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FUTURE MOBILITY:
THE INNOVATION SPACE BEYOND THE VEHICLES OF TODAY.

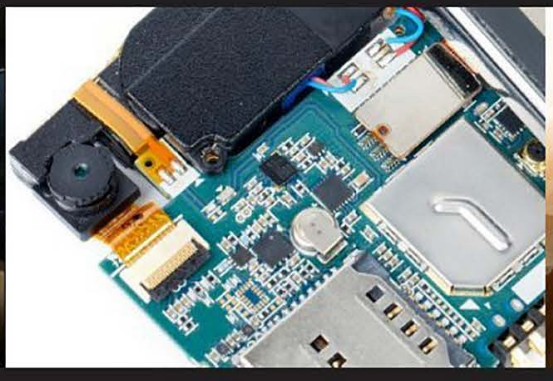
Advancing EV Electronics with Light-Curing Technology

How Light-curing materials and technologies are being used in advanced EV electronics

Chris Morrissey, Sr. Manager, Automotive Electronics BD, Dymax Corporation

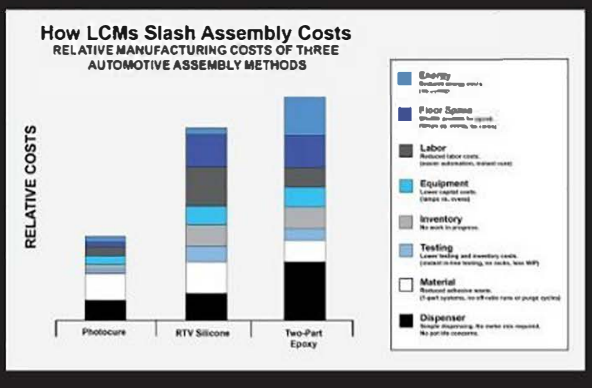
The global automotive electronics market is projected to grow to a CAGR near 6-7% over the next five years, with the electrification and Advanced Driver Assistance Systems (ADAS) segments positioned to surge to 16%. This unprecedented growth, along with increased environmental regulations and safety requirements, to the consumer desire for enhanced in-vehicle conveniences, has vehicle manufacturers seeking ways to improve system performance while decreasing overall costs. Traditional solvent-based materials and mechanical fasteners may be less expensive to purchase and implement, but long term, increase overall manufacturing costs. As a result, many design engineers of EVs, BEVs, and PHEVs are turning to light-curing technology to solve issues related to low throughput, difficult waste disposal, and field failures.

"Legislated changes, consumer demanded items (particularly those relating to convenience and/or comfort) as well as safety enhancements, have driven automotive development year after year. Today, with the added popularity of electrification and autonomous driving, the volume of electronics in vehicles is growing fast even as vehicle demand moderates. These drivers, combined with an increased need for cleaner emissions and improved fuel economy are also increasing the need for environmentally compliant materials." Chris Morrissey, Sr. Manager, Automotive Electronics, Dymax Corporation explained.



Three market segments driving the increased use of light-curing technologies in the design of EV electronics are ADAS, infotainment, and battery management systems (BMS). There is a need for materials that solve common issues associated with the sensors, modules, and circuits found in camera modules, lidar, printed circuit boards, and EV batteries. Additionally, replacing technologies that contain hazardous ingredients, produce waste, and require higher amounts of energy to process is becoming more important. There is also a desire to increase functionality, reduce circuit size, and extend warranties.

40 years ago, Dymax was instrumental in the development of light-curable materials (LCMs) as we know them today. Through the ingenuity and forward-thinking of the company's founder, Andrew G. Bachmann, a chemistry that was environmentally friendly and would significantly increase productivity in industrial manufacturing processes was created. LCMs can provide significant benefits over conventional bonding (or joining) technologies, including lower operating costs driven by lower labor needs, space savings, lower energy demand, and higher throughput.



How do light-curable materials work?

Light-curable materials are typically comprised of five basic elements: the photoinitiator, additive, modifier, monomer, and oligomer (Figure 1). The ultraviolet (UV) light-curing process begins when the photoinitiator in the LCM is exposed to a light-energy source of the proper spectral output. As illustrated in Figure 2, the molecules of the LCM split into free radicals (initiation), which then commence to form polymer chains with the monomers, oligomers, and other ingredients (propagation), until all ingredients have formed a solid polymer (termination). Upon sufficient exposure to light, the liquid LCM is polymerized, or cured within seconds.

The types of light-curable materials successfully being utilized throughout the EV electronics market include structural adhesives, conformal coatings, encapsulants, and masking resins. Since their inception Dymax LCMs have helped to minimize environmental impact. Formulated products are all one-component, solvent-free, halogen-free, RoHS compliant, eco-friendly, and meet REACH (no substance of very high concern (SVHC)) requirements. Using these products offer manufacturers the benefits of:

- Improving structural bonds
- Protecting circuits from environmental damage
- Minimizing movement and shrinkage
- Addressing thermal management, thermal shock, and vibration
- Enhancing PWB/PCA functionality and performance
- Eliminating shadow-area concerns
- Solving cure-confirmation issues

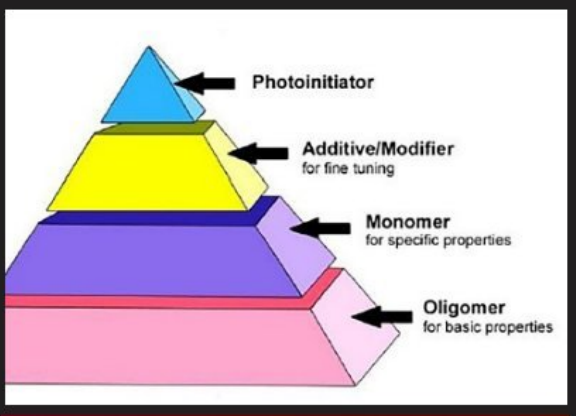
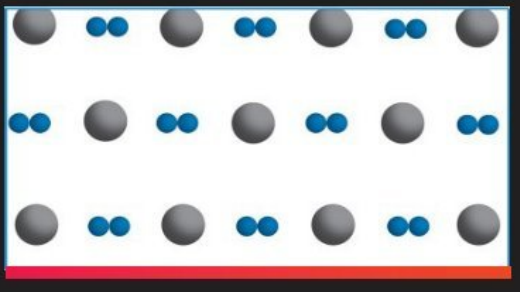
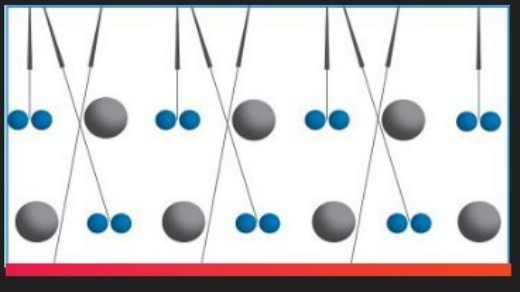


Figure 1 LCM Composition

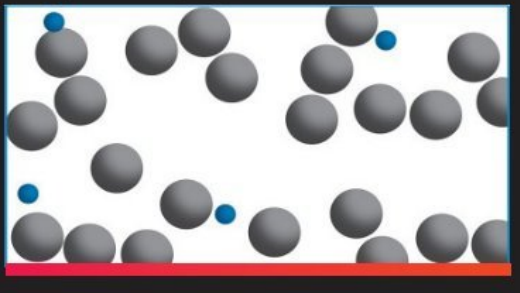
1. Liquid unreacted state



2. Photoinitiators generate free radicals



3. Polymer Propagation



4. Polymer Termination

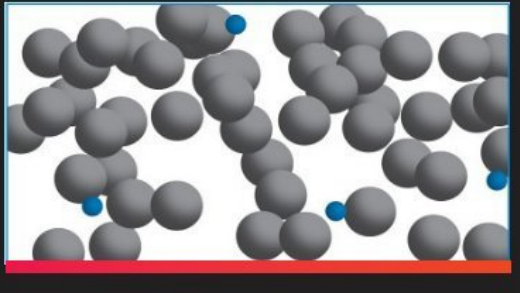


Figure 2
Polymerization
Process

Adhesives

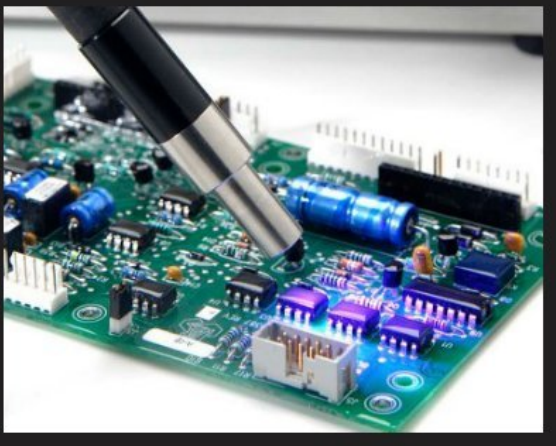
Light-curable adhesives cure in seconds upon exposure to UV/Visible light. They form high-strength, environmentally resistant bonds to plastic, metal, and glass substrates used in automotive electronics manufacturing. Due to their ability to bond to a wide variety of substrates, they excel at assembling dissimilar materials, something that cannot be done with traditional fastening methods and other chemistries. The fast cure of the adhesives is one major advantage LCMs have over other slow-cure and labor-intensive application processes.

Masking Resins

Temporary, peelable electronic maskants are applied to printed circuit board components to protect them prior to conformal coating application or wave solder and reflow processes. Extremely fast cure allows boards to be immediately processed without the need for racking or waiting. The products conform to intricate designs, are non-slumping for vertical and horizontal surfaces, are compatible with gold and copper connector pins, and are resistant to solvent-based conformal coatings and primers. After proper cure, the maskants leave no silicone, ionic contamination, or corrosive residues when removed.

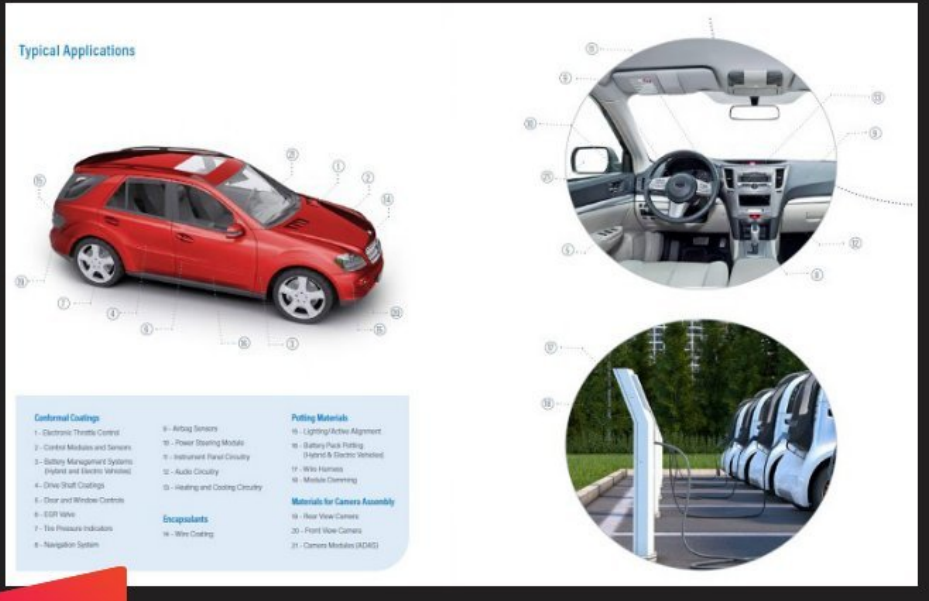
Conformal Coatings

Conformal coatings enhance the long-term reliability of automotive electronic parts. When applied to circuitry on printed circuit boards they act as protection against destructive environmental conditions, that if left uncoated (unprotected), could result in a complete failure of electronic systems. A key advantage to light-curable conformal coatings is the ability to use a non-solvated “green” (100% solids) material. Other important material properties include resistance to rapid and extreme temperature changes, as well as protection against high heat, humidity, moisture, chemicals such as gasoline, and corrosive materials like salt and sulfur.



Encapsulants

Encapsulation and wire bonding materials for bare die, wire bonds, or integrated circuits (IC) found on PCBs exhibit excellent protection against thermal shock, heat, humidity, and various corrosive elements. Their fast cure helps reduce processing and energy costs associated with alternative technologies.



EV Electronics Applications Where LCMs Are Utilized

There are a number of technologies formulated into various LCM chemistries to improve the overall manufacturing of EV electronics.

Curing in Shadow Areas

Dual-Cure Light/Moisture-Cure Technology

Dual-cure coatings are formulated to ensure complete cure in applications where shadow areas on high-density circuit boards are a concern. Previously, areas shadowed from light were managed by selective coating – eliminating the need to cure in shadow areas – or a secondary heat-cure process. Shadow areas cure over time with moisture, eliminating the need for that second process step or concerns of component life degradation due to temperature exposure.

Multi-Cure® Light/Heat Cure Technology

Multi-Cure adhesives and coatings combine the high-speed cure of UV or UV/Visible light with secondary cure mechanisms that enhance polymerization. Secondary cure mechanisms, which include moisture, thermal, or activator cure, are useful when light can only reach a portion of the bond line, or when tacking a part prior to final cure to allow easier handling and transport during the manufacturing process.

Enhance Bond-Line Inspection

Blue Fluorescing Technology

Many light-curable materials feature technologies that enable easy visual cure confirmation and post-cure inspection. In high-speed manufacturing, automated vision systems are employed to inspect finished parts for imperfections in the bond line or to detect incomplete coating coverage. Formulations with blue fluorescing technology are visible under low-intensity black light for easy visual confirmation of properly finished parts.

Brightly Colored Materials

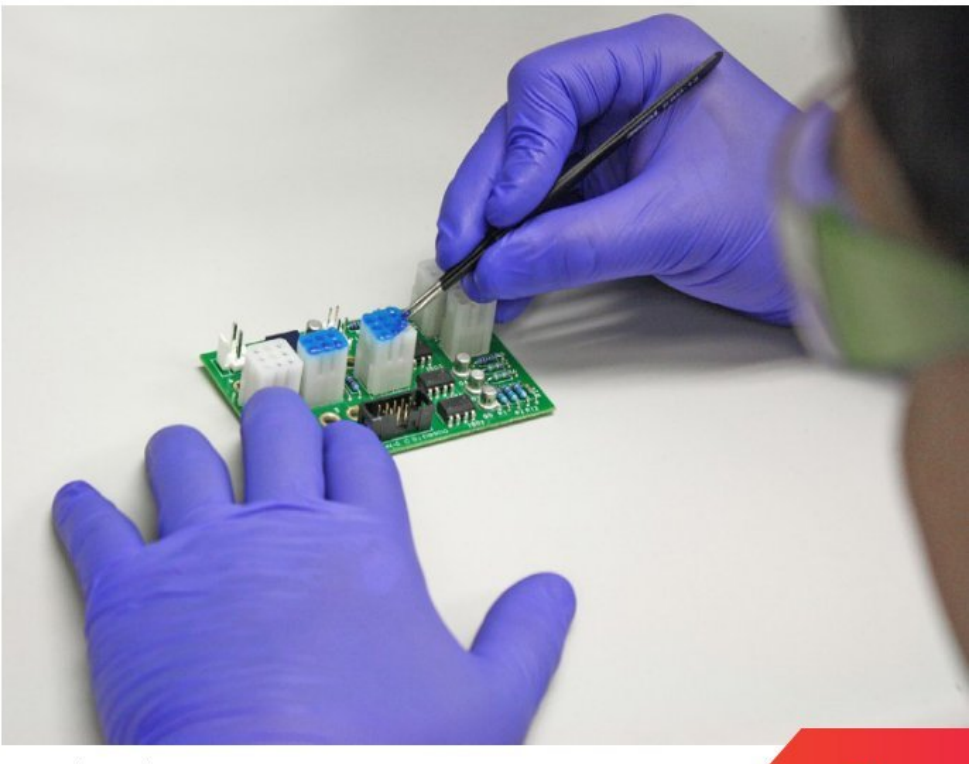
Some LCMs contain a color pigment such as pink or blue in the uncured state, that enable them to be easily seen when dispensed onto substrates to ensure complete material coverage. Once exposed to the appropriate amount of LED/UV/Visible light energy, the color transitions to another color or turns colorless, providing confirmation of full cure.

Speed up Production with Environmentally Friendly Curing

LED Light-Curing Technology

Due to the costs and difficulty associated with the disposal of hazardous waste, manufacturers are starting to implement LED-curable materials and light-curing into their processes. LED curing is considered a "green" technology because it offers manufacturers the following benefits:

- High electrical efficiency and instant on/off capability for lower operational costs
- Long service life that eliminates bulb replacement and reduces maintenance costs
- Compact equipment that reduces the size and cost of the light-curing system
- Cool light radiation extends curing capabilities for heat-sensitive substrates
- "Green" attributes eliminate mercury and ozone safety risks and handling costs
- Narrow wavelength spectrum emission minimizes substrate thermal rise



ADAS - Active Alignment (CMOS) & Lidar (adhesives, encapsulants)

Adhesives and encapsulants are used for a variety of camera module and lidar applications including camera module fixation, lens to housing, lens fixation, IR filter bonding, housing to substrate, die attach, windscreen bonding, and image sensor to substrate. Critical to the manufacturing of camera modules for ADAS is the positioning and staking of lenses within the camera module housing. The industry is moving away from passive alignment (mechanical fixturing with clips, i.e.) which can cause the lens to shift, tilt, defocus, and rotate. Active alignment using light-curable adhesives enables fast fixturing (in seconds) for high accuracy (< 0,1mm) and multi-axis alignment with optical control. Additionally, since the polymerization doesn't happen until exposure to light energy, assembled parts can be moved until properly positioned. After positioning, encapsulants are used for environmental protection of the components. CMOS adhesives also feature:

- Cold ship/storage, as well as ambient storage
- Low shrinkage
- LED and/or heat-cure capability
- Moisture and thermal-cycle resistance

Some other benefits these materials bring to the assembly process include urethane acrylate and cationic UV and/or heat cure technologies, LED-curable formulations, very low movement, heat and humidity resistance (85°C, 85% relative humidity), and excellent bonds to metal and plastics.

Infotainment (PCB Based) (conformal coatings, encapsulants, maskants)

A key consideration for engineers looking to employ light-curing technology in their PCB designs is whether or not boards feature high-profile components that cast shadow areas where light cannot reach. Newly formulated 100% solids conformal coatings feature secondary moisture curing that allows material under shadow areas to cure, helping to eliminate concerns about uncured material on the PCB. These products exhibit high reliability in tests such as heat and humidity resistance (85°C, 85 % relative humidity), thermal shock resistance (-55°C to +125°C), and corrosion resistance (flowers of sulfur, salt spray and common automotive fluids). Dymax dual-cure conformal coatings allow for the design of smaller, more dense PCBs by allowing shorter spaces between conductors, increased mechanical support for components, and improved fatigue life of solder joints.

Encapsulants are polymeric materials used to protect die (chip) and interconnection to ensure long-term reliability of chip-on-board (COB) assembly. Dymax materials are used in liquid and glob top encapsulation applications where they are dispensed on top of a chip and its wires and then cured to form a protective barrier.

Light-curable maskants are temporary materials that are used at the board level to protect printed circuit boards during surface finishing and assembly processes.

EV Battery Packs/BMS (conformal coatings, encapsulants, adhesives)

The EV battery pack includes a battery management system (BMS) to monitor state of charge, temperature, current, balance cells, determine permissible operating conditions, and send information to the driver. Common EV battery applications include potting and wire bonding of battery modules, coating protection of PCBs in BMS, sealing battery case enclosures, and encapsulating electrodes in unit cells. A range of LCMs are used to adhere and protect these components, including conformal coatings for thermal management and exterior protection, structural adhesives for housing and frames, and encapsulants for wire bonding. Dymax materials are most effectively used where bonding and fixation of cylindrical li-ion battery cells must be secured within plastic housing cells and coating of PCBs.

"From the design phase through performance testing, we assist manufacturers in solving their most complex application problems. As the EV electronics market evolves, we will continue to develop light-curing technology that makes manufacturers more capable and efficient" Chris concluded.