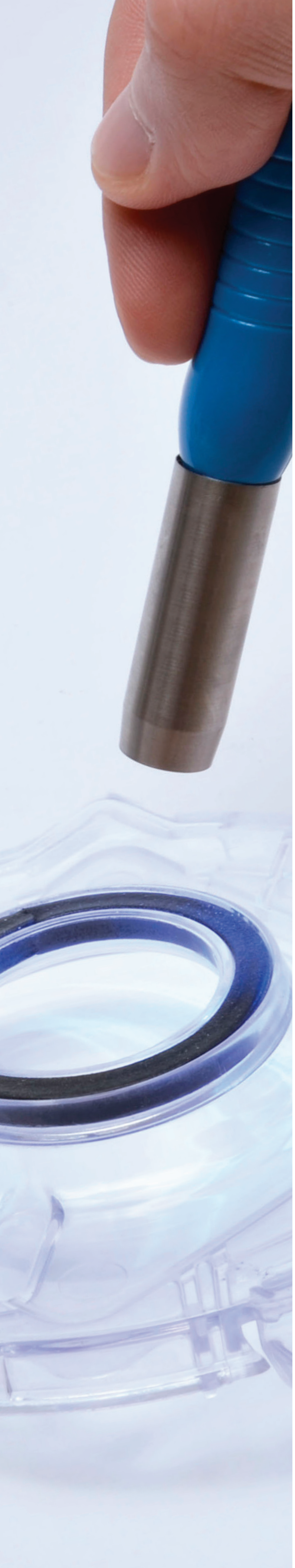

TECH SPOTLIGHT

How Dual Curing Adhesives (UV Light + Heat) Improve Manufacturing

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How Dual Curing Adhesives (UV Light + Heat) Improve Manufacturing

For decades, cationic UV curable adhesives and coatings have brought simplicity and consistency to the manufacturing space. Available as stable, single-component systems, UV curables require no precise weighing, mixing, or pot-life monitoring. With an unlimited working time, parts can be assembled with less operational constraints and greater consistency. The cure-on-demand nature of UV is fast, convenient, and especially advantageous for joining thermally sensitive substrates.

Most UV formulations benefit from being 100% reactive, include no volatile carriers or solvents, and are energy efficient. The manufacturing process is simplified as cationic UV systems can cure in ambient air and are not significantly inhibited by oxygen. Primary drawbacks of UV include risk of under-cure in "shadowed" or blocked regions; this may result in areas with inconsistent material properties and may limit adhesive thickness and joint design.

During bond assembly, a UV curable adhesive must be able to "see" the UV light source that triggers cure. Cure initiates after exposure to UV light at a wavelength that is specific to the photo-initiator used in the formula. The extent of cure is determined by the amount of UV energy absorbed by the adhesive. This absorbed energy, sometimes called "dose," depends on process factors such as exposure time, intensity (irradiance) of the UV light source, spectral output, distance from UV source, optical transmission properties, and adhesive thickness.

Relying solely on the UV cure mechanism may limit bond design, as UV-opaque substrates may limit transmission of the UV light into the entirety of the adhesive mass. This may result in under-cured "shadowed" regions where UV energy absorption was locally insufficient and resulted in non-optimal cures. Substrates may block UV due to their bulk transmission properties, the presence of UV absorbing additives, or both. Geometric factors in the joint may also reduce or limit depth of cure.

The limitations of UV curing can be mitigated by including a secondary cure mechanism based on heat. Inclusion of a thermal post-cure results in a more robust and consistent joint and resolves the risk of under-cure in "shadowed" or blocked areas. After quick fixturing assisted by UV cure, the part can be more rapidly assembled and moved through the production process.

Secondary thermal cure achievable at temperatures as low as 80°C is possible in some products. Lowering the cure temperature threshold improves energy economy, reduces thermal stresses, and protects thermally sensitive substrates. The formulation latitude for UV adhesives is wide and encompasses tailorable optical properties like clarity, transmission and refractive index. Skilled formulators can control and provide application specific requirements for viscosity, shear-dependent rheology, modulus, environmental resistance, and others.

The Power of UV + Heat, Dual-Curing Products

Master Bond offers a full line of 100% reactive, UV + Heat dual curing products that reach full cure with UV energy, heat energy, or both. The UV cure reduces fixturing time while heat assures consistent cure throughout the bond line. Thermal cure is initiated at temperatures as low as 80°C (176°F) which opens new opportunities for thermally sensitive substrates. Employing thermal cure at higher temperatures, 125-150 °C (257-302°F), reduces cure time and further increases the glass transition temperature to boost chemical and thermal resistance.

The Power of UV + Heat, Dual-Curing Products (continued)

The benefits of Master Bond dual-cure products can be gained in various applications including bonding, coating, sealing, and small encapsulation. Cationic UV cures economically, minimizes shrinkage, and does not suffer from oxygen inhibition. Formulated for convenience and versatility, Master Bond *UV15DC80* and *UV22DC80* product lines are available in a wide range of viscosities and bond well to glass, metal, various plastics, and ceramic materials.

Master Bond has leveraged its formulation and industry expertise to create dual-cure compounds that meet the rigorous property and compliance standards required in many industries. *UV15DC80* or *UV22DC80* product lines can be used in various applications such as medical devices, optical and fiber-optic constructions, electronics, aerospace and as a 3D printing resin. Select grades are formulated to comply with USP Class VI, ISO 10993-5 cytotoxicity or NASA low outgassing.

The Right Properties, the Right Solution

Viscosity and rheology control are critical for high quality manufacturing and assembly. Rheological behaviors such as shear-thinning, thixotropy or self-levelling can be achieved based on the demands of the application. Optimal viscosity is determined by the coating or application method being used. Well formulated, low-viscosity compounds will readily flow and self-level—spin coating used in photolithography exploits this behavior to create highly uniform layers deposited on silicon wafers. For applications where adhesive is brushed or automatically dispensed, a medium viscosity may assist with controlling optimal bond thickness. On the high end of the viscosity spectrum, thixotropic and non-drip pastes help enable rapid fixturing while avoiding messy drips.

Uniform, Thin-Film, Spin Coated: Viscosity Control Enables Precision Manufacturing

Viscosity is a critical control point for a manufacturing process—spin coating provides a unique example of the degree of manufacturing precision that can be obtained with the correct viscosity. A liquid coating is applied to a substrate and spun; the centripetal force draws the coating into a thin, uniform layer. The coating thickness can be controlled by the viscosity of the coating and the angular velocity (RPM) employed in the spinning process.

The Lightwave Devices Group from MESA Research Institute utilized spin coating along with Master Bond *UV15* compound to construct polymeric multimode waveguides for use in optical interconnects and local-area-network communication systems. The researchers were able to achieve uniform coating thicknesses of 3 to 34 µm in the RPM range of 400 to 6000 RPM. Further reduction in coating thickness can be accomplished by reducing the coating viscosity with an appropriate solvent. Master Bond *UV15DC80LV* is the dual-curing version of the product.

While viscosity is critical during application and the manufacturing process, the performance properties of the adhesive or coating are crucial to product integrity and reliability. Hardness and modulus are important material properties that describe the deformation behavior of the compound when exposed to mechanical stress, and these properties must be thoughtfully considered when engineering an adhesive joint or coating.

The ability of a material to resist deformation via mechanical indentation or abrasion is characterized by hardness or durometer. Shore hardness is commonly employed for indentation measurements, and a value increasing from 0 to 100 indicates increasing hardness. To cover a wide range of materials, different scales are used. Shore A scale is commonly used for soft, elastomeric materials whereas Shore D covers harder, higher modulus materials.

Modulus—a ratio measure of stress over strain—provides more specific information about material stiffness. Shear forces may pull parallel to the bond-line resulting in creep stress or tensile forces may pull perpendicular to the bondline resulting in peel or cleavage stress. It is critical to consider what types and magnitudes of stresses may be experienced by the bond or joint over the course of its lifespan; an adhesive with the correct properties can then be chosen to assure long-term integrity and performance.

Tensile modulus—also called Young's modulus—is a measure of stiffness when a material undergoes tension or compression. A material with a high tensile modulus is stiff and does not readily deform under tensile / compressive load; a low tensile modulus material is more compliant and will readily deform when pulled or compressed. Shear modulus expresses the stiffness of a material when exposed to a force parallel to its surface. High shear modulus is important to mitigate creep and may help to improve dimensional stability within the adhesive joint under stress or at elevated temperatures.

Additional properties to consider are the glass transition temperature (T_g) as well as resistance to environmental factors such as moisture, solvents, temperature and electrical current. The proper choice of base resin and filler materials is critical for controlling the final properties including shrinkage, modulus, coefficient of thermal expansion (CTE), T_g, dimensional stability, and thermal / electrical conductivity. Filler particles further enhance bond strength by providing bulk displacement that reduces the internal stress build-up that occurs during cure.

Nano-Scale, Big Benefits

Master Bond *UV22DC80-1*, filled with nano-silica, provides a stiff, high modulus adhesive designed for precise alignment within the bond joint. An optimized loading of nano-silica serves to improve tensile strength, abrasion resistance, and dimensional stability. Bond strength and joint stability are further enhanced by minimal shrinkage and a low thermal expansion coefficient.

Formulated for Your Industry

Medical Devices & Surgical Instruments:

High-value assembly of disposable and reusable medical devices, diagnostic equipment, sensors and medical electronics requires adhesives with rigorous standards for compliance and physical properties. Joining the dissimilar materials used in medical devices requires reliable and versatile adhesion properties. Master Bond's UV15DC80Med is compliant with USP Class VI and cytotoxicity by ISO 10993-5. Added benefits are adhesion to a wide variety of substrates and resistance to various sterilization methods including repeated autoclaving.

Optical & Fiber Optics Assemblies:

Dual-cure compounds provide enhanced fixturing ability enabling delicate assembly work on the dissimilar substrates used to manufacture lasers, optical devices, and fiber optics. Bond line control, dimensional stability, and superior coefficient of thermal expansion (CTE) enables reliable bonds with small clearances.

Use of Master Bond UV22DC80-1 in bonding, sealing, and potting fiber optic cables results in a stable bond that enables the final assembly to maintain its physical integrity and reliability. High optical clarity and transmission (>95%) can be achieved in most of the visible and near IR range and is thickness dependent. A refractive index of 1.5 to 1.55 is typical for most formulations. Master Bond tests its products under accelerated environment aging conditions (85°C/85% RH) to ensure the adhesive remains physically and chemically sound. A combination of high Tg, strong adhesion, low shrinkage, hydrophobicity, and low CTE enables a strong bond-line that is resistant to moisture ingress and adhesion loss.

Electronic Assemblies:

Electronics applications require the adhesive to seal or protect against moisture, dust, chemicals, thermal imbalances and electrical arcing; adhesives must possess the correct balance of physical, thermal and electrical properties necessary to protect the integrity of the assembly. Master Bond's dual-cure line provides a high dielectric strength material formulated in a range of viscosity to accomplish applications from glob top to conformal coatings. The addition of the heat curing mechanism provides assurance that even thicker coatings will be properly cured. The low-viscosity of UV15DC80LV is ideal for conformal coatings while UV22DC80TK and UV22DC80ND allow for high-viscosity glob top applications.

Aerospace Applications:

For aerospace applications, a precise and dependable joint must be assured over a wide range of temperature and environmental conditions. Master Bond UV22DC80-10F is loaded with nano-silica to provide superior dimensional stability, low shrinkage and an enhanced serviceability range of -100 to 350°F (-73°C to +177°C). Nano-silica filler boosts tensile strength and modulus while the product is formulated to meet the NASA low outgassing requirements as determined by ASTM E595.

3D Printing Applications:

Polymeric additive manufacturing in the form of 3D printing is quickly becoming a common tool for rapid prototyping and design. Existing fused-filament fabrication (FFF) technology are widespread, but the technology is limited in terms of speed, resolution and surface finish due to the high force required to melt and fuse the polymeric filament. The technique of stereolithography employs a gel-like, photo-polymerizable resin that enables greater resolution and manufacturing speed while minimizing process temperature. Master Bond UV15DC80 can be used in stereolithography as a photo-polymerizable resin wherein it is extruded by the coating head and then cured by a UV laser to produce a hard, durable 3D object.

Conclusion

The cure requirements of traditional adhesives have long provided roadblocks to product design engineers. Reliance upon two-component systems with limited pot-life, time-dependent viscosity or high-temperature post-cure adds to manufacturing costs and hinders operational throughput and simplicity. UV curable formulations provide a single-component solution with rapid, on-demand-cure; however, the design engineer must be aware of cure limitations that may arise within the joint due to blocking or "shadowing" of the UV light source.

To address these standing limitations, Master Bond's UV15DC80 and UV22DC80-1 UV + Heat product lines have the benefits of UV cure enhanced with low-temperature thermal post-cure at temperatures as low as 80°C. Formulated for various applications, Master Bond's dual-curing products are available in a wide array of viscosities and with outstanding mechanical, thermal and electrical properties.

Future Work

Although UV is considered a low-energy, low-temperature curing method, the use of UV LED technology offers additional benefits. UV LED's emit at a very narrow wavelength, are inherently safer, run cool, and use less energy than existing UV lamps. Master Bond is presently developing a UV + Heat product line that cures using 405 nm UV LED's to tap into these benefits. Additional research is being conducted in the area of 3D printing using Master Bond products as a photo-polymerizable resin with thermal post-cure to provide enhanced properties and resilience.

For further information on this article, for answers to any adhesives applications questions, or for information on any Master Bond products, please contact our technical experts at Tel: +1 (201) 343-8983.

MASTER BOND UV + HEAT DUAL CURING PRODUCT LINE

Master Bond Grade	Viscosity, 75°F, cps	Tensile Strength, 75°F, psi	Hardness, 75°F, Shore D	Service Temp Range °F	Applications
UV15DC80LV	150-500	>5,000	>70	-60 to 350	Low-viscosity version of UV15DC80 for conformal and spin coating applications. Good chemical and scratch resistance with low shrinkage.
UV15DC80	45,000-60,000	>5,000	>70	-60 to 350	Moderate viscosity adhesive. Excellent tensile strength and modulus with superb electrical properties. 3D printing applications.
UV15DC80Med	45,000-60,000	>5,000	>70	-60 to 400	Medical version of UV15DC80 meeting USP Class VI requirements, ISO 10993-5 cytotoxicity. Good balance of properties; resists sterilants.
UV15DC80TK	80,000-120,000	>5,000	>70	-60 to 350	Higher viscosity version of UV15DC80. Refractive Index 1.52 and dielectric constant of 3.49 @ 60 Hz and 75°F. Apply by brushing, rolling, or troweling.
UV15DC80ND	Paste	>5,000	>70	-60 to 350	Formulated with paste consistency for non-drip application. Excellent hardness and chemical resistance properties.
UV22DC80-1	500-3,500	6,000 to 8,000	80-90	-100 to 350	Nano-silica filled with exceptional CTE, minimal shrinkage and superior dimensional stability. Optical applications requiring high transmission in VIS, near-IR.
UV22DC80-10F	5,000-15,000	6,000 to 8,000	75-85	-100 to 350	Same advantages of UV22DC80-1 but tailored for the Aerospace industry. Meets NASA low outgassing with wide service temperature range.
UV22DC80TK	40,000-80,000	6,000 to 8,000	75-85	-60 to 350	Higher viscosity with outstanding tensile strength and modulus. Exceptional dimensional stability and shrinkage. Useful in glob top applications.
UV22DC80ND	Thixotropic Paste	6,000 to 8,000	75-85	-60 to 350	The benefits of the UV22DC product line formulated as a non-drip, thixotropic paste. Useful in glob top applications.

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