ADVANCES IN SPOT CURING TECHNOLOGY

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Spot curing technology is the process by which a spot of energy of a specific wavelength bandwidth and irradiance is used to cause a coating, encapsulant or adhesive to change from a liquid to a solid state. The photochemical process is the same used for UV curing varnishes, wood coatings, and UV paints but the difference lies in the area of cure.

As a brief review, the technology uses the ultraviolet (UV) and visible spectrum emitted by vaporized mercury within a pressurized quartz envelope (see figure 1 for a spectral output graph). These lamp assemblies are known as mercury lamp systems or UV-curing systems. In the wood coating and graphic arts industry, they are medium pressure mercury long arc lamps (linear curing systems) used to irradiate a large area with UV energy. For the rework of small areas in the coating and encapsulation process, high pressure short arc lamps are used as a final step to prevent the scrap or expensive rework of material. They are also very commonly found in the electronics industry, hard disk drive industry and optoelectronic industry for the bonding, sealing or encapsulation of small components and areas.

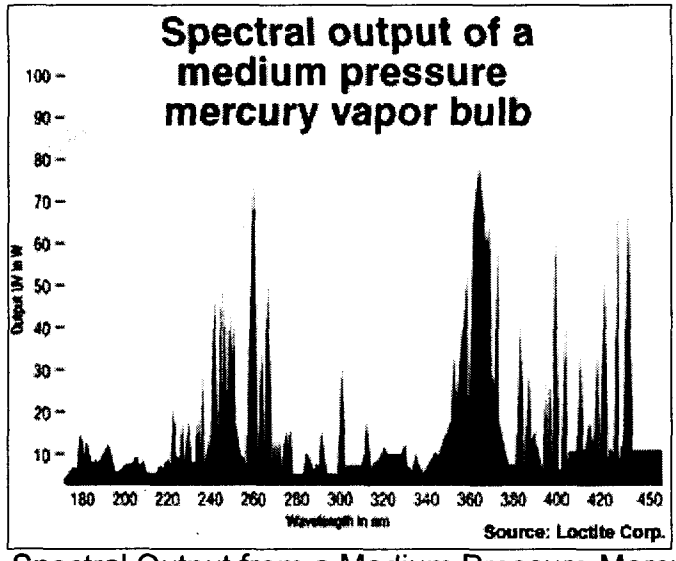

Figure 1. Spectral Output from a Medium Pressure Mercury Lamp

Coatings, encapsulants and adhesives used in the various industries have moved away from solvent-based formulations and moved towards reactive systems such as photo-curing formulations (also known as UV/visible curing), heat curing

formulations, and combinations of both curing systems. The fastest polymerizing systems belong to the UV/visible family where a wide range of paints, coatings and adhesives have been formulated to address the evolving requirements for glossy coatings, fast cures, and safe solvent-free cures. Whereas the initial large-scale use of UV/visible light can be traced back to ancient Egyptian times, the modern commercialization of UV curing resulted from its popularization in the graphics industry and wood coating industry. Soon afterwards, the electronics industry used it in PCB photolithographic processes. Niche markets for highly controlled irradiance resulted in the photo-curing of assembly glues and the encapsulation of electronic components.

The wood coating industry tends to benefit most from linear curing systems. However, there is a need for spot repairs and applications of high UV energy. Most of the paper however will detail the benefits of spot curing in specific industries such as the data storage industry, the medical device industry, and the electromechanical industry. The key benefits highlighted in the case studies are ease of use, reduction in operating costs and improved productivity.

Brief Background of Spot Curing

Note the spot curing system in figure 2. This system has an interactive menu system providing full process control and traceability; interfacing with external logic; and full bandwidth control. Many of these features may not be found in common industrial spot cure systems but should be considered at all times when optimizing process conditions. The key points with spot curing are to maintain the irradiance under control for a specific bandwidth.

Figure 2. Novacure™ Spot Curing System

Coating Repairs and Small Applications

Coating formulations used in the graphics industries, wood coating and other large area applications tend to be applied and cured in fairly thin layers. These coatings are also sensitive to absorption in specific bandwidths, peak irradiance and total dosage according to their photoinitiator, their chemical reaction (free radical or cationic) and their pigmentation. In other words, there are specific cure windows where the coating will be optimized in its final physical state as a result of the type and amount of energy transferred to it.

One particular wood coating application involves the localized repair of small defects in UV coated hardwood floors. The limit of cure area is approximately a circle of 50mm in diameter but slightly larger areas may also be addressed with the correct spot curing equipment. There are specific customers in Europe and North America using this repair method.

Another specific encapsulation application involves the localized repair of porcelain assemblies which have defects (holes and voids) resulting from the glazing and manufacturing process. A specific user mixes an acrylate based formulation filled with UV photoinitiators and pigments (simulating the glazing color) to backfill the voids and hence reduce their scrap rate.

A common artesanat application (found in Europe, Asia, and North America) involves the use of UV/visible light curing adhesives with optically clear properties to manufacture crystal figurines, glass sculptures, and even glass furniture. The key requirement in this application is the controlled use of energy to provide a minimum amount of glue shrinkage while providing a structurally sound assembly. Typically the glass substrate must be transparent to UV although they may be colored in the visible spectrum as figure 3 shows.

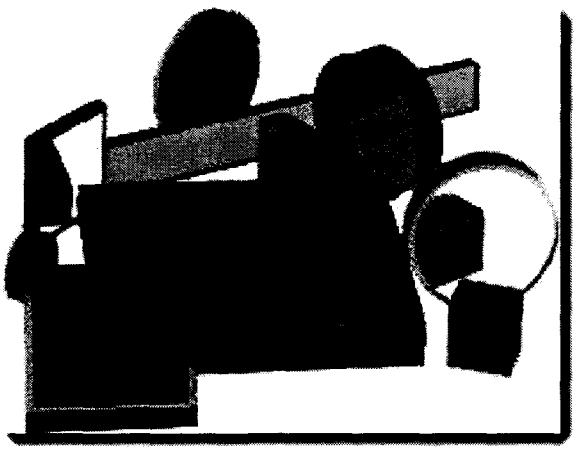

Figure 3. Glass/optics Bonding Capabilities

Data Storage Industry

The data storage industry (also known as the disk drive and optical drive industry in Asia) has undergone radical changes in its assembly technology and its manufacturing base. The disk drives which are used to store data in magnetic memory have reduced in size from boxes weighing several pounds to enclosures so small that they could be used in laptop computers and navigational systems. Consequently, traditional fastening assembly methods have been largely replaced by light-curing adhesives. The adhesives themselves, once cured, must meet stringent outgassing requirements in addition to the usual requirements for consistent physical properties. The adhesives of choice have been formulations which are solvent-free and photopolymerizable (commonly referred to as UV/visible formulations).

The key adhesive applications involve the bonding of miniature components in precise locations. Figure 4 shows the internal components of a disk drive assembly. Typically spot curing systems are used because of the control that can be had over the area of illumination and because of the high energy output in concentrated areas which is possible only from a tightly focussed spot cure system. There are over a dozen applications within the disk drive assembly. Some of these include tacking the read/write head to the suspension arm (HGA), bonding the interconnect wires on the suspension and head-stack assembly, encapsulating the wire-to-flex connections (strain relief of fine wires), bonding voice coil and magnet components, and retaining and sealing cylindrical assemblies. Spot curing and UV/visible technology are an integral part of the disk drive assembly process and are a major contributor to the cost advantages of an Asian manufacturing base by empowering the user (or automated system) to consistently manufacture products in high volume.

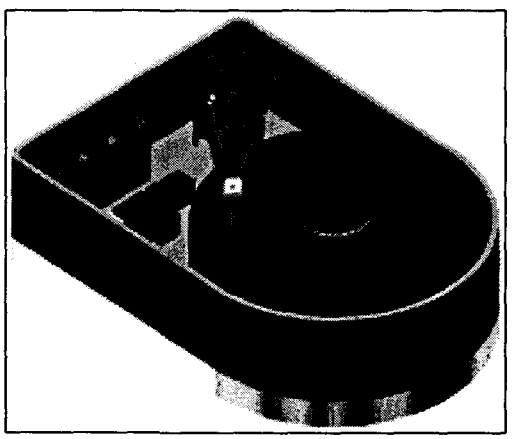

Figure 4. Disk Drive Assembly (*courtesy of Read Rite)*

Key parameters to consider in disk drive assembly operations are:

- ✓ Adhesive Selection and Physical/Chemical Cured Properties.
- ✓ Appropriate Curing Bandwidth Selection (typically the entire UV spectrum is important for tack free assemblies. There may also be some requirement for visible energy for certain adhesives).
- ✓ Appropriate Curing Intensity Selection (when tacking adhesives, very high energy is required for a high volume process but a lower controllable amount of energy is required for full cure and/or specific physical requirements from the adhesive).

The Medical Device Industry

The disposable medical device industry works within a highly regulated environment (FDA, GMP,ISO) and usually functions in a labor-intensive workplace. Consequently assembly processes are strictly documented and regimented. Medical devices, by their very nature, tend to be invasive and tend to be composed of a variety of materials (plastics and metals). They may also include electronic subcomponents and systems integrated with delivery devices (neural sensors, oxygenator systems, pumps and valves). Photo-curing adhesives have formed an important part of this industry for decades. Spot curing has also formed the backbone of this industry due to the ease of use of these systems in manual and semi-automated environments.

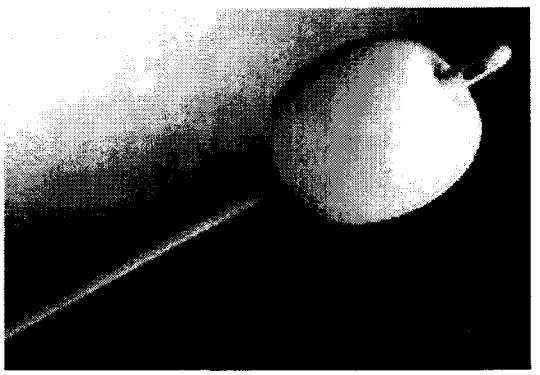

Figure 5. Bonding and Sealing a Balloon Catheter.

The adhesives used in the industry are required to either be composed of FDA approved ingredients or more commonly, the bonded assembly should have passed toxicity testing and clinical trials. This is often true for medical devices incorporating electronic assemblies even though they may not be completely invasive. Consequently, the way the adhesives cure is very critical since the curing method may also affect the physical properties of the bonded devices. Typical

applications involve the bonding of dissimilar materials such as tube to connector bonding, steel needle to hub bonding, balloon to tube bonding, sealing of electronic enclosures, and the encapsulation of electronic circuits in medical devices.

Key parameters to consider in medical device assembly are:

- ✓ Adhesive selection (the uncured properties may be important as well as the cured properties when considering processing requirements and end-use requirements)
- ✓ Bandwidth selection (this is particularly important when dealing with plastics or other components which may absorb energy from particular wavelengths and be physically affected by this absorption. A specific example can be seen when irradiating off-the-shelf polycarbonate with broad band UV. This causes very rapid heating of the substrate resulting in permanent damage to the plastic. The solution is to choose a narrow band filter centered around the highest effective wavelength (usually centered around 365nm) to provide energy which will not be absorbed by the polycarbonate but will also polymerize the adhesive in question.)
- ✓ Intensity selection (the correct amount of energy is required to cure the adhesive without causing undue shrinkage when encapsulating or undue stresses when bonding components together).

Electromechanical Assemblies

UV/visible applications include the assembly or encapsulation of a combination of electrical circuits, controls, coils assembled with or within mechanical assemblies. Under most assembly conditions and design for manufacturing specifications, the use of adhesives will reduce the number of assembly components or will complement simpler press-fit, snap-fit, and staking operations. This is done through the use of the adhesive's key property of behaving as a liquid until forced to cure. Light-curing adhesives and spot curing systems are ideal partners in these applications. Modern spot curing systems can provide a controlled window of bandwidth and irradiance to obtain the desired cured physical properties.

Figure 6 shows a typical application involving a motor assembly where a seal is required to prevent migration of lubrication fluid which could contaminate surrounding assemblies (the specific figure shows the motor used within a disk drive assembly where contamination would be a problem). Other electromechanical assemblies such as locking screws holding PCBAs, voice coil motors, electromechanical relays, and miniature motor assemblies are ideal applications for the use of spot curing technology.

Key parameters to consider in electromechanical assemblies are:

- ✓ Assembly selection (due to the majority of substrates being opaque, the use of adhesives with additional curing mechanisms such as heat, activator, or anaerobic curing may be critical)
- ✓ Bandwidth selection (based mostly on the adhesive formulation but may also depend on whether substrates are UV or heat sensitive).
- ✓ Intensity selection (based on the degree of cure, degree of tack and amount and type of adhesive used).

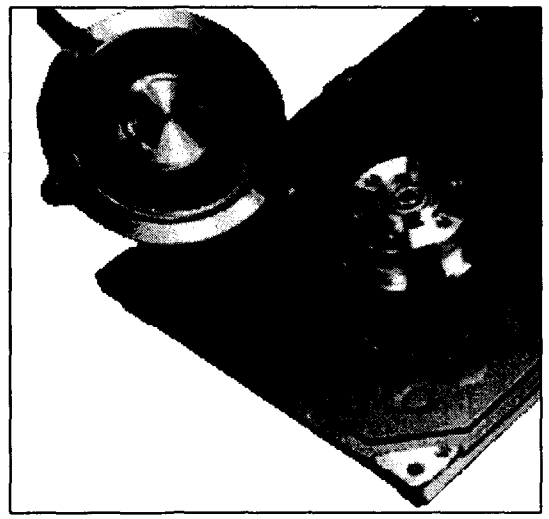

Figure 6. Spindle Motor Assembly (*courtesy of Nidec)*

Choosing the Right Curing Equipment and Process

Choosing the right spot curing system is as important as choosing the correct coating, encapsulant or glue. There is an important relationship between the user, the chemical supplier and equipment supplier. The chemical suppliers and equipment suppliers maintain excellent relationships to provide the best complete system to benefit the user. Generally either the chemical supplier can provide a list of equipment suppliers or vice versa for the selection of the best curing system for the application.

Typical spot curing systems will consist of quartz halogen dental light (with high visible and low UV output), black-lamp sources (with very low UV output over large spot areas), and high pressure mercury lamp systems (see figure 7 for an application example of this latest system in production). Selection will be dependent on various parameters; adhesive energy/bandwidth curing requirements, substrate conditions, and process conditions (degree of automation, load factor, productivity requirements).

Figure 7. Medical Device Bonding Application (*courtesy of USCI*)

Most important of all the user must keep in mind that the appropriate use and selection of the spot curing system will distinctly affect the cost, efficiency and ultimately the productivity of the UV/visible curing process.