Nailing Your UV Curing Adhesive Process

by Peter Swanson, MA (Cantab), Managing Director, INTERTRONICS

Introduction

The benefits of using a light cure adhesive or coating are well documented, including process speed and simplicity that lead to increases in productivity[1]. To achieve accuracy and repeatability, all the process variables need to be understood, and eliminated or kept within acceptable tolerances. Clarity and control of the variables will give manufacturers confidence in their process.

Qualify the process

OK, the design has been finalised, the parts have been fabricated, and the adhesive has been specified[2]. It was probably a quality person who originally said, "the task of engineering is to make it work once, while the task of quality assurance is to make it work all the time"; nevertheless, it is now the task of the process development team to take these parts and materials and establish a bonding process that works *all the time*. Prior to commencing production, the manufacturer should qualify this process, and in doing so gain a complete understanding of the process design.

In certain regulated industries (e.g., medical device manufacturing), the resulting process needs to be *validated*, a more onerous exercise; by collecting and assessing data, from process design right through to full production, we establish scientific evidence that the process is capable of consistently delivering quality product. There also needs to be a clear plan for how to maintain and verify the process on a continued and long-term basis.

Focal points

The two principal focal points are to ensure that a) the adhesive has undergone an optimal cure, and b) the adhesive is been applied in the correct quantity and in the correct place. In both cases, the key is to identify the process variables, which need to be understood and eliminated, or kept within acceptable tolerances. It is important to qualify the process by using actual production parts, with the final specified substrates and manufacturing tolerances.

Curing lamp wavelength and intensity

The adhesive product data sheet should give guidance on the appropriate curing lamp. This should include types of bulb if a mercury arc lamp — a long wave UV-A metal halide bulb is most commonly specified for adhesive curing. If an LED UV curing lamp is recommended, then a wavelength or wavelengths should be stated – 365 nm, 385 nm, 395 nm or 405 nm are common. Some guidance on the required intensity may be given; if not, we recommend a minimum of 50 mW/cm2. Once specified, the lamp type and wavelength should not be changed without a requalification.

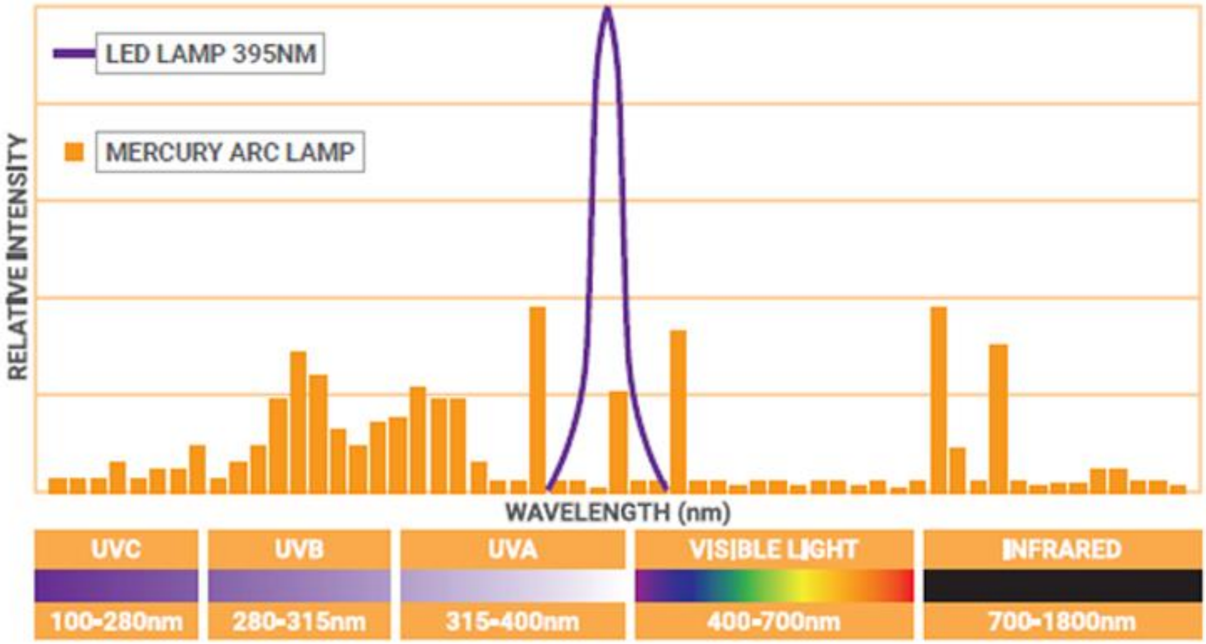

Figure 1 – The spectral output from a 395nm LED UV curing lamp compared to a mercury arc, broad spectrum lamp

Determine full cure

In setting up a UV light curing process, the key to success is ensuring that the adhesive or other light curing material receives the correct "dose" of UV curing energy in order to cure as completely as possible.

Dose is the total energy arriving at the surface per unit area and is made up of the intensity of the light combined with the time duration of the exposure. We use the term "intensity" to mean the irradiance or radiant power arriving at a surface per unit area, and we measure this in W/cm^2 or mW/cm^2. The UV element of the sun's rays reaching us in the UK (on a very sunny day!) would be about 2 mW/cm^2, whereas the latest UV curing equipment can have intensities of up to 40,000 mW/cm^2. In scientific terms, dose is measured in J/cm^2 and equals W/cm^2 x seconds (intensity x time). In very general terms, it is better to have a higher intensity for a shorter time, than a low intensity for a longer time.

Every application is different; each has a particular set of substrates, bondline topography, and varied light transmission characteristics. These affect the amount of light energy getting into the bondline. So the dose for an optimal cure must be determined using practical testing on production parts.

We can define full cure as the point at which additional cure time or intensity no longer improves the physical properties of a cured material. The process engineer should choose measurable parameters with which to empirically detect the amount of cure, such as bond strength or adhesive hardness. These should be measured post cure, after return to ambient temperature.

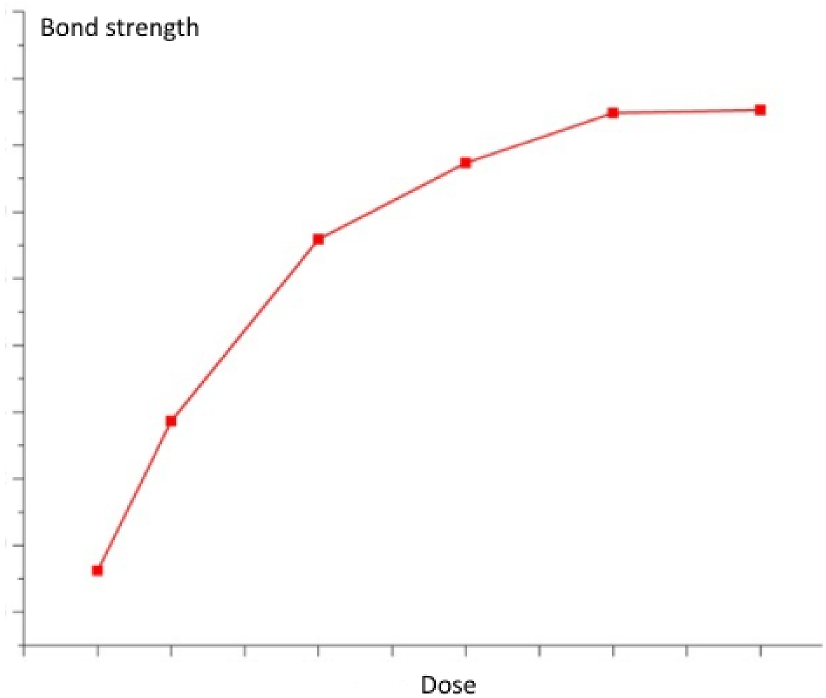

Figure 2 – Determining full cure by measuring bond strength against curing dose

Some materials have features to help understand when cure is complete, such as Dymax See-Cure colour change technology. Adhesives with this capability change colour (e.g. from blue when uncured to clear when cured) and provide a visible indicator of cure.

Determine minimum intensity and exposure time

Having understood how to determine a "full cure" on production parts, the process development engineer can then qualify the process parameters to achieve this — determining the minimum dose required for full cure in the specific application, using empirical testing.

There are two methods to achieve this. Method one is to set the exposure time and vary the UV light intensity to determine the minimum intensity that achieves cure within that time. This is an appropriate method for faster or high output production lines where cure speed is important to maintain line throughput. It may require high power UV curing lamps, or multiple lamps, in order to obtain cure within the set time. Method two is to set the intensity and vary the exposure time, to determine the minimum exposure time; if it transpires that the minimum exposure time is too long, engineers can then opt for a higher intensity, or specify multiple, sequential curing units.

It is important to note that, as a rule of thumb, curing intensity decreases with distance under an inverse square law. Distance from the lamp to the bondline is a very influential variable, and should be fixed in process development; place the curing lamp or lightguide as close to the bondline as feasible — and then fix that distance, removing the variable.

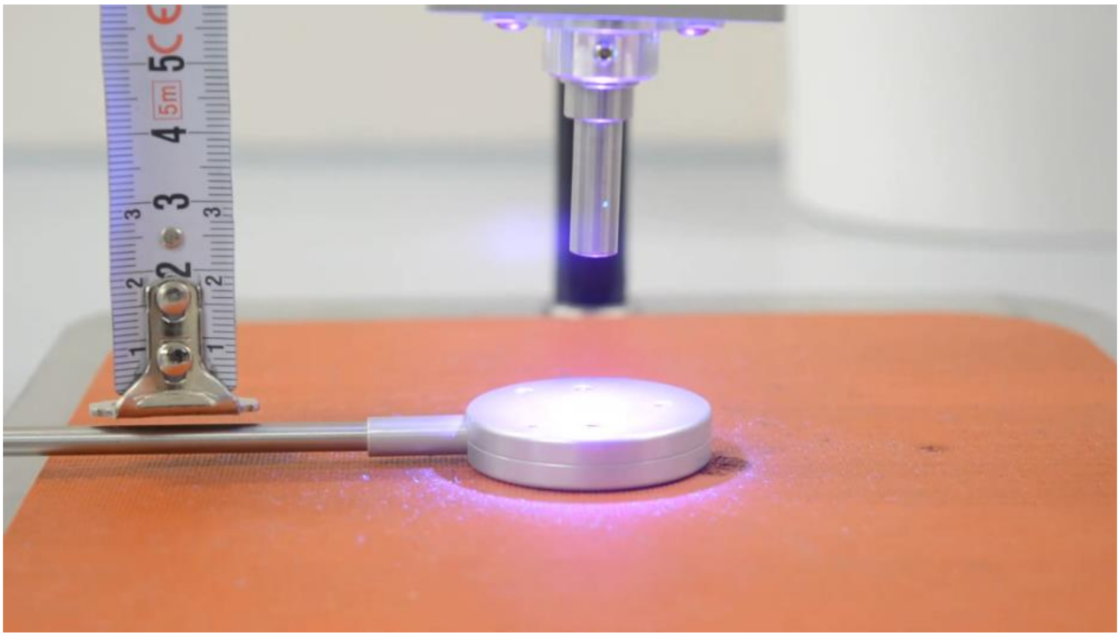

Figure 3 – UV curing intensity or power is proportional to the inverse square of the distance from light source to bondline

Broad spectrum UV curing lamps based on mercury arc lamp technology (the workhorses of the industry for many decades) bring with them another variable. The curing intensity decreases with hours of operation; this needs to be monitored using an appropriate radiometer, and bulbs replaced when the intensity is too low for optimal cure. One ramification of this: if a high intensity/short time strategy is pursued, bulb changes might be quite frequent, with increased associated costs. UV curing lamps based on LED technology do not lose their curing power over time in any appreciable way.

In addition, the intensity may not be consistent across the entire light source output, so manufacturers can perform intensity mapping — taking several intensity readings across the illuminated area — to understand what is happening. The manufacturer may have to define intensity based on the low power areas of the light source to make sure parts cure fully in production. This is useful insight for manufacturers curing multiple parts at once on a fixture or pallet.

Determine the safety factor

The next step is to determine a safety factor, as this will help create a robust process capable of withstanding unavoidable variations in the parts and the process. The safety factor is added on to the minimum intensity to create the minimum intensity limit. For example, if the minimum intensity for full cure in five seconds is determined to be 75 mW/cm2, a safety factor of 50% would make the minimum intensity limit 113 mW/cm2.

Every application is different, and determining an appropriate safety factor and minimum intensity therefore lies with the user. From experience, Intertronics would recommend a 25% safety factor, but for best results we suggest you consult our team, who can advise you on your specific application.

Define the upper intensity limit

Too little a dose of UV light can result in an incomplete cure, but there are also risks associated with too much. The manufacturer can determine the highest intensity that still produces acceptable parts in the time frame, without causing any damage to the substrate or adhesive from too much energy.

After these steps, the process has a defined upper and lower intensity specification for the specific application, which leads to full cure in an appropriate time. The process must be developed so it stays within these defined limits.

Process control
Manufacturers should monitor and document the output intensity of their curing lamps, to assess the health of the system and ensure it is consistently within the limits established in process testing. The intensity of a mercury arc broad spectrum lamp decreases over time, so regular output checks are recommended. While there is some predictability to the degradation curve, operating factors like how frequently the curing lamp is turned on and off can affect the degradation appreciably.

Mercury arc UV curing lamps may take up to five minutes to achieve full intensity after being switched on, and this should be taken account of — we usually recommend that mercury arc lamps are left on all day. LED UV lamps, however, are instant on/off and have no warm-up or warm down time. LED UV lamps have minimal intensity degradation over time, and introduce less process variability, so are a good choice if they are a viable option to cure the specified adhesive.

The manufacturer should check whether the lamp's intensity is sufficient (more than the minimum intensity limit) using a radiometer and adjust intensity or replace the bulb if it has decreased. As with other manufacturing activities, the process should be clearly documented, including the serial number of the radiometer used, when it was last calibrated, exposure time, distance from part and more.

Figure 4 – A radiometer should be used to regularly check the intensity of the UV curing lamp

To ensure that the qualified process is well managed, regular checks and preventative maintenance are recommended. The regular intensity check (some customers do this at the start of every shift) should be done using calibrated radiometers from the same manufacturer; different models can show incomparable readings. Use a fixture or jig to ensure that the radiometer sensor is always in the same place in respect of the light source. Regular cleaning of reflectors and the ends of light guides will remove the effects of accumulated dust and contamination. Schedule checks of the transmission of the light guide, as these also will suffer some degradation over time.

Figure 5 – UV curing lamp lightguides should be regularly checked for cleanliness and UV light transmission

Dispensing

Application of UV curable adhesives is a relatively straightforward process; they are single part, only cure when they are exposed to the correct light, and can often be specified with a procedure friendly viscosity.

The process qualification involves determination of the minimum and maximum amounts of adhesive required to achieve the specified bond strength. This, like the light dosage analysis, should be done empirically using actual production parts. Once these tolerances have been established, the appropriate dispensing technology can be specified and implemented. The choice of adhesive application method can range from simple time/pressure dispensing controllers to highly developed positive displacement equipment[3]. Whatever technology is chosen, accuracy and repeatability should be checked to ensure that the tolerances are met. Dispensing needles should be replaced regularly, and the dispenser maintained to a schedule.

Adhesive placement should be detailed, and checked for accuracy and repeatability. Take account of the flow or wicking tendency of the adhesive, and make sure that the bondline is void free. Narrow tolerances here may require some form of automation, like a dispensing robot, in order to keep to the qualified process.

Figure 6 – Dispensing accuracy and repeatability can be significantly improved with automated, robotically controlled processes

Conclusion

The more variation a manufacturer can eliminate, the more controlled the process will be — we know how much engineers hate variation. But, if the variation can't be eliminated, it can be understood and accommodated by the process.

Because there are so many nuances between different applications, the best approach is to partner with an experienced adhesives supplier. It is best to work with a supplier experienced in materials, dispensing technology, and curing lamps, who understands all of the details, and can help you validate your process from day one, and beyond.

References

1) Where Adhesives Beat Mechanical Fasteners – Nicole Langer, *Machine Design*, August 2005
2) Designing-in Light Curing Adhesives – Peter Swanson, Intertronics White Paper, July 2014
3) The "Endless Piston" Pump – Technology for Precision Dispensing – Peter Swanson, Intertronics White Paper, March 2012

Picture credits

Figures 4, 5 – Dymax Corporation, www.dymax.com

Contact

intertronics
adhesives, coatings, sealants & equipment
for your manufacturing and technology applications

INTERTRONICS
Station Field Industrial Estate
KIDLINGTON
Oxfordshire
OX5 1JD
England
t 01865 842842
e info@intertronics.co.uk
www.intertronics.co.uk

About INTERTRONICS

INTERTRONICS supplies adhesives, coatings, sealants and equipment to customers with high technology, high performance assembly applications. Our customers are manufacturers in industries such as electronics, medical devices, plastics, optical, automotive, energy, defence and aerospace.

We specialise in adhesives and adhesive systems, namely bonding, coating, sealing, encapsulating, potting, masking and gasketing products, together with the most appropriate equipment and accessories for surface preparation, mixing, application, dispensing, and curing them. The provision of insightful technical and applications guidance is a cornerstone of our business. We help you find the optimal materials and processes for the manufacture, assembly or repair of your products, safeguarding and enhancing performance and integrity and, in turn, your profitability and reputation.

Ever since being established in 1979, when our main market was the printed circuit board assembly industry, we have enjoyed a reputation for customer focus, excellent service and post-sales support. We now supply over 3,000 regular customers, including multinational manufacturers, production facilities, specialist design and development businesses, universities, training organisations and government establishments.

Visit the **about us** section of our website for more information.

More questions?
Please call us on **01865 842842** or email **info@intertronics.co.uk**

Share with a colleague
Please feel free to pass this white paper along to your interested friends and colleagues.

Stay in touch!
Please let us keep you up to date - fill in this form to receive **JoinedUpThinking**, a regular, simple e-mail containing ideas for the practitioner of high technology, high performance assembly.