorbed at the surface of the material. In order to do this effectively the ink is composed of a combination of oligomers, monomers, and photo initiators. Monomers are the building block of all matter that can be chemically reacted with each other to form polymers. In the UV curing process they act as diluents to lower viscosity of the material being cured. Oligomers are moderately low molecular weight polymers that can be further reacted to form an even larger polymer. The presence of oligomers dictates the properties of the ink, adhesive, or coating. The third component of the ink is unique to UV curing: the photoinitiator. This ingredient is necessary to absorb light which then produces free radicals. The free radicals are responsible for inducing the chemical reaction between the monomers and oligomers to make the polymers and ultimately cure the solution (RadTech International North America, 2005).



UV Curing Process (SpecialChem S.A, 2009).

The amount of energy required for UV curing depends on the ink composition and the substrate. The energy is determined and measured by the wavelength of the light rays. Packaging applications usually required energy between 250 to 450nm. Like sound waves, the shorter the wavelength the photon travels, the higher the energy applied. UV curing processes are characterized by the total amount of UV energy applied per unit surface area (Lapin, 2008).

As mentioned above, UV curing equipment include medium pressure mercury lamps, pulsed xenon lamps, LEDs and lasers, but this list is not all inclusive (RadTech International North America, 2005). UV curing equipment is bought as single lamp units fixed to speed conveyors. Two, four, eight or more lamps can be set up depending on volume demand, each with variable power sources for speed control, varying total input energy, automatic shut-down equipment and cooling alarms. Ultraviolet light curing equipment is basically an artificial source for sunlight. Cylindrical or spherical vacuum bulbs generally contain a very small quantity of mercury (Bean, 2006).

The smallest energy particle used for EB curing is the electron. Equipment is composed of the electron beam, a vacuum pumping system to maintain the high level of vacuum, a power and control system, a conveyor and shielding system. Complete systems incorporating all of these elements sometimes are referred to as "self-shielded" EB curing systems (Epstein, 2008). In the process, electrons are accelerated through a vacuum chamber to create an electric wave. The electrons then pass through a filament, typically made of titanium filament or "window" accelerates the electrons in specific directions due to a voltage potential between the "back" and the "front" of the device (Epstein, 2008). Electron beam generators used in curing applications are designed to create a "shower" or "curtain" of directed electron beam energy that can be used for industrial curing processes (Bean, 2006).


EB curing system (Epstein, 2008).

The ink used in EB curing is similar in composition to UV curing ink besides one particular component. EB curing does not require a photoinitiators. A typical EB electron upholds 70,000eV, while most chemical bonds that inks consists of are of an order of 5eV

Obviously, EB electrons have ability to penetrate through the matter to cure because they contain a greater amount of energy than a chemical bond does. Therefore, EB curing is more effective in thinker inks and coatings and performs better with different color inks, as it does not use light which can reflect off (Lapin, 2008).

The energy in EB curing is limited to the equipment used and what acceleration it can eject electrons. The range of accelerating potential typically used in packaging applications is approximately 80 to 180kV. Similarly, the "dose" for EB curing depends upon the ink composition and the substrate used. The electrons lose some energy during the application process. As the electrons pass through the foil window and air space between the window and the substrate it loses energy. Therefore, if the EB unit is set at 100kV, the substrate is only enduring 70kV (Lapin, 2008).

Packaging Applications

As technology develops, the list of packaging and printing applications for radiation technology grows. A general list of printing and coating applications for curing processes include: flexible packaging, folding cartons, tags and labels, cup and tub, and point-of-purchase display printing (RadTech International North America, 2005).

As flexible packaging has increased in popularity in the food industry, many companies have put pressure on the Food and Drug Administration (FDA) to approve radiation curing for food applications.

A 28-member group, which includes Printpack, Rock-Tenn and MeadWestvaco among others, is charged with addressing FDA clearance for Food Contact Notifications (FCN) for UV/EB formulas. By pooling resources, the alliance hopes to cut the cost of doing pre-application tests, data compiling, assessment of dietary exposure, and the final filing of the FCNs. (Bluestein, 1995).

The group's goal is to overcome the FDA's Code of Federal Regulations that states that food packaging materials can not (1) adulterate food or (2) cause taste or odor in food and (3) must be suitably pure for their intended use (Page, 2006).

As for consumer products not to be ingested, the applications are endless. A list of companies that have already converted their printing process include: Procter & Gamble (P&G), FASTSIGNS, Inc, and Taylor Guitars.

Samples of flexible packaging utilizing EB technology (Sanders, 2003).

Present Alternatives

Printing inks are made of four components each with a specific role in the manufacturing process including pigments, resins, solvents and additives. The pigment is used to color the ink and make it opaque, the resin binds the ink together into a film and then binds it to the surface and the additives alter the physical properties of the inks to adapt the ink formula to each individual application. Solvents are used to keep the ink liquid during the process. It is necessary for the ink to be liquid when applied to the printing plate and all the way until it has been transferred to the surface that is being printed. At the point of transfer, the solvent must separate from the remaining components to allow the image to dry and bind to the surface. One way to look at it is: solvent typically functions as a "carrier" for the "solids" portion of the material (Lapin, 2008).

Currently, most packaging manufacturers use solvent- and water-based inks to dry inks onto packaging materials such as corrugate, paperboard, and flexible components. The solvent process in particular produces the greenhouse gas CO_2 by thermal oxidation which is required to handle the emissions. Some critics of solvent-based processes agree that it is a wasteful process in terms of sustainability. The solvents used are derived from fossil hydrocarbon sources. In a Radtech report, Stephen C. Lapin states that “It is quite wasteful to use such a high value material for such low-value temporary function.” It seems he would support the idea that solvent usage has not changed with the packaging industry regarding sustainability.

Advantages

Rich Sanders, sales manager for Energy Sciences, Inc. (Wilmington, MA), described UV/EB technology with “Five E’s” at the UV/EB 2004 Technology Expo and Conference: “efficient, enabling, economical, energy-saving and environmental-friendliness.” To say the least, UV/EB curing benefits include immediate cure, high chemical- and moisture-resistance, low VOCs, good adhesion to plastics, and lower dot gain for higher-quality package printing.

The obvious advantage of using radiation curing is the excellent print quality on paper, corrugate, rigid plastic and flexible film. Even an average UV flexo ink has high gloss and excellent chemical, abrasion and heat resistance. These properties make UV flexography ideal for use in applications such as bottle labels that must endure bumps and scuffs in shipping as well as product leakage (Butschli, 2004, Section 1, ¶ 5). Dennis Rule, a packaging development manager with Procter & Gamble (Cincinnati), reports advantages that resulted form the switch from simple, lacquered cartons to EB-laminated OPP-film on cartons for its Quick Dissolve detergent lines. The move increased gloss by 60 percent, created a stiffer box for stronger top loading on pallets and resulted in a consistent moisture barrier for the sensitive product (Spaulding, 2004).

UV/EB curing can reduce the upfront capitol cost required to design a printing line as well as daily manufacturing costs. First, according to RadTech International North America (2005), UV/EB curing lamps “UV/EB technology translates into not only big energy savings, but also as much as a 55 percent reduction in capital and installation costs." This is because UV lamps and EB units are much less expensive than solvent-based drying units. Equipment for this technology was not always relatively inexpensive in the industry. Like any new technology, when UV lamps and EB units were first introduced prices were not justifiable for packaging industries. As time passes the equipment prices have become more viable and the technology is infiltrating the packaging food industry in the form of adhesives, coatings and inks.

If your product demand is low, UV lamps would be a wiser economic choice, as each lamp is less expensive than one EB system. Proceeding with UV lamps also allows accommodates for future growth, as you can simply add another lamp to the line. However, EB units are more reasonable when dealing with high volume production (Bean, 2006).

Ink composition is similar in both processes; however they are currently more expensive than traditional solvent inks. Though, because of the unmatched printing quality the ink seems to pay for itself by catching the consumer's eye over any conventional ink package on a shelf. Graphics will increase sales by its unmatchable quality.

Another plant concern is machinery footprints because space is often limited on a manufacturing line. Traditional drying ovens take up about 500 to 1,000 square feet, while UV machinery only takes up about 50 to 100 square feet. At a space cost of $.50 per square foot per month ($\$.50/sq^2/month$) conventional oven would cost in a range of $3,000-$6,000 per year. UV machinery would cost within a range of $300 to $600 (RadTech International North America, 2005). EB machinery is a bit more bulky, however only one is often required to sustain a line, while several UV lamps may be used in simultaneously on a line. Space is money.

Adding UV/EB equipment to a line also reduces operation costs by eliminating steps and materials in the conventional process. Both curing processes do not require a lacquer, while most solvent-based printing does in order to harden and shine. Also differing from conventional printing, the new technology does not need a film and laminating adhesive, as there is no need for adhesion.

The curing takes the place of these materials because the print substrate acts as a release substrate as well (Lapin, 2006). UV flexo inks exhibit superior press stability with no solvent replenishment, mid-run viscosity adjustment or constant pH monitoring necessary. On press, the consistency of UV flexo inks translates to maximum ink mileage, and it can increase the amount of salable print by minimizing print quality fluctuation during a run and minimizing down time for line adjustments.

Another great advantage of UV/EB curing is that the equipment can be placed in-line to allow for one step manufacturing, as opposed to previous methods where the material is often taken off line to dry in ovens for periods of time. Anthony Bean provides an example of taking advantage of the compact UV lamps and their ability to be constructed on-line: "on a multi-unit printing press UV curing allows the inks to be cured between each printing or coating unit." In-line curing allows for proactive quality checks. Just after the material cures an inspector can identify if the process is running correctly or not. If not, they can act immediately after the malfunction occurred, as opposed to the oven process where you may not truly know if the process is wrong until ink is full dried, this could take hours. That would be hours of bad product: a manufacturers nightmare. UV/EB curing is an obvious advantage to line efficiency, quality control, and product consistency. Ultimately it increases speed, therefore cost savings.

Sustainability Benefits

There are two main reasons as to why radcure is a more sustainable printing process than the conventional solvent based ink systems. The first is that it requires less energy and the second is that the process does not emit volatile organic compounds, or VOCs. It is important for manufacturers and converters to reduce their cost without jeopardizing the integrity of the end product. Well, radiation technology both reduces energy cost and increases the quality of printed materials.

A RadTech study has reported that using radiation technology a US manufacturer reduced the total amount of energy they used 80% compared to the traditional system (RadTech International

North America, 2005). This energy savings is predominately a result of the processes not needing an extensive drying and cooling system. The last steps in the conventional system are extremely energy intensive. The system relies on high elevated temperature dryers to evaporate the solvent or waters used to dry and set the ink, then on high airflow assist with the removal, and finally chill rolls to cool the ink (Sanders, 2006). RadTech International North America determined that the ovens and cooling equipment require approximately $44,736 per year in energy. While an electric UV system only requires $22,560 per year for the same volume (RadTech International North America, 2005).

The use of UV/EB curing processes reduces the amount of greenhouse gas and VOC emission by reducing the reliance of burning fossil fuels. As stated before, radiation curing is energy efficient and uses equipment that is cooler and smaller than that of other drying systems. After governmental programs, such as the United Nations and the EPA confidently determine the immediate and long term dangers of greenhouse gasses and VOC emission in the environment there will most likely be emission caps put on manufacturers. Radiation curing will help companies meet the requirements (Pianoforte, 2005). A RadTech study reports that a UV can-coating process line found an over 65% reduction in greenhouse gas emissions. The study compared UV curing to a water-based coating line with an incineration process. The energy story was also positive with an 80% reduction in the total amount of energy used by the facility's UV can coating process, compared to that of the conventional thermal system.

Limitations

For EB printing to become truly successful in flexible packaging, several hurdles need to be cleared, says Duncan Darby, product development manager with Alcan Packaging (Chicago). The hurdles include "lowering adhesive performance in some applications; structural performance and interactions with polyolefin layers and laminating inks; regulatory status for migration of monomers; costs of materials and slower processing speeds; and the capital expense of an existing, installed base of dryers and oxidizers used for traditional laminating." Darby feels that all these problems can be overcome with time, new technology and a closer look at bottom-line economics by converters and their customers (Spaulding, 2004).

Safety/Health Risks

The manufacturing processes and equipment for UV/EB curing provides additional safety. The solvent-free chemistry provides an explosion-proof environment. In UV curing, the ultraviolet light emits strongly in rays that can be categorized similar to the sun. Personnel are protected from these light waves through equipment designed to prevent openings of the equipment. It is practice that personnel working around UV equipment wear UV absorbing protective eye wear because stray light may reflect off of the cured substrate. Also, maintaining skin moisture is important when operating UV equipment. The use of barrier moisturizing creams and skin conditioning soaps is strongly recommended.

Heat can be generated in two different steps during curing processes. Infrared energy and ultraviolet light energy can transfer heat to the coating material being used. However, this heat is generally very. The second heat source is from the chemical reaction of forming polymers to cure. However, the only time the heat is a danger is during a web break when the material would stay under the light system.

Accidents, although rare, are stopped quickly by shutting off the lamps or units. Only the materials immediately under the units are in danger. Explosions or large incinerations are extremely rare and improbable. The monomers will not cause a fire however, the heat of combustion of the substrate or coating material may cause a fire.

Electron beam curing equipment provides even less opportunities to be exposed to the energy. A tungsten electrode is heated until electrons are emitted from the metal, and then the electrons accelerate through a vacuum with the use of increasing magnetic fields. Any radiation emitted during the process is completely shielded so there is no operator exposure.

Discussion/Conclusion

As UV and EB curing becomes more widely accepted in the flexible packaging industry, the needs and demands of converters, manufacturer, customers, and government will drive the development of new units and enhance the technology even further. All signs are pointing to a future growth in radiation curing including; environmental initiatives, manufacturing logistics, feasible financials, and excellent graphic quality. Sustainability is a mega-trend that seems to be turning into a way of life. It is safe to say that developing governmental requirements regarding harmful emissions will be the largest driver in regard to radiation technology in packaging applications. Like most new, innovative technologies, the radiation curing industry is thriving through a process most thought impossible. Only time can tell what is in store for packaging graphics.

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