TECH BRIEFS

MEDICAL DESIGN BRIEFS

SPECIAL REPORT:
MEDICAL MANUFACTURING AND OUTSOURCING

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HLC™ Technology enables curing in light and dark areas.

Engineering the Future of *Medical Devices with Advanced Light-Curing Technology*

The assembly of medical devices is an intricate process that demands precision, efficiency, and reliability. As technologies evolve, the medical manufacturing industry continually seeks innovations that can overcome traditional challenges in device assembly.

One such innovation is HLC™ (Hybrid Light-Curable) technology that merges the best qualities of anionic and free radical chemistries to overcome the limitations of traditional adhesives like cyanoacrylates (CAs) and epoxies. This next-generation hybrid technology enables curing in light and darkness with either UV/visible light or a combination of UV/visible light and contact/moisture and the ability to bond to diverse and opaque substrates, which are critical keys to successful medical device manufacturing.

How HLC Technology Works

The curing process of HLC technology initiates upon contact with the substrate, using surface moisture for initial adhesion before light-induced curing forms strong, cross-linked polymer structures. The combination of anionic polymerization and free radical cross-linking is used to meet many design challenges and provide desirable outcomes.

What Is Anionic Polymerization?

CAs are known for their fast-curing and strong bonding capabilities, even in dark areas. Still, they are hampered by sensitivity to moisture and temperature variations, which can lead to brittleness, weakened structural integrity, and reduced flexibility in the bond.

These chemistries are driven primarily by anionic polymerization-like processes, typically triggered by humidity or moisture on the substrate surface. The propagation of the anionic sites is similar to anionic polymerization, but the moisture (or other nucleophiles) reacts with the cyano group in the monomer to generate the negatively charged anion familiar to the traditional anionic process. The chain reaction continues rapidly once initiated, leading to these products often being referred to as *instant adhesives*. These materials are most effective for small-area bonds and/or tight-fitting components.

What Is Radical Cross-Linking?

In contrast, light-curable materials offer stronger, more resilient bonds but are limited by their need for light exposure, which restricts their use with opaque or light-absorbing materials.

Radical cross-linking involves the formation of covalent bonds between polymer chains through a free-radical mechanism, typically initiated by exposure to specific wavelengths of light in the UV to visible spectrum. The process used in light-curable urethane acrylates enables the formation of durable bonds essential for medical devices requiring long-term stability and strength. Radical cross-linking allows control over the curing process, reducing risks like blooming and allowing time for part adjustment before curing is initiated.

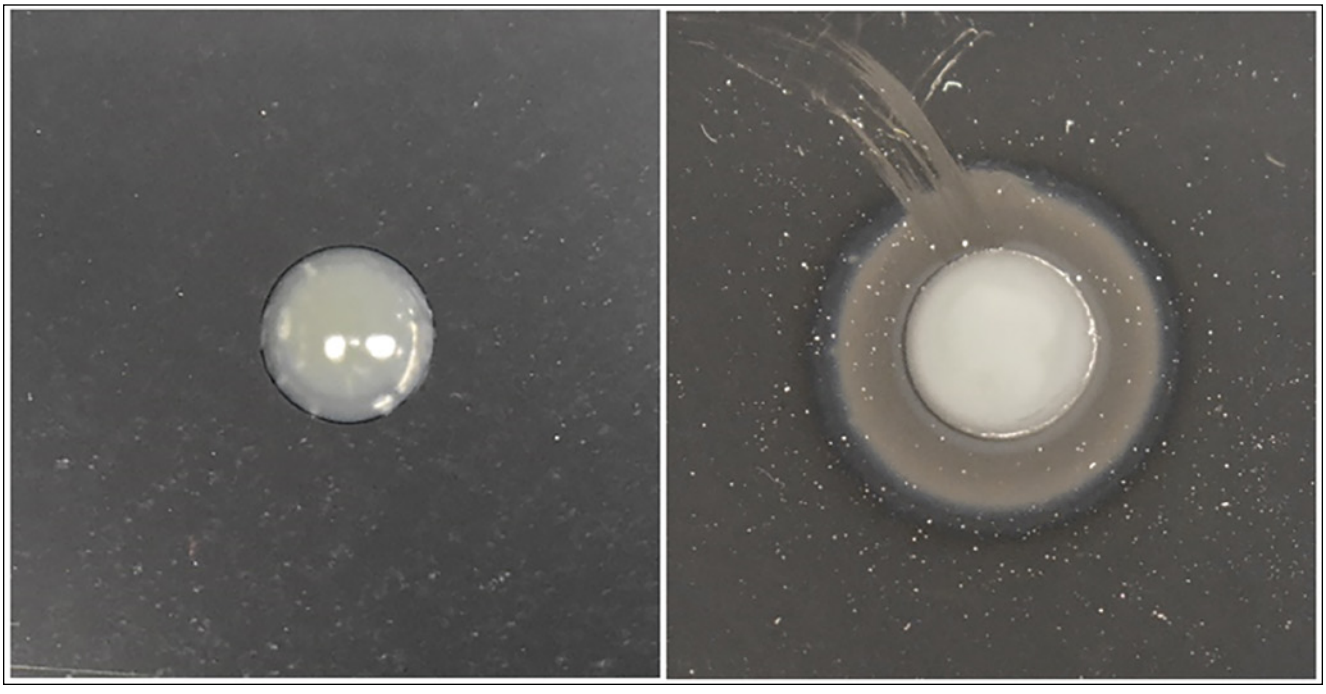
When joined together, these two technologies form the foundation of the patented HLC Technology and how it functions.

Benefits of Adhesives with HLC Technology

Adhesives with HLC technology benefit not only from the ability to cure in both light and darkness but some products feature other important properties, including ultra-low viscosity (3 cP) for capillary flow into tight-fitting assemblies, biocompatibility approvals, cure upon exposure to low intensity (~20 mW/cm^2), bonds to multiple substrates such as ABS, PC, PEBA, and PMMA, and tack-free surfaces after proper broad-spectrum or LED light cure.

HLC products can also overcome some challenges that mechanical fasteners, one- and two-part epoxies, hotmelts, RTV silicones, PSAs, cyanoacrylates, and UV acrylics can pose, including blooming and poor aesthetics, slow cure, low impact resistance, and limited long-term moisture exposure.

Additionally, these one-part materials eliminate the need for mixing, primers, or accelerators to help simplify the manufacturing process by reducing labor and material costs and decreasing the likelihood of errors associated with multi-component systems. Curing quickly in light and dark conditions is particularly valuable on automated production lines, where speed, high throughput, and end-product integrity are paramount.



With light-cure (no blooming) Without light cure (blooming)

Advanced Light-Curing Technology

Features	HLC Material	Cyanoacrylate
Fast Cure Speeds	✓ Light cure in 1-30 seconds; Non-light fixture in 5-75 seconds	Fixture only in 10-60 seconds
Tack-Free Surface Cure	✓ Tack free with low intensity light (20 mW/cm^2) <5 seconds	Specific formulas only ; Requires use of activators
Open Time (Time Before Cure Begins)	10-30 seconds	10-30 seconds
Moisture Resistance	✓ Patented technology to increase moisture resistance	Not designed for high humidity or long-term moisture exposure
Temperature Resistance	✓ Patented technology to increase temperature resistance	Not recommended for ≥225ºF (107ºC)
Opaque Substrate Bonding	✓ Not an issue	✓ Not an issue
Impact Resistance	✓ Patented technology to reduce brittleness and increase impact resistance	Brittle with little impact resistance
Equipment	✓ Equipment can be used to improve cure time and reduce crazing but not required for dark areas	✓ No equipment required
Gap Cure	✓ Can accommodate close gaps or larger bond gaps with light cure	Requires close contact
Blooming	✓ Low to no blooming after proper cure	Produces white haze around bond line during or after the cure
Stress Cracking	✓ Rarely an issue with proper cure	Tiny cracks in plastic can occur before or during the cure
Bondable Substrates	✓ Bonds dissimilar substrates	Does not typically bond dissimilar substrates

This table illustrates many benefits of using HLC materials over cyanoacrylates.

Advanced dispensing systems for HLC adhesives help prevent premature curing.

HLC adhesives bond various materials, including metals, plastics, and composites used in medical device designs. Their superior resistance to moisture and thermal degradation also helps to improve overall quality and durability across a wide range of operating conditions. Formulations also have no solvents added, supporting worker safety, easier disposal, and sustainability initiatives.

Why Blooming and Adhesive Delivery Are Issues

HLC materials offer many benefits over other chemistries, but two critical challenges device manufacturers face that HLC technology can help solve are blooming and adhesive dispensing or delivery options.

Blooming, or *chlorosis*, is a common problem in adhesive applications with cyanoacrylates. It occurs when the cyanoacrylate monomer volatilizes and interacts with moisture in the air, forming a white, powdery, or frosted appearance that can detract from the device's visual appeal. Factors contributing to blooming include surface contamination, non-optimized bonds or improper processing considerations, and environmental factors.

Advanced dispensing systems are required to effectively tackle concerns around material longevity, including reducing contamination after opening. Controlling exposure to moisture and air provides precise, contaminant-free delivery of the material. These systems also eliminate the need for downpacking, further reducing exposure to foreign matter. Maintaining the adhesive integrity before dispensing will help extend the material's working time, keep a consistent viscosity for dispensing stability, and preserve the quality of the bonds throughout the manufacturing process.

How HLC Technology Helps

- Efficient UV curing quickly solidifies the adhesive, minimizing the chance for monomer volatilization and uncured areas on components.
- HLC formulations are less sensitive to humidity and temperature fluctuations, helping maintain consistent environmental conditions during device assembly.
- The advanced dispensing systems required ensure accurate material application, help reduce material contamination, and shorten working time.

Dispensing Systems for HLC Materials

Specialized dispensing systems are vital in optimizing the adhesive application process for HLC materials. These technologies provide exact control over adhesive placement and volume, improving accuracy and minimizing waste. The engineering of these dispensing mechanisms ensures rapid application of the adhesive, boosting production efficiency and enhancing the overall effectiveness of the assembly process.

Conclusion

HLC™ (Hybrid Light-Curable) technology represents a significant leap forward in medical device manufacturing, enhancing bonding capabilities, manufacturing efficiency, and substrate versatility. By merging the rapid curing and strength of anionic and free-radical chemistries with advanced dispensing systems, HLC technology addresses a broad range of assembly challenges, like curing in light and dark areas, blooming, humidity resistance, and dispensing concerns.

As the industry continues to evolve, embracing HLC technology will be important for manufacturers aiming to innovate and improve the reliability and functionality of medical devices.

This article was written by Michael Ford, Director of Business Development and Product Management, Global for Dymax, Torrington, CT. For more information, visit www.dymax.com. ■

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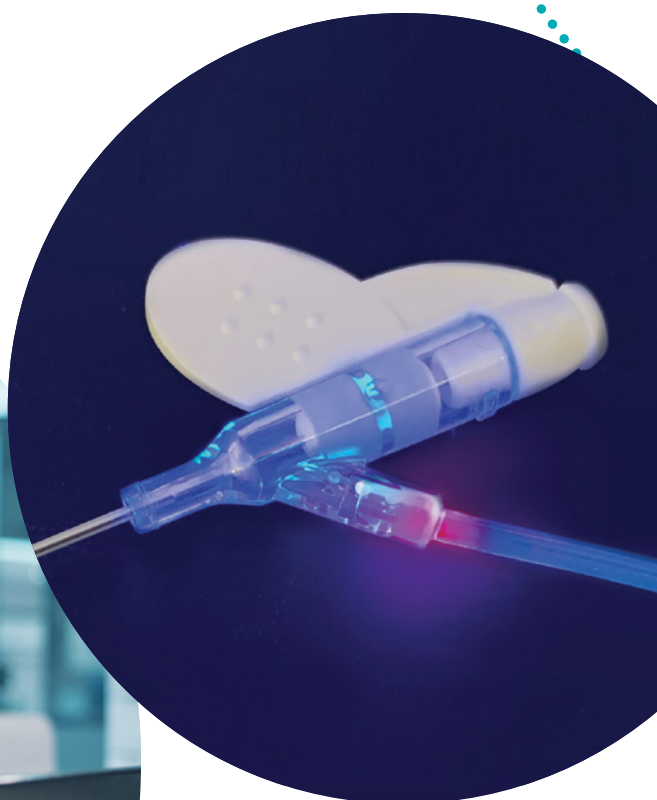

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