Shedding Some Light on Adhesive Curing

Adhesives are a key component in the assembly of a variety of medical devices. Unfortunately, specific curing requirements of certain types have caused difficulties for manufacturers using traditional adhesive options. Visible light curing adhesives, however, enable the use of equipment that costs less, offers a safer solution, and enables greater flexibility in the design of the product.

By Christine Salerni Marotta

Adhesives are playing an increasingly prominent role in the design and assembly of highly effective medical devices used for diagnostic, treatment, and prevention purposes. Adhesives make it possible to deliver smaller, less invasive, more intricate devices that meet higher performance standards.

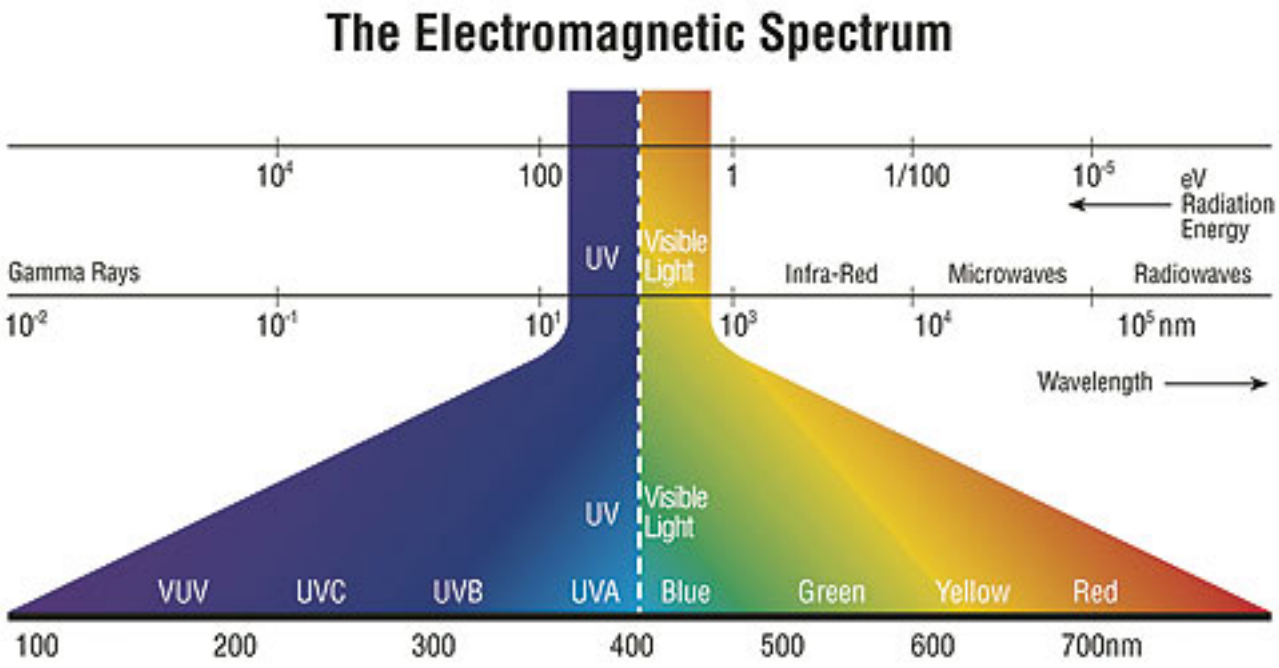
UV/V adhesives cure through some UV-blocking and slightly tinted substrates, and are used on respiratory masks as well as other medical devices.

While a variety of adhesive technologies are available, light curing adhesives are the preferred method of assembly for moderate to high volume medical device manufacturers. In the last two years, light cure adhesive technology has experienced huge advancements –the greatest of which is the elimination of UV light as a cure requirement. Adhesives are now available that cure using light in the visible spectrum to deliver a safe, efficient, immediate cure for a broad array of medical devices.

UV Technology Review

Approximately 40 years ago, the adhesive industry introduced acrylic-based adhesives that cured or solidified on exposure to UV light. Concurrently, UV light cure equipment became commercially available. This early UV technology offered medical device manufacturers distinct advantages over traditional adhesive technologies such as cyanoacrylates and epoxies, including a rapid cure, adhesion to a variety of substrates, the ability to fill large gaps, and easy automation.

Light curing acrylic adhesives cure or harden to form thermoset resins when exposed to light of the appropriate wavelength and intensity. The uncured liquid adhesive contains both the monomer and photoinitator. When UV light is introduced, the UV photoinitiators absorb the light energy and divide or fragment it into reactive species called free radicals. The free radicals then cause the monomers to link up and form thermoset polymers.



The electromagnetic spectrum organizes light by wavelength with UV light to the left and visible light to the right.

The electromagnetic spectrum organizes radiant energy of all types by wavelength. UV curing is accomplished using light on the left half of the spectrum. Typically, 200 nm to just below 400 nm is considered usable UV light.

High intensity light sources are typically required to cure UV adhesives. Light in this range can severely damage the skin and eyes and therefore, requires operators to wear protection (shielding, eyewear, and gloves).

As most UV light systems offer a broad spectrum of output from 200 to more than 700 nm, they also emit infrared or heat energy. Temperatures under some UV lamps can reach 150&#176F –a problem for thermally sensitive parts such as thermoplastics that can discolor and/or distort under these conditions. As a by-product of start-up, some older UV systems emit ozone –a poisonous gas that must be vented out of the plant.

Presently, traditional UV light sources can cost anywhere from several thousand dollars to well over $20,000, depending on the sophistication of the system. With replacement lamps or bulbs costing approximately $500 each, system maintenance costs easily exceed several thousand dollars annually for each UV curing system.

UV curing adhesives themselves have several performance limitations. As UV light must reach the adhesive bond line to achieve full cure and the associated performance properties, transmission through substrates is critical. A variety of factors dictate the ability of the light to reach the adhesive. Most colored substrates will not transmit UV light. Many grades of clear plastics include additives such as UV inhibitors that prevent discoloration during sterilization and/or aging, but these additives can also prevent curing. Similarly, when curing through large volumes of adhesive in a potting or filling application, the adhesive itself can act as a transmission limiter and result in a low depth of the cure.

In the early 1990s, adhesive formulators introduced UV/visible (UV/V) adhesive systems that respond to 200 to 390 nm UV light as well as 400 to 410 nm light, at the cusp of the visible electromagnetic spectrum. This technology cures using many existing broad-band emitting UV light sources and takes advantage of a slightly greater portion of the spectrum.

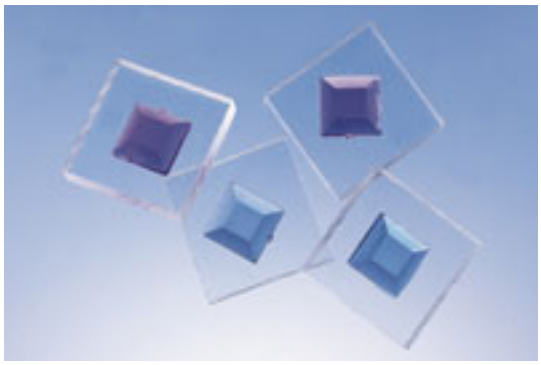
The addition of the 400 to 410 nm visible photoinitiators improved the curing and performance characteristics of UV/V adhesives. These adhesives work with UV-blocking and slightly tinted substrates, and the cure rate and cure through depth are also improved. In some cases, cure depths in excess of 0.25 in. are achieved with the appropriate combination of adhesive, light source, and process.

The cure rate for many UV/V adhesives is as fast as 10 to 20 seconds, a substantial reduction from the 45 to 60 second cure of earlier generation UV/V adhesives. A beneficial process called “photobleaching” occurs with UV/V adhesives where the slight discoloration of the cured material fades over time upon exposure to ambient light. Early UV adhesives did not experience photobleaching and, therefore, retained their slight yellow color for the life of the device.

The advent of the UV/V photoinitiators allowed a wide range of formulating options, ranging from hard, rigid resins to semi-flexible materials. UV/V adhesives are widely used on medical devices including needles, fluid devices, and respiratory masks and circuits. Numerous variations carry ISO 10993 biocompatibility compliance, ensuring medical device manufacturers of their suitability for an extensive range of disposable and non-disposable devices.

True Visible Curing Technology

The latest generation of light cure adhesives features new photoinitiators that react solely with light in the visible wavelengths that exceed 425 nm. These new adhesives cure in less than 10 seconds and are compatible with metals, glass, and a wide array of plastics. They can be used on UV-blocking substrates and select colored materials, particularly translucent grades of purple, blue, gray, and white.



Visible light cure adhesives react solely to visible light over 425 nm and work easily on UV-blocking and colored materials, particularly translucent gray, purple, blue, and white.

Visible light curing materials offer adhesion comparable to most commercially available UV/V adhesives, with particularly high adhesion on polycarbonate and polyvinylchloride (PVC). Additionally, the current grades of visible light adhesives meet strict ISO-10993 biocompatibility requirements. This new technology can cure to depths in excess of 0.5 in. and is therefore suitable for potting.

Much of the benefit of visible light cure technology is directly tied to the efficiency of the cure equipment. An ever-growing range of “focused” visible light sources provide considerable processing advantages for medical device manufacturers.

Visible light cure systems are available in both point and flood configurations that can be lamp or bulb based, similar to some early UV systems. The output of these light sources is considerably narrower banded than the current commercially viable UV light systems. Typical bulb-based visible light sources provide output ranges of approximately 400 to 600 nm and minimize excess unusable light and infrared (heat) energy output. Due to substantial heat reduction, visible light cure technology can be used on temperature sensitive materials and/or devices.

The initial cost and on-going maintenance expenses for visible bulb systems are considerably less than those of traditional UV and UV/V systems. The initial cost for most commercially available visible systems is well under $2,000. With bulb lives twice those of standard UV and UV/V bulbs, medical device manufacturers can realize a nearly immediate cost savings in maintenance alone.

A second category of visible light cure equipment, light emitting diode (LED) technology emits very focused visible light wavelengths –a significantly tighter output range than visible lamp technology. In most cases, LED curing systems emit at one primary wavelength such as 420 nm, and offer slight amounts of residual light in nearby wavelengths (&#17715 nms).

LED systems are extremely efficient and cost effective as excess and unnecessary broad-band light and heat/infrared energy are not emitted. LEDs produce higher outputs that more effectively cure the adhesives. Whereas a traditional UV light

source might offer an output irradiance of 150 mW/cm^2, a visible LED system offers more than 2 W/cm^2.

LED curing systems, currently available as point or spot sources, are predicted to have light output lives in excess of 10,000 hours and are typically built into solid-state housings that make them extremely durable and portable. This long-life and durability translates to immediate and on-going cost savings. These systems take up less space than UV cure equipment and are easy to automate.

Safety is perhaps the most significant benefit afforded by higher wavelength visible light cure systems. Because the light output is visible, UV-related system shielding and operator protective equipment can be minimized or eliminated. Safety glasses are often still recommended due to the brightness of the visible light sources. By eliminating infrared and ozone, the systems do not require heat protective equipment or extensive and costly ventilation systems.

A relatively limited number of visible light cure adhesive grades are currently available. In the near future, medical device manufacturers can expect a variety of new visible formulations with enhanced physical properties and broader viscosity options. Light sources are also continuously evolving, particularly in the area of LED systems where higher output, broader cure areas, and new configurations will result.

Typical Applications

Safety – The safety benefits of visible light cure systems have inspired needle manufacturers to transition to this new technology to eliminate the extensive venting and shielding required with UV/V acrylic adhesives. Operators are no longer required to remain behind light shields or to use heat resistant safety wear.

Low Temperature/Rapid Cure – Two-part epoxy systems used to join the cylindrical polycarbonate component of pre-filled drug delivery systems resulted in long cure times and racked parts. The drugs within these devices often cannot be exposed to temperatures greater than 100&#176F and polycarbonate substrates can be tinted –factors that eliminate traditional UV/V adhesives as an option. Visible light cure adhesives that cure using LED point cure systems can reduce cure time to less than 30 seconds without generating excess heat, while providing ISO-10993 biocompatibility compliance.

Quality Improvement – Visible light cure adhesives have replaced solvent welding for filling tongue and groove joints in polycarbonate blood collection devices. Visible bulb-based flood systems mounted over a conveyer can cure the visible light cure adhesive, delivering consistent performance and eliminating sporadic leaks in the devices. Since visible light cure adhesives will cure well beyond the required gaps in the part, manufacturers could back off slightly on part tolerances.

Conclusion

Visible light cure adhesives offer a wide array of advantages to medical device manufacturers due to the multitude of concerns these companies have with regard to aesthetics, biocompatibility, sterilization, safety, and cost. While they may not be

the ideal solution for every single device application, a visible light cure adhesive does offer a preferred alternative to many of the traditional options previously used in assembly tasks.

ONLINE

For additional information on the technologies and products discussed in this article, visit Henkel Corp. at www.loctite.com/medical [1].

Christine Salerni Marotta *is the Medical Market Development Manager for Henkel Corp. She is responsible for the development and management of the medical disposable and non-disposable business for Henkel. Marotta can be reached at 860-571-5100 or* christine.marotta@us.henkel.com *[2].*

Source URL (retrieved on *07/24/2014 - 5:27pm*):
http://www.mdtmag.com/articles/2007/03/shedding-some-light-adhesive-curing

Links:
[1] http://www.loctite.com/medical
[2] mailto:christine.marotta@us.henkel.com