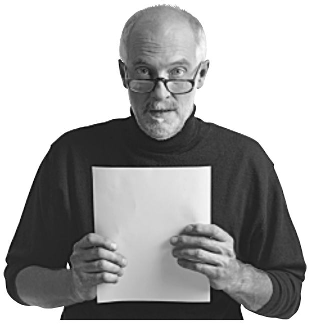

Technical Paper
Presented at REPLItech 2000

If you missed the presentation at Replitech 2000, here is your opportunity to catch up.

Pulsed UV Curing for DVD Production

Pulsed curing technology allows light to penetrate through opaque materials efficiently and thus avoids heat-induced substrate damage.

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Abstract

Thermal management plays an important role in the manufacturing of CDs and DVDs. Heat buildup on substrates needs to be kept at the lowest possible level. The magnitude of the problem increases with the productions of DVDs. The bonding process requires light penetrating through a substrate. Deep penetration and low temperature have long been a benefit of pulsed UV/Visible curing. After listing the reasons why pulsed UV/Visible curing penetrates opaque substrates with little or no heat build this paper outlines the optimization of the method for matching the pulsed light with substrates and curing formulations. The three most critical components of a DVD bonding production system are spectrum, peak power, and pulse duration. The "tuning" of these critical variables plays an important role in the matching process.

When CDs require curing of lacquer coatings, continuous mercury lamp systems have traditionally been the selected method fur curing. These surface coatings are easily reached by the UV light.

The curing requirements for DVD bonding are significantly different: the light must penetrate a 0.6 mm polycarbonate substrate containing one or two information layers on one or both sides to reach the bonding adhesive. Moreover, light needs to penetrate the DVD polycarbonate layer with sufficient energy to effect a through cure at a low temperature and high speed. Further, new developments in DVD (such as DVD 18 which are double sided, dual layered) post even tougher penetration requirements. Because DVDs have shallower and smaller pits, smaller track pitch and tighter tolerances of tilt and jitter than CDs, the effect of temperature on the substrate is much more pronounced. The expansion of DVD technology will certainly move producers to solve tougher curing problems and lower production costs.

With one particular type of UV curing—pulsed UV curing—these obstacles can be readily resolved. Pulsed UV curing differs from continuous UV curing in a number of ways. This article discusses the key characteristics of pulsed UV curing for DVD bonding at lower substrate temperatures: high peak power for penetrating thick and opaque materials, instant (in microseconds) on-and-off power application, lamp design flexibility and safety, as well as other universal benefits (See Figure 1.)

CURE PENETRATION

For the DVD, one important difference is in the deep penetration peak power as illustrated in Figure 2. With its high peak power, light from the pulsed lamp penetrates

Figure 1: An automated DVD bonder, at the WAMo facility in Pennsylvania uses pulsed curing.

the opaque substrate with sufficient energy to complete the cure. In comparison, a continuous UV mercury lamp delivers most of its energy as heat at or near the surface of the disc.

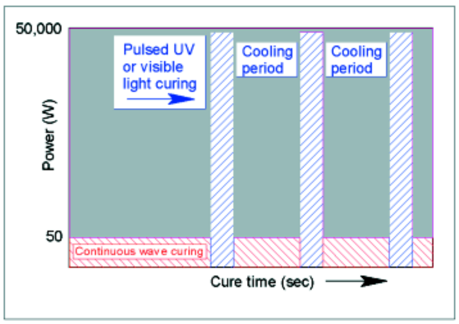


Figure 2: Instead of continuously warming the substrate, as does continuous curing, pulsed light provides cooling periods between pulses.

Consider two ways of expending the same amount of energy: you can either power a 10 watt continuous lamp for 10 seconds or you can power a 1,000,000 pulsed lamp for 100 microseconds. This is analogous to nailing a board. You could press on a nail with your finger for 10 seconds, or you could exert the same amount of energy and drive the nail in with one whack of a hammer. Pulsed light, like a hammer, delivers the light at a high peak power for deep penetration.

Deep penetration of a substrate also depends on another pulse characteristic: pulse width. Warner Advanced Media Operations (WAMO) recently tested thermal loading of DVD 10 discs (dual sided, single layered) using two pulsed UV lamps with different pulse widths. The more energetic pulse lasted nearly 1 ms, with smooth ramp up and drop off. The second pulse contained only 60% as much energy, but presented it in a 0.32 ms pulse with a very sharp onset and a higher peak power. To cure the discs, 6 pulses of the more energetic system or 10 pulses of the less energetic system were required. When the WAMO researchers measured the temperature of the

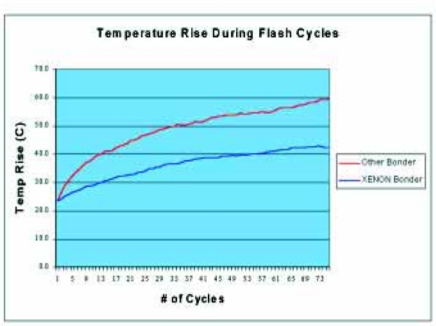


Figure 3: Temperature rises at glass surface vs. cycles of minimum required flashes.

glass pattern underneath the DVDs over a number of cycles, they found that the longer pulses raise the glass temperature considerably more than the shorter pulses (see Figure 3.)

CURE TEMPERATURE

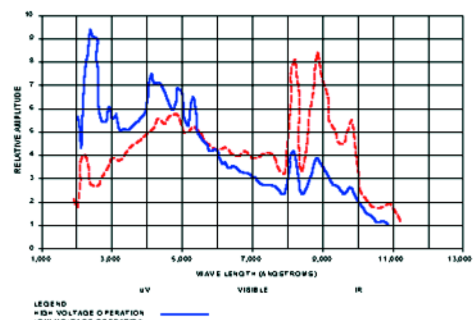
All DVDs are plastic and made from heat sensitive polymers. Processing steps that overheat the plastic can cause changes in the tilt. Excessive tilt can impair the quality and yield. For the DVD manufacturer, this is clearly unacceptable. The lower substrate temperature that can be achieved with pulsed UV curing can help prevent excessive tilt. There are five key reasons for low temperature buildup in the substrate during the DVD bonding process with pulsed UV curing:

1. short duration pulses; too fast for heat buildup,
2. cooling zone between pulses,
3. pulsed UV lamps run cooler than mercury lamps (which must operate at a high enough temperature to vaporize that metal),
4. high peak power of pulses eliminate the need for high average powers, and
5. no continuous infrared radiation; lamps can be turned completely on or off in microseconds.

ON/OFF PROCESSING

Most CD UV curing today is achieved with conventional mercury vapor lamps that must be left on continuously. The warm-up time and mechanical shielding necessary for the non-curing phase of the cycle for these lamps are undesirable for DVD production. Pulsed UV lamps provide full curing energy in microseconds instead of the several minutes of warm-up time necessary for electrode mercury vapor lamps.

Figure 4: Pulsed curing uses a wide spectrum through the UV and visible.



The chief virtue is the degree of control this affords the user. Processes can happen, stop - start - stop - start, with the pressing of a button or sending of an electronic signal from a programmable logic controller (PLC). For DVD makers, the important benefits are that since the substrate is at a lower temperature, it is less likely to warp like a potato chip and the lamp has a longer lifetime. This leads to better quality, higher yields, and lower operating costs.

This can also translate to process improvements, to significant savings in time and lamp maintenance on high-volume manufacturing lines. It is also safer for the lamp to be completely off when not curing. Processes can be more easily optimized with the control offered by pulsed UV curing.

Turning the light off without time penalties can also be important. With pulsed UV lamps, the pulses can be stopped instantly without incurring a time penalty for getting the line running again.

SYSTEM SAFETY AND VERSATILITY

Pulsed UV curing has two other characteristics that are not critical for most applications, but provide icing on the cake: it can be used with less toxic chemicals and it uses broad spectrum light.

Figure 5: Spiral lamp provides a different illumination pattern than linear lamps.

Neither the lamps nor the curing formulations contain toxic chemicals. Most UV lamps contain toxic mercury, a hazard should the lamp envelope be damaged. Pulsed UV lamps contain no mercury. For some companies, this has been reason enough to switch to pulsed UV curing.

This means that the user need no longer be concerned about the environmental regulations that cover using or disposing of solvents. The adhesive and coating formulations used for DVD manufacturing contain no solvents and only crosslink completely upon exposure to sufficient ultraviolet light. The ultrahigh peak power of pulsed UV curing insures that a complete cure results in all of the liquid converting to a solid. The material cures rapidly without emitting volatile gasses, so no toxins contaminate the air.

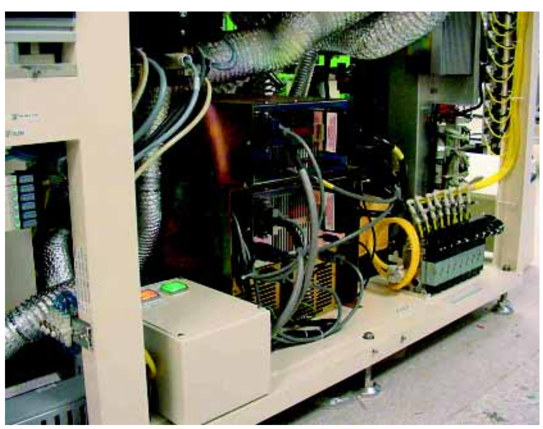


Figure 7: Some pulsed UV lamps have compact power supplies,which help minimize the footprint of an automatic bonder.

Pulsed UV curing can emit in both the UV and visible regions of the spectrum. (See Figure 4.) This is ideal for use with newly developed formulations that require both visible and UV light to cure. These adhesives won't cure when exposed to fluorescent room light (like visible curing adhesives), and required less UV light than adhesives that cure with only UV light. Broad spectrum pulse lamps provide a wide range of wavelength selection that offers an advantage to DVD manufacturers: these systems can be used with multiple adhesives from different vendors. Buyers of fully automated multimillion-dollar machines tend to like having more than one formulation choice for their processes.

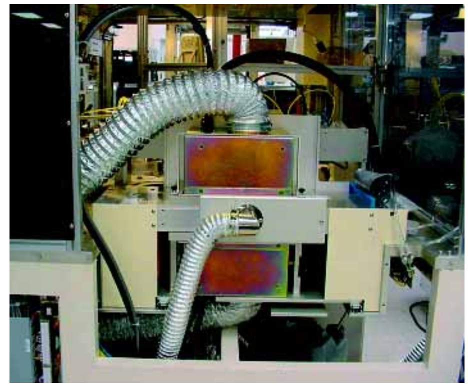


Figure 6: Pulsed UV lamp housings (Top and bottom) sandwich the DVD in the WAMO bonder.

Another area of choice for DVD manufacturers is the shape of the lamp. Traditionally, mercury lamps have been limited to short arc or linear designs, but other shapes may fit the application better. For example, a spiral lamp housing can be separated from the power supply with an umbilical cord (see Figure 6.) Because the power supply can be located away from the lamp, and because it can be made relatively compact, it provides original equipment makers with flexibility in placing components (see Figure 7).

As we've shown here, pulsed UV curing can solve a variety of problems for DVD manufacturers, by offering a technology for adhesive bonding that avoids heat-induced damage to the discs and penetrates farther through materials for thorough cure bonding at high speed. Pulsed UV curing lends itself to DVD production because the lamp geometry, spectrum, and pulse shapes can be designed to match the DVD substrate and bonding adhesive. Working with pulsed lamps, which can be switched on and off without warm-up and cool-down periods, can also make the engineer's life easier, because these lamps can be adjusted for thermal management, have longer lifetimes, and are easier than continuous lamps to correct tilt for higher yields.

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