

UV Sheet-Fed Printing

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Overview

Sheet-fed lithographic printing with UV-curable inks is the largest UV ink-printing process, followed by UV web litho, UV screen, UV flexo, UV letterpress and UV inkjet. UV curing capability exists on thousands of sheet-fed presses and can be installed either with the purchase of a new press or can be retrofitted onto an existing sheet-fed press. UV litho printing on sheet-fed presses is used mainly for various types of retail folding cartons, food packaging folding cartons, commercial printing and labels.

UV lithographic printing has been a rapid growth area since the 1980s, and the ready availability of UV hybrid inks since around 2000 has brought additional growth. Much of the growth has been at the expense of conventional oil-based sheet-fed printing. The effectively instantaneous cure achieved in UV systems gives the printer the ability to cut, fold, glue and ship immediately after coming off the press. Being able to respond quickly and not have the lag time and inventory problems caused by conventional ink drying times of two to three days are strong financial incentives for a printer to make a move to UV printing. The ability to convert an existing press with minimal mechanical issues and relatively low cost (compared to EB) reduces the barrier to entry. Good adhesion to plastic substrates, excellent moisture/chemical resistance and the very low VOC emissions of UV inks vs. conventional inks are other advantages.

The chemistry of UV lithographic inks is similar to other UV-curable systems in that photoreactive monomers and resins (usually acrylate chemistry) are combined with pigment, photoinitiators and various additives. EB litho inks are essentially identical, except that no photoinitiator is required. UV litho inks run and print with equal and sometimes better print quality than oil-based inks depending on the specific press setup, such as interstation curing vs. end-of-press curing and other process variables.

Several manufacturers of presses equipped for UV litho printing are in the market, including all of the large sheet-fed and web press companies. Also, there are many suppliers of UV lamp systems, enabling printers to convert existing lithographic presses to have UV capability. Several of these same lamp suppliers are OEM suppliers to the press manufacturers.

Markets

UV litho printing makes up about 80% of the energy cure litho market (UV sheet-fed, UV web, EB web). For UV litho

Quick summary

UV lithographic printing is the oldest and largest of the energy-curable printing technologies.

UV printing is divided between sheet-fed and web printing, and it is used for a wide variety of applications on many different substrates.

Costs of owning and operating a UV press are greater than for a conventional litho press, but the advantages of instantaneous drying, essentially zero VOC emissions, high chemical resistance and high print quality often make UV lithographic printing the best choice.

only, the ratio of sheet-fed to web presses is around 2:1, but the ratio of ink usage for sheet-fed to web is closer to 1:1 because of the higher press speeds and ink consumption rates on web presses. Some of the newer sheet-fed presses now run at the speed of some web presses. Sheet-fed UV litho can be for folding carton, commercial printing, advertisement and many submarkets. Substrates used vary widely, from uncoated paper to paperboard to coated commercial stock to many plastics, vinyls, films and foils. Web UV litho printing is mostly for food packaging and is on paperboard or polyboard.

Growth potential: UV

UV litho printing has been growing around 9% to 12% per year during the 1990s but is closer to 5% from 2002-2007. Most of this growth has been in sheet-fed UV litho, either with new presses or with converted presses. Some of the current growth comes from LED, HUV and similar modifications to existing UV light systems. They eliminate ozone and the venting necessary for its removal. They also eliminate IR light, which causes heat. The relative ease of converting a sheet-fed press to be UV-capable, plus the use of UV hybrid inks that do not require complete dedication of a press to UV inks, should allow continued growth in the 5-10% range. Converted presses can be switched between UV (especially UV hybrid) and conventional litho inks until the printer generates enough volume to enable dedication of a press to UV.

Regional strengths

The United States is the largest market for UV lithographic inks, although Europe is also a very large market for UV sheet-fed litho. Worldwide, sheet-fed UV litho is the most common

energy-curable lithographic process, largely because the cost of converting a conventional press to be UV-capable is fairly small.

Benefits and limitations

Benefits

The primary benefits of UV sheet-fed litho include:

- 1) It gives very sharp, good quality print.
- 2) It can be used on a wide variety of substrates.
- 3) It is a very green, low-emission process.
- 4) Very good chemical resistance can be obtained.
- 5) Sheet-fed printing allows rapid job change and is more efficient than web for short-run work.
- 6) The use of UV hybrids allows printers to add UV capability without committing to it.
- 7) The ink is fully dry and ready to ship immediately as it comes off the press.

Limitations

The most important limitations of UV sheet-fed litho include:

- 1) A higher ink cost vs. conventional litho.
- 2) A higher operational cost (UV lamp electricity, lamp replacement) vs. conventional.
- 3) Some additional capital cost for a new press with built-in UV capability.
- 4) Some presses do not provide a good location for mounting UV lamps, which can result in light leaks onto blankets, rollers or the plate.
- 5) The inks in a wet, uncured state are skin and eye irritants.
- 6) UV inks typically have shorter shelf lives (~ 6 months) and require more delicate handling and storage (heat, UV-light exposure) than conventional inks.

Other issues

Several other important issues affecting the use and application of UV sheet-fed litho printing include presses, print quality, inks, operating conditions and safety.

UV press issues. In most UV presses, UV lamps are mounted after each printing station to give interstation curing. This means the inks are dry-trapped, and darker, harder-to-cure colors can be applied early to have several exposures to the UV light. This is true for both web and sheet-fed presses.

UV lamps. It is very important to have the UV lamps be at least five inches longer than the substrate is wide. This is necessary to achieve full curing on the edges of the web. UV lamps also become less efficient with age. Checking the energy output from the lamps is important, or the degree of ink cure will decline, leaving the ink film soft and tacky. Energy output can be checked with several types of sensing devices known as radiometers (check with your lamp supplier) that can help you track lamp output vs. age. Typical medium pressure mercury vapor electrode lamp life is 1,000-1,500 hours for the longer wavelengths used to cure inks and up to 1,000 for

shorter wavelengths used to cure coatings, so a weekly check (depending on number of shifts) is advisable. There are a variety of different options to choose from in UV curing systems, such as electrode, microwave and narrow bandwidth LED.

Heat management (press). Since the UV lamps emit much energy in the infrared (IR) region, heat build-up must be controlled. When substrate movement through the press stops, shutters close to prevent the high-intensity UV light from scorching and causing a fire. When moving, the temperature of the substrate still will increase. Knowing the temperature sensitivity of the stock is important to avoid scorching or dimensional stability problems, especially in films. However, temperature control is possible, and even shrink-wrap film can be run under UV lamps.

Temperature build-up also is affected by ink color. Black inks absorb much more IR energy than light colors, and thus get hotter. Heat management is accomplished through the reflector design, reflector coating, quartz IR filters, forced air cooling or chill rollers. Lamp manufacturers have gotten very creative in reflector design and lamp housing for heat management, using various water-cooling strategies to reduce heat transfer from lamp to web. Heat management and placement in the press are the biggest technical issues facing lamp manufacturers.

Print quality. UV litho inks often have tacks in the high teens (at 1,200 rpm) and print very sharp dots. On plastic, film, SBS or polyboard, UV inks deliver top-quality graphic images. However, with lower quality papers and boards, lower tacks may be required to prevent picking and piling. This, combined with stock roughness, can reduce the apparent print quality. However, UV inks produce a better quality print on uncoated papers since they are cured instantly, while conventional ink dots can spread because of absorption into the substrate and result in lower gloss because of their slower dry times.

Inks: General information. Besides being curable, UV inks for lithographic printing have several features in common, such as they have a paste-like texture. As with oil-based inks, the best print quality is obtained with the thinnest film of the strongest and heaviest ink that does not pick or damage the stock while remaining in good balance with the fountain solution. Since most UV presses have interstation curing lamps, the inks are dry-trapped. This allows more latitude in formulating. UV hybrid inks, though, are designed to cure with less than full interstation curing. This means there is some wet-trapping with UV hybrids, and tack sequencing can come into play. Also, since the inks are designed to be energy-curable, the formulas have no added volatile organic compounds (VOCs), and thus are environmentally friendly. Because the inks are cured into a polymeric film, UV-curable inks usually have excellent rub and chemical resistance properties.

Inks: UV properties. UV-curable inks are made up of a mixture of reactive monomers, resins (oligomers), pigments and additives. A special – and necessary – additive in UV-curable inks is the photoinitiator. UV light is absorbed by the photoinitiator, which converts the light energy into chemical energy. This chemical energy then causes the polymerization of the monomer/oligomer mixture into a cured ink film. The monomers and oligomers have different roles. The monomers are used primarily to control viscosity, but other properties, such as cure speed and adhesion also can be changed. Oligomers give the basic film-forming properties of the ink. Different chemical backbone structures of the oligomers impart such properties as hardness, flexibility, toughness, adhesion, pigment wetting, ink/water compatibility, cure speed etc. Additives include various modifying agents for controlling film surface energy, slip or COF, rub resistance, misting, adhesion or pigment wetting.

UV lamps should always be shielded to prevent premature curing of the UV inks. There are some very high-quality UV inks in the marketplace, but they're not too smart. Anywhere stray UV light strikes the ink, curing will result. The ink doesn't know that it hasn't been printed yet, it sees the UV energy – and it's “party time.” It is very important to keep stray UV light from the ink roller train or from any contact with the ink until the ink is properly placed on the substrate.

Heat management (inks). In addition to stray UV light, premature ink curing can be caused by excessive exposure of the inks, even in unopened cans, to heat. Never store UV-curable inks outside, in direct sunlight or in warehouses where the temperature can regularly exceed 100°F. If possible, shelf life will be greatly extended if inks can be stored below 80°F.

Safety. In addition to normal pressroom safety concerns, UV systems have two special safety issues: UV lamps and the UV inks. UV lamps can cause eye damage if one looks directly at them. UV lamps should always be shielded to protect press operators, as well as preventing premature curing from stray UV light as discussed above.

UV inks have some special handling issues. Many years of practical production history show that UV inks are safe, but they must be treated with respect. Some people develop allergic skin rashes upon contact with the components of UV inks. These rashes can be severe. Not everyone is sensitive to the inks – some people show little reaction, some are immediately sensitive, and some show the allergic reaction only after repeated exposure. These issues are handled by proper safety and housekeeping procedures. For instance, nonpermeable gloves should always be worn when handling or cleaning up the ink. Ink spills should be cleaned up immediately. Any contact of the ink with unprotected skin should be washed immediately with soap and water.

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On press, UV inks are quite different than conventional oil-based inks, and the printer must check the rollers, blankets, plates and fountain solution to ensure all the components are mutually suitable. Also, press wash-up materials usually are very different for UV vs. oil-based inks. This can be a problem area for UV hybrids – if everything is set on the press to run conventional rollers and blankets with UV hybrids, and then the printer uses an aggressive cleaning material that causes roller swelling, little has really been accomplished. Cleaning materials for UV hybrid inks need to be carefully checked, before going to press, that they will both clean the inks and not swell the rollers.

Costs

Costs for UV lithographic printing can be divided into three major categories: 1) press-related costs (including new press purchases, press conversions to UV or other press modifications), 2) ink-related costs and 3) operating costs (utilities, fountain solution etc.).

Press-related costs

A new sheet-fed press will cost a few million dollars, but the incremental cost to make it a UV press is what is really of interest. Installing UV lights on an 8-color sheet-fed press with a coater can cost, at the time of writing, up to \$600,000. The cost of adding UV capability to a new press can be less than that of converting an existing press because, for existing presses, press components often have to be moved to make room for the UV capability. Also, new presses can be designed with many UV-friendly features built in.

Ink-related costs

UV inks typically run two to three times more expensive per pound than conventional oil-based lithographic inks due to the cost of the UV-curable raw materials, but the 100% solids nature of UV inks somewhat makes up for this differential.

Operating costs

While UV inks often require special fountain solutions, rollers and blanket rubber, the operating cost differential vs.

conventional inks is not important for these issues. UV hybrid inks are designed to run with the same fountain solutions, rollers and blankets as conventional inks. UV processing does have special operating costs. The power to run high-wattage UV lamps plus the regular replacement costs of the quartz UV lamps can be significant.

In the sheet-fed litho environment, the choices currently are conventional oil based litho or UV litho. EB is not a commercial option at the time of writing, being limited at the moment to web presses.

The curing process

Sources of ultraviolet light include sunlight, fluorescent lamps, mercury vapor lamps and, most recently, LED sources. UV light is a form of electromagnetic radiation, which includes radio waves, microwaves, infrared, visible light, X-rays, gamma rays and cosmic rays. Ultraviolet light exists between visible light and X-rays. All these forms are essentially the same physical phenomena, differing mainly in the wavelength and the frequency of radiation.

Ultraviolet light is energetic enough to break some chemical bonds. This energy starts the photochemical reaction necessary to polymerize UV-curable inks and coatings.

In UV curing, the term nanometer or nM (one billionth of a meter) is used to describe the wavelengths of UV light. The UV spectrum extends from 180 nM to 400 nM. The primary wavelengths needed for curing inks and coatings are around 250 nM and 365 nM. The most widely used UV-LED's have a very narrow bandwidth at 395 nM.

A photoinitiator or photoinitiator system is a molecule or combination of molecules that, when exposed to UV light, initiate polymerization at a much faster rate than would occur in their absence. Most often, no polymerization would occur without the photoinitiator system.

Photoinitiators absorb UV light and convert the light energy into chemical energy. To cure UV inks and coatings, the photoinitiator must absorb the UV light from the lamps. The wavelength of UV light that activates the photoinitiator must be available from the lamp. If a photoinitiator is activated at a wavelength of 250 nM, but this wavelength is not emitted by the lamp, no activation will take place. If the lamp does emit light at 250 nM, but the formula contains a high percentage of other non-initiator materials that absorb the same wavelength, then much less curing will occur. An ideal formula contains only materials that do not absorb the wavelengths that activate the photoinitiator. This is rarely the case under practical formulating conditions.

Monomers, oligomers, pigments and additives make up the remainder of UV-curable inks. Monomers and oligomers

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accept the chemical energy from the photoinitiator, and then use this energy to join together in long chains through chemical reaction (polymerize).

The advancements by equipment suppliers today have led to higher and higher UV-energy output from the lamps. The energy-curing industry usually refers to energy input requirements of a lamp in watts per linear inch or centimeter. This is because most existing UV systems and some newer ones do not have a device that measures output energy. A UV bulb six inches in length requiring 1,200 watts of energy has 200 watts per inch or 80 watts per centimeter energy input requirement. The output energy will be a mixture of UV light, visible light, infrared and heat. A UV radiometer is required to measure UV light output in mw/cm^2 (peak irradiance) and mj/cm^2 (energy density or dose). Radiometers are the most precise way to measure UV light output, although there are other methods, such as color-changing stickers. Many years ago, 200 watts per inch was standard on most equipment. Today there are many equipment suppliers and a variety of designs, special wavelength output and lamps as high as 600 watts per inch or higher. Development of UV-curable products and troubleshooting issues should involve UV output energy measurement.

As the lamp energy output increases, the ability to cure inks and coatings also increases. Higher lamp intensities provide the ability to cure inks and coatings at faster speeds without increasing the number of lamps. Higher lamp intensities also allow formulators to reduce the amount of photoinitiator, reduce the level of reactivity or both. This often improves product performance. In older UV lamp systems, lamp intensity steps up with throughput speed (low, medium or high). Each level represents about a third of the lamp's output potential. Newer lamp systems have up to 10 step levels or even 100% linear increase with press speed. The ability to change lamp output is necessary to prevent over cure during makeready press speeds and to ensure proper cure at production speeds. Newer systems also have the option of running less than full power when UV bulbs are new and higher as they age while still ramping up with speed.

Understanding the printing equipment is important, and UV-curable inks and coatings must be formulated to take advantage

of that equipment. Lamp energy (watts per inch) the number of lamps and through put speed are critical pieces of information. Slowing throughput while maintaining lamp output has a similar effect as increasing lamp output at a given throughput. Both methods increase the amount of UV energy received by the UV-curable inks or coatings. Fortunately most systems today control this with computers.

UV curing lamp systems contain reflectors to direct and focus the UV energy onto the printed substrate. For most lithographic printing, elliptical reflectors are used. These reflectors focus the UV at a focal point. This is the point at which the UV light is at its maximum power. The reflector provides two-thirds of the total UV energy to the substrate.

If the ink or coating is too close to the lamp, the UV energy is not yet focused or maximized. If the ink or coating is too far from the lamp, then the UV energy is beginning to disperse. When the ink or coating is too far from the focal point, the energy is weaker. This will affect the ability to cure the ink or coating properly.

A typical UV bulb consists of a quartz glass tube filled with various blends of mercury and other chemical compounds. By changing the chemical composition of the ingredients inside the bulb, changes in UV light output take place. When electricity is passed through the chemicals inside the bulb, they are heated to high temperatures. When these chemicals reach high enough temperatures and become gases, they also give off energy as light.

A standard mercury vapor lamp emits light in both the short wavelength and long wavelength spectrum. Modern UV bulb manufacturers produce bulbs that emit more strongly in specific areas of the UV spectrum. Bulbs now can be produced that emit primarily short wavelengths with very little long wavelength light. Other bulbs emit primarily long wavelengths with few short wavelengths. Such optimized wavelength bulbs have a higher energy output at the desired wavelengths without wasting energy generating unused light. All UV lamps emit visible light as well. Because of the intense visible light and the UV light, looking at UV lamps without proper shielding can be harmful.

The wavelength of light that a UV lamp emits is very important. The photoinitiator in most UV coatings absorbs and is activated by short wavelengths around 250 nm. If the UV lamp does not emit wavelengths at 250 nm, very little curing will take place. Pigmented systems are much more difficult to cure, since the pigments compete with the photoinitiators for the UV light.

Pigmented inks use a photoinitiator that is activated at long wavelengths, since longer wavelength light can penetrate

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deeper. This helps reduce the effect of UV light absorption by the pigment. To cure pigmented systems effectively, the lamp must emit long wavelengths around 365 nm. The selection of wavelengths of light emitted by the lamps is determined by the wavelengths of absorption of commercially available photoinitiators. If the wavelengths emitted by the lamp do not match the wavelength of absorption of the photoinitiator, little curing takes place.

Many different substrates are used for UV-curable printing and coating. These substrates can affect curing. A UV ink or coating may be very fast curing on one substrate and too slow on another, even when cured under the same conditions and with the same equipment. The method of UV curing involves light. Anything that can influence the path of light can affect cure.

Some substrates reflect UV light. UV inks and coatings will cure very well on these. UV light that makes it down to a reflective substrate is reflected back into the ink or coating for additional curing.

Some substrates absorb UV light. On these substrates, UV inks and coatings will cure slower than the same product on a substrate that reflects UV light.

There are also transparent substrates, such as clear plastics. Whether they absorb UV light or allow it to pass through, UV-curable inks and coatings will cure slower on transparent substrates than on a UV reflective substrate.

An important side effect of the very fast curing process with UV systems is the effect upon gloss. UV inks are normally lower in gloss than conventional oil-based inks. This is because there is a surface roughness on top of the ink film as it emerges from the nip. There is a little "legginess" in the ink that leaves the ink film surface uneven. This is true for both oil-based and UV inks. However, in oil-based inks, there is time for leveling of the ink surface to occur, and oil-based ink gloss is

usually pretty good. However, UV inks pass under the lamp within a fraction of a second after emerging from the nip, and any surface roughness on the ink film is frozen in place by the curing process. This roughness causes reflected light to scatter, coming off the ink film, and as a result, gloss is lower.

UV coatings, however, are known to have very high gloss. While this may seem counterintuitive, there is logic behind the observation. UV coatings are much lower in viscosity than UV litho inks, and therefore flow and level much, much faster. When they are cured, they form a hard, uniform surface on the print that reflects light very well, giving high gloss. UV coatings that are applied from an anilox roll coating unit (essentially a flexo unit) give higher gloss than UV varnishes that are applied in a litho printing unit. This is because the litho-applied UV clears must have higher viscosity in order to function in a litho printing unit, and therefore do not flow and level as quickly as a coating designed to be applied in a traditional coating unit.

Anything that interferes with the ability of the UV coating to form a flat, glassy surface will cause reduced gloss. Compatible blankets, rollers, photopolymer plates, etc. are necessary since the coating must first lay smooth on them in order to arrive at the print surface in the same way. Loss of gloss also can occur if there is too much wet chemicals under the cured UV coating. These chemicals can attack the coating and cause a significant reduction in gloss. Oil-based chemistry and UV chemistry are not compatible and will result in substantial loss of gloss if applying UV coating over wet oil ink.

Conclusion

UV lithographic printing is the oldest and largest of the energy curable printing technologies. UV printing is divided between sheet-fed and web printing and is used for a wide variety of applications on many different substrates. Costs of owning an operating a UV press are greater than for a conventional litho press, but the advantages of instantaneous drying, essentially zero VOC emissions, high chemical resistance and high print quality often make UV lithographic printing the very best choice. ■