XLamp® LEDs
Chemical Compatibility

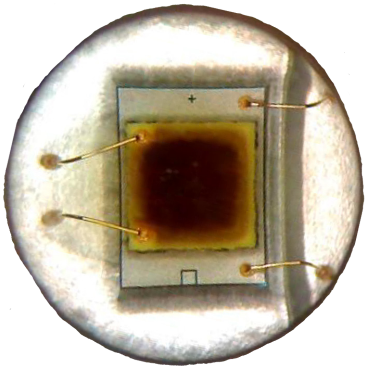

Figure 1: XLamp® LED discolored as a result of exposure to incompatible chemicals

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EXECUTIVE SUMMARY

The designs can impair the performance and reduce the lifetime of these illumination systems. Glues, conformal coatings, O-rings, gaskets, and potting compounds are examples of materials frequently used in the construction of LED-based luminaires or lamps and often contain VOCs. The presence of chemically incompatible VOCs on or near LEDs can degrade the light output levels or cause changes in the chromaticity point of the light. The photograph in Figure 1 above is an example of this VOC degradation on the surface of an LED. This sensitivity to VOCs is not unique to one LED manufacturer but is a known problem for all types of blue, royal blue and white-light LEDs. Chemical incompatibility in SSL is often a localized phenomenon that occurs in luminaire designs that seal portions of the system, resulting in an LED operating environment having elevated temperatures with little or no air movement. However, with proper design and adequate testing, chemical incompatibility effects can be prevented.

Cree LED maintains lists of chemicals known to be incompatible with XLamp LEDs and has partnered with materials manufacturers to inform our customers with information on acceptable materials. These lists are in the Appendix at the end of this document. Customer testing is a good way to further develop an understanding of chemical incompatibilities of a new LED lighting

design. With proper material selection design and testing, chemical incompatibility effects can be minimized or removed from SSL designs.

BACKGROUND AND INTRODUCTION

Most SSL luminaire types are implemented with a blue light LED chip covered with a yellow phosphor and silicone encapsulant to convert the blue light to a broader white light spectrum. This entire LED assembly is covered by a silicone-based lens. Figure 2 is a cross-section drawing of a typical lighting-class LED.

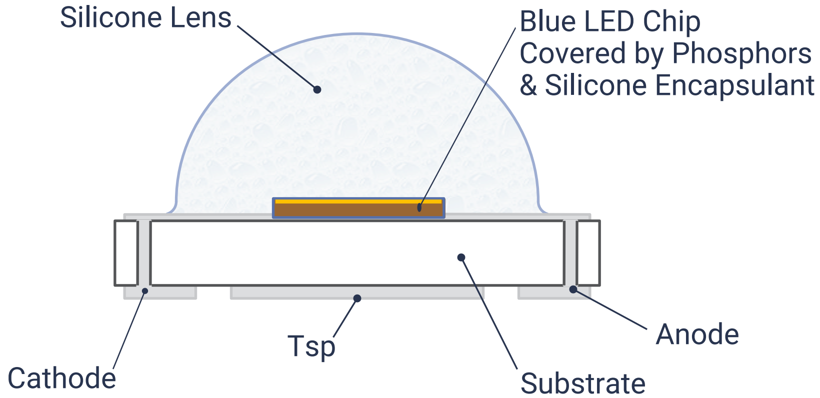


Figure 2: Cross-sectional structure of a typical lighting-class LED

The unique silicone polymers utilized in LEDs have excellent light transmittance characteristics: stable over wide temperature ranges, resistant to yellowing due to ultraviolet (UV) exposure and easily molded. This results in a high-performance yet cost-effective LED. The basic structure of the LED's lens and encapsulants is a silicone polymer, which is a stable chemical compound.

Any VOCs present in an SSL system can diffuse into the gas-permeable silicone lens and encapsulants of the LED. Within the molecular structure of these silicone materials, the VOCs will occupy a free space in the interwoven silicone polymer. With subsequent exposure to high photon energy emitted from the LED, along with the heat from the lighting system and the environment, the volatile compounds trapped in the LED's lens or encapsulants can discolor. This discoloration of the trapped VOCs can degrade the light emitted from the LED. This discoloration tends to occur in blue, royal blue and white-light producing LEDs that use blue wavelength LED chips with yellow phosphors for spectrum conversion. This sensitivity to VOCs is not unique to one LED manufacturer but is a known problem for all types of blue, royal blue and white-light LEDs. Chemically induced discoloration is less prevalent and not as noticeable with amber, red and green LEDs; these color LEDs have longer wavelengths and therefore a lower frequency and produce lower photonic energy compared to blue LEDs. Photonic energy (E) is defined by the Planck-Einstein equation of $E = hf$, where h is Planck's constant and f is frequency, thus a higher frequency produces a higher photonic energy.

This application note presents:

- Real-world examples of discoloration caused by VOCs
- Sources of chemical incompatibility from the general classes of materials used in SSL systems
- Discussion and examples of the reversibility of discoloration from VOCs
- Cree LED's recommended best practices to maintain chemical compatibility

- Procedures and test processes for measuring and assessing potential chemical interactions
- Chemical incompatibility test results

EXAMPLES OF CHEMICAL INCOMPATIBILITY

This section contains multiple examples of real-life discoloration caused by VOCs. Figures 3 and 4 show a luminaire based on six XLamp XR-E LEDs. Figure 3 shows the light output at initial turn-on and Figure 4 shows the same luminaire after less than 100 hours of operation. Figure 4 shows significant yellowing of the light output, which is likely caused by a color shift in the LEDs. It is worth noting the space between the circuit board and the external optical plate is a nearly sealed microenvironment. The most likely explanation is that VOCs have caused this discoloration of the surface of the LEDs.

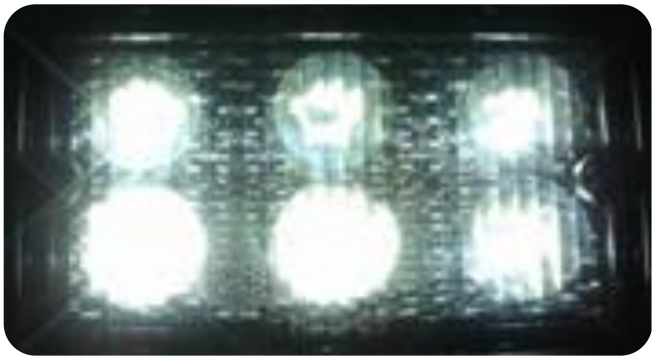


Figure 3: XLamp XR-E LED-based luminaire at initial illumination

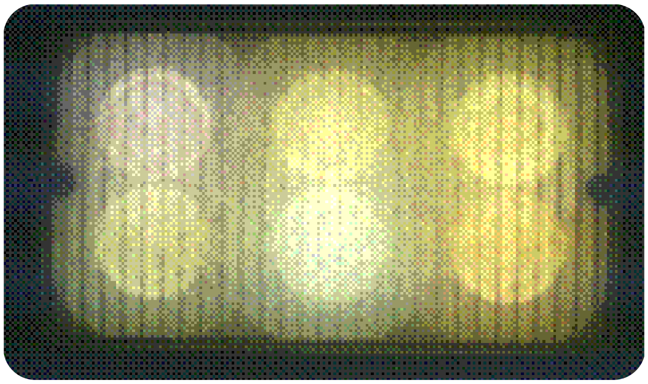


Figure 4: XLamp XR-E LED-based luminaire, yellowed after 100 hours

From left to right in Figure 5 is a pictorial representation of a silicone polymer as VOCs are introduced that occupy the free spaces in the silicone. After exposure to heat and high photonic energy, this introduction results in VOC-based discoloration.

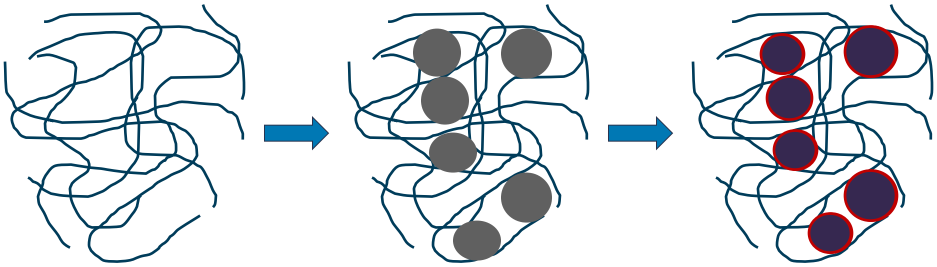


Figure 5: Left to right - Silicone chains; VOCs occupying free spaces in the silicone; discoloration as a result of VOC exposure to heat and photonic energy

Using chemicals containing VOCs in manufacturing SSL systems can result in LED light quality degradation or even complete luminaire failure. Figure 6 illustrates the degradation effect from a VOC on the silicone encapsulant that covers the LED chip.

Figure 6: Examples of normal (left) and VOC degraded LED (right)

The photograph on the left in Figure 6 is the normal appearance of an XLamp LED. On the right, the same type of XLamp LED chip has a pronounced brown discoloration due to exposure to VOCs while in operation with high photonic power output at nominal environmental temperatures. This discoloration of the encapsulants is on the top of the LED chip, localized to the area just above the chip surface, closest to the source of heat and high photon energy. Note that discoloration can occur at various points in an LED's lifetime; factors that affect discoloration of VOCs include heat, photonic energy and wavelength. Figure 7 shows several examples of the effects of chemical incompatibility in the LEDs.

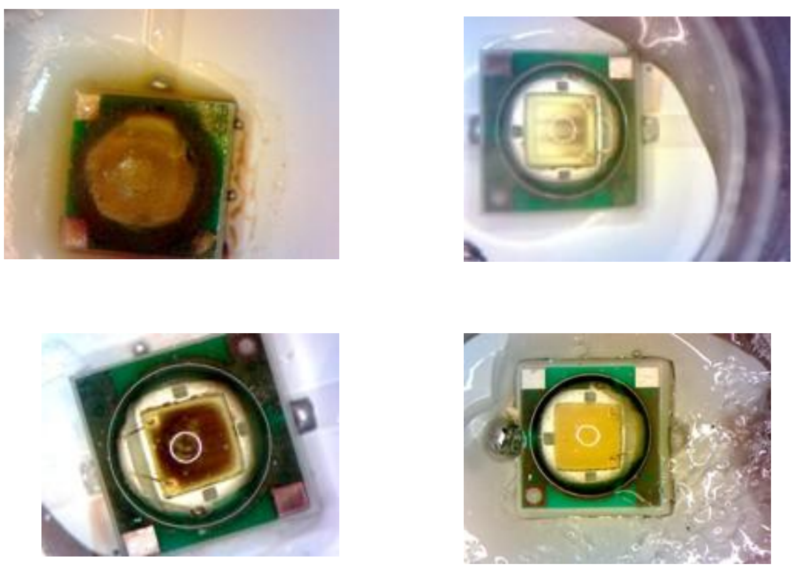


Figure 7: A variety of XLamp LEDs showing chemical incompatibility

VOC-based discoloration can occur as a result of outgassing of solid materials. The sequence of pictures in Figure 8 documents just such a case of chemical incompatibility. Cree LED investigated the source of LED discoloration and, even though the LEDs were not in a sealed environment, an LED on the luminaire discolored, as shown in the upper left photograph.

Figure 8: Sequence of VOC investigation

The root cause of the problem was revealed as the disassembled unit sat overnight on a white piece of paper. The next day, indication of outgassing from the small gaskets was evident on the paper, as shown in Figure 9. The gasket material, in close contact with the LED lens, offered a source of VOCs, which ultimately led to the LED's discoloration. This case demonstrates the importance of testing all chemicals and materials in the specific application and environment for which they are intended to be used.

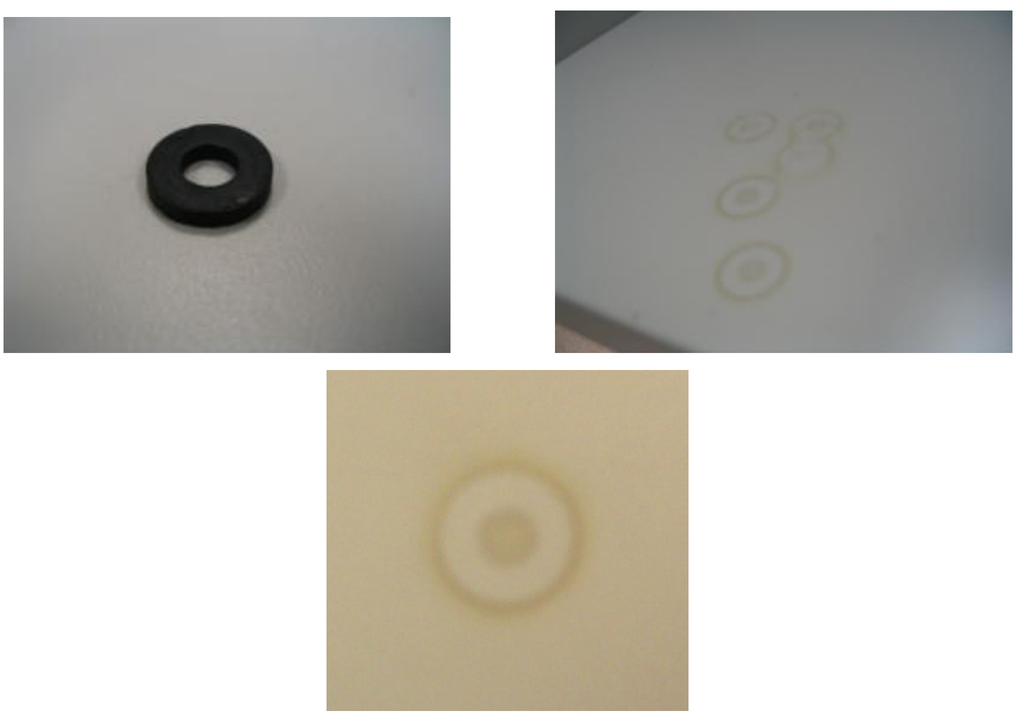
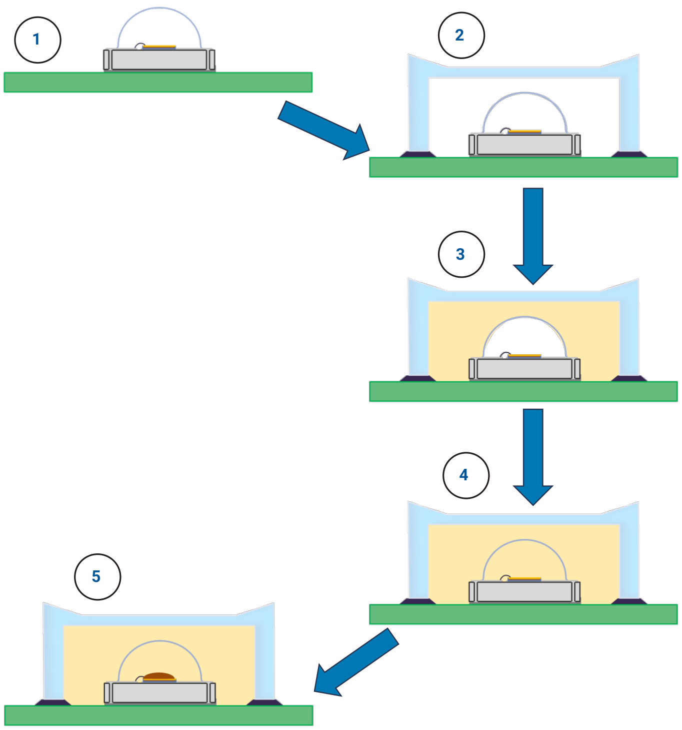


Figure 9: Evidence of VOC outgassing from an O-ring

REVERSIBILITY OF VOC-BASED DISCOLORATION

The VOCs occupying a free space within the lens or encapsulant typically do not cause permanent damage to the silicone material or the LED chip. In many instances, removing a secondary optic or otherwise venting the LED's environment will allow it to clear and recover in just a few hours of operation. However, the discolored VOC in the silicone polymer will not clear if the LED's operating environment remains saturated with the VOC.

Figure 10 shows an example of the progression of VOC discoloration of an LED in a microenvironment, formed by a sealed secondary lens.



1. The LED is mounted to a printed circuit board.
2. A secondary optic is attached to the board with glue.
3. VOCs emitted from the glue are trapped beneath the optic.
4. The VOCs diffuse through the silicone lens.
5. The VOCs in the encapsulant above the chip surface discolor..

Figure 10: An example of the progression of VOC discoloration of an LED

The photographs in Figure 11 are examples of this type of chemical degradation followed by outgassing of the VOC, which clears up a darkened LED. In Figure 11, photograph 1 is a VOC-darkened LED caused by operation in an environment with incompatible VOCs. Photograph 2 is after 24 hours of operation in a VOC-free environment and photograph 3 is after 48 hours without the presence of VOCs. Photograph 4 is after 72 hours of VOC-free operation and the LED is clear.

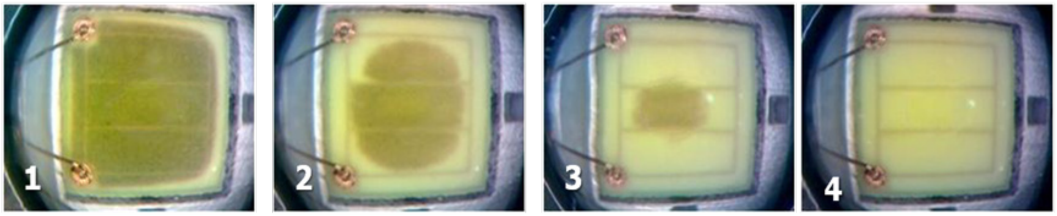


Figure 11: VOC-degraded LEDs allowed to outgas

Cree LED's application engineering team conducted a controlled chemical compatibility experiment to demonstrate and document the effect of this VOC reversibility on LEDs. Over an interval of 450 hours, three sets of ten LEDs (thirty LEDs in total) were first contaminated with a known high-VOC chemical and then for more than 450 hours tested for luminous flux output in three different test environments. One group was in an open-air environment, the second group in a sealed secondary optics environment and the third group started out with sealed optics, but was vented at 325 hours into the test.

The first group of ten LEDs operated in the open-air environment and despite the deliberate contamination showed no degradation from the initial luminous flux measurements of approximately 100 lumens. The sealed second group suffered a 90% loss of light output after 450 hours of operation. The third sample group of LEDs, after 325 hours of operation, also suffered a 90% loss of luminous flux output. Venting the enclosure of this third sample group allowed the VOCs to escape and 24 hours later the third sample set of LEDs recovered virtually all of the lost luminous flux output. Figure 12 is a graphical summary of the luminous flux output versus time for these three test cases.

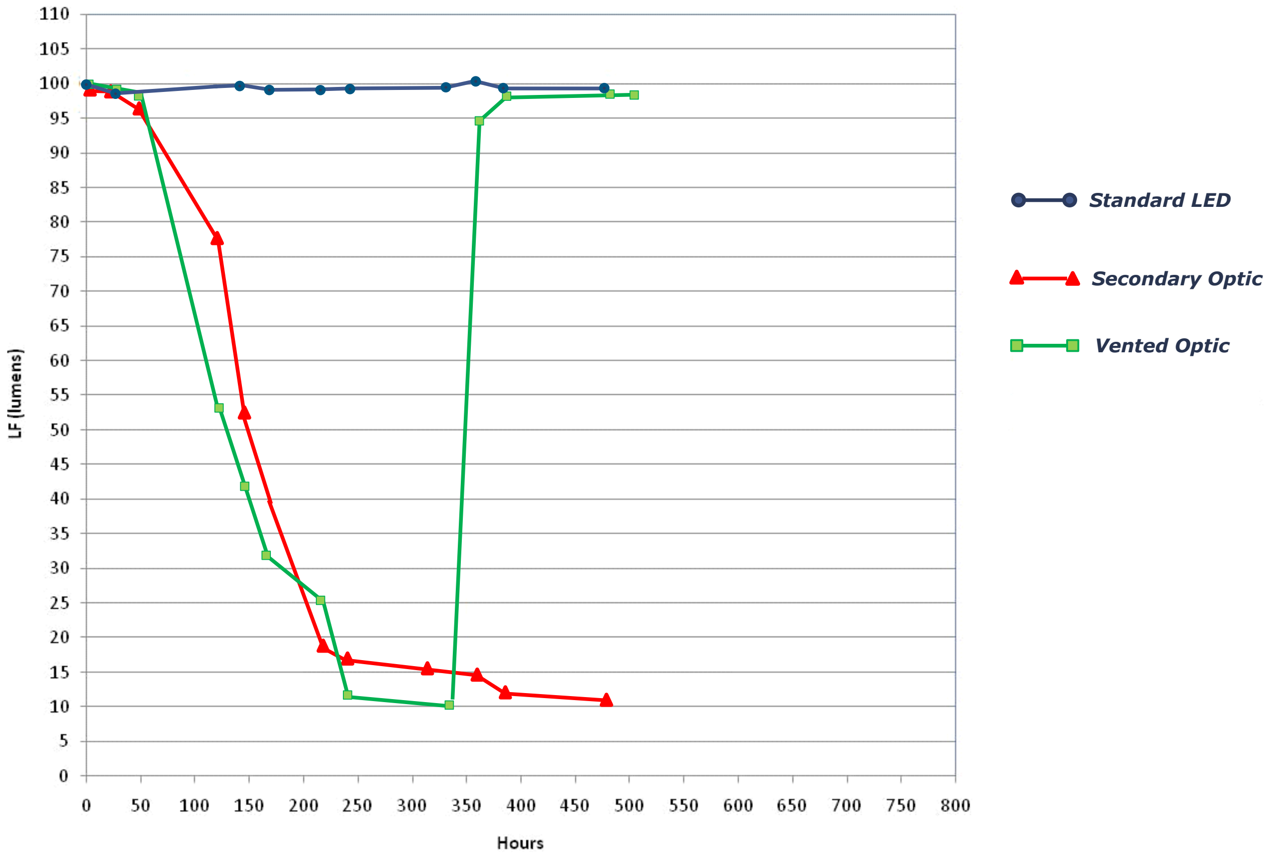


Figure 12: Results of chemical compatibility test to investigate reversibility of VOC discoloration

Figure 13 provides additional examples of the reversibility of VOC discoloration. The photographs in the top row show the VOC discoloration; the photographs in the bottom row show these same LEDs clear of discoloration after operation.

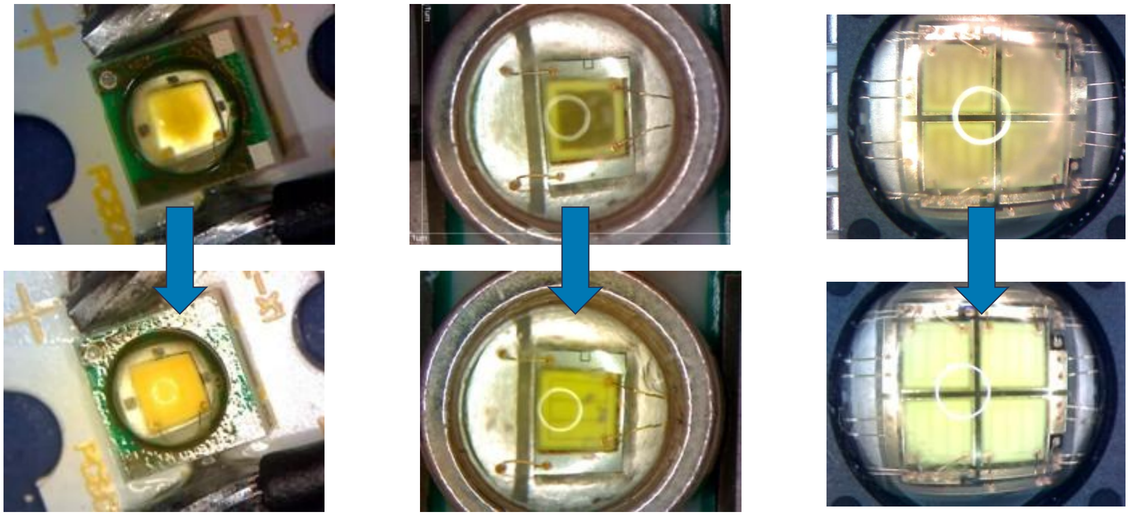


Figure 13: Examples showing the reversibility of VOC discoloration

MATERIAL SELECTION CONSIDERATIONS

Testing materials used in luminaires prior to production can help prevent unexpected problems once the product is in production and operating in the field. Special consideration needs to be given to gasket materials, solder, flux and residual chemistry, such as machine oil on metal surfaces. Anything that will come into contact with the LED lens should be carefully considered. Even FR-4 boards can outgas at elevated operating temperatures.

Most materials will outgas during the curing process regardless of whether the material is an adhesive, a conformal coating or a potting compound. During material curing, a VOC released around the LED can have a negative effect on the LED's light emissions. Thus the choice of the materials used in a luminaire is as important to the luminaire's performance as the heat sink, driver and optics.

Prior to using a material in an LED-based fixture, consult documentation regarding the materials recommended for use with the LED. Table 1 and Table 2 below are short lists of materials known to cause luminous depreciation, as well as some materials that have been found to not have a negative impact. The appendix is a more complete source for materials that have been found to work in and around LED fixtures. Cree LED recommends that customers conduct the chemical compatibility test outlined in the Chemical Compatibility Test Procedure section on page 11 when deciding whether to use a chemical or material.

The chemical composition of the atmosphere in a fixture as well as the environment present around the light source is critical for the lifetime of the fixture. No material should be considered for use in a luminaire without checking with the product supplier or consulting the LED manufacturer. The more information considered prior to using a material, the better the fixture performance will be throughout the lifetime of the fixture.

Many common chemicals can outgas aromatic hydrocarbons, and fumes from even small amounts of these chemicals tend to discolor or damage LEDs. Cree LED has found the common chemicals listed in Table 1 to be harmful to LEDs, so Cree LED recommends not using these chemicals anywhere in or around an LED-based luminaire.

Table 1: Common chemicals with known LED compatibility issues

Chemicals that can outgas hydrocarbons/arenes (e.g., toluene, benzene, xylene)
Methyl acetate or ethyl acetate (e.g., nail polish remover)
Cyanoacrylates (e.g., "Superglue")
Glycol ethers and dipropylene glycol monomethyl ether (e.g., electronics cleaners)
Formaldehyde or butadiene (e.g., PLIOBOND® adhesive)
Chlorine, including bleach-containing cleaners and sprays

Cree LED found no issues when testing a number of circuit board conformal coatings with XLamp LEDs. These specific coatings are listed in Table 2.[1] However, do not apply conformal coatings directly on an LED lens, as this will the affect LED optical performance and reliability.

Table 2: Conformal coatings compatible with most LEDs

Selected conformal coatings found safe to use with XLamp LEDs
Dow Corning® 1-2577
Dow Corning 1-4105
Dow Corning 3-1953
Humiseal® 1B51NS
Humiseal 1B73
Humiseal 1C49LV
Humiseal 1H20AR1/S
Humiseal UV40
Shat-R-Shield
Specialty Coating Systems – Parylene
TechSpray® Turbo-Coat™ Acrylic Conformal Coating (2108-P)

The Cree LED application engineering team is constantly expanding its experience with compatible and incompatible chemistries. As part of a luminaire manufacturability evaluation, in addition to any testing performed, contact the local Cree LED Field Application Engineer for updates on Cree LED's latest experiences with compatible and incompatible materials.

CHEMICAL COMPATIBILITY TESTING

Chemical compatibility testing validates that the chemicals or compounds within an SSL system are compatible with the LEDs utilized. The focus of this testing should be on gasket materials, adhesives, conformal coatings, soldering flux or any residual chemicals that may be in close proximity to the LED lens.

Cree LED has created a chemical compatibility test kit for various LEDs in the XLamp LED product line. The kits are complete with a metal-core circuit board populated with six LEDs and glass vials with adhesive to create an airtight test environment. Available in three configurations, these test kits cover the following different Cree LED types:

1. MX-6

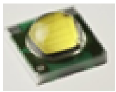
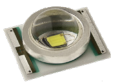
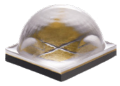
1 This list is provided for informational purposes only and is not a warranty or endorsement. The results obtained are specific to the test method, volume and material applied and environmental conditions under which it was performed. To verify compatibility, Cree LED recommends that all chemicals and materials be tested in the specific application and environment for which they are intended to be used.

2. XP-E

3. XHP50

Combination kits containing different subsets of these LEDs as well as XR-E LEDs have been sold in the past. Cree LED recommends choosing the kit with the LED that most closely matches the architecture of the LED used in the customer's system, and performing the tests with any chemicals or compounds to be used.

Table 3: XLamp LED product examples

Product Examples			
MX-6	XP-E	XR-E	XHP50
			

All test kits include Arctic Silver®, part number ASTA-7G, a thermal adhesive tested to be compatible in close proximity to high-power LEDs. Figure 14 is a photograph of a chemical compatibility test kit for Cree LED XHP50 LEDs with all the supplied test materials.

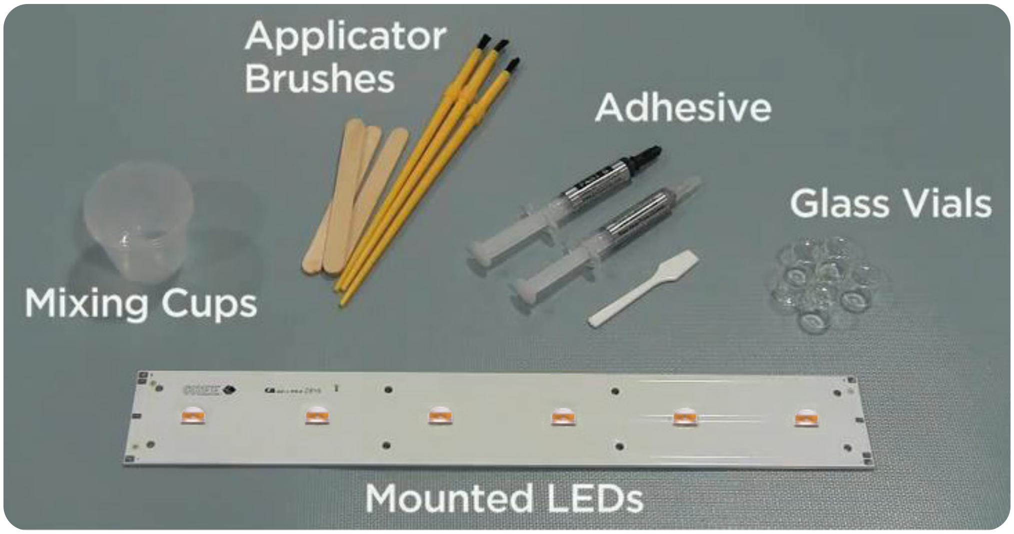


Figure 14: Chemical compatibility test kit

The test kits utilize small sealed glass enclosures that test a single material or chemical sample for any effect on a single LED. The proper test setup is to place the material under test on top of the first three LEDs on the board, then place the same test material at the base of of the next two LEDs such that the test material is away from each of the two LED's lens. The final LED will be the control reference that tests an LED without any sample material. An airtight seal made by the Arctic Silver adhesive around the diameter of the glass vials covers the LED and sample material.

Wires from a constant-current supply connect to each chemical board. Drive current varies based on component type, i.e., 700 mA for the XP-E and XR-E LEDs and 350 mA for the MX-6 LED. Testing typically lasts for about 1000 hours, monitoring for changes in light intensity or color or simply just the visual appearance of the LED's phosphor layer with the LED turned off. Test results indicating chemical compatibility issues often show up in 48 hours after initial illumination. Figure 15 shows a typical chemical compatibility test setup under operation for about 720 hours. Note the color shift in the LED third from the left and a significantly dimmer LED fifth from the left.

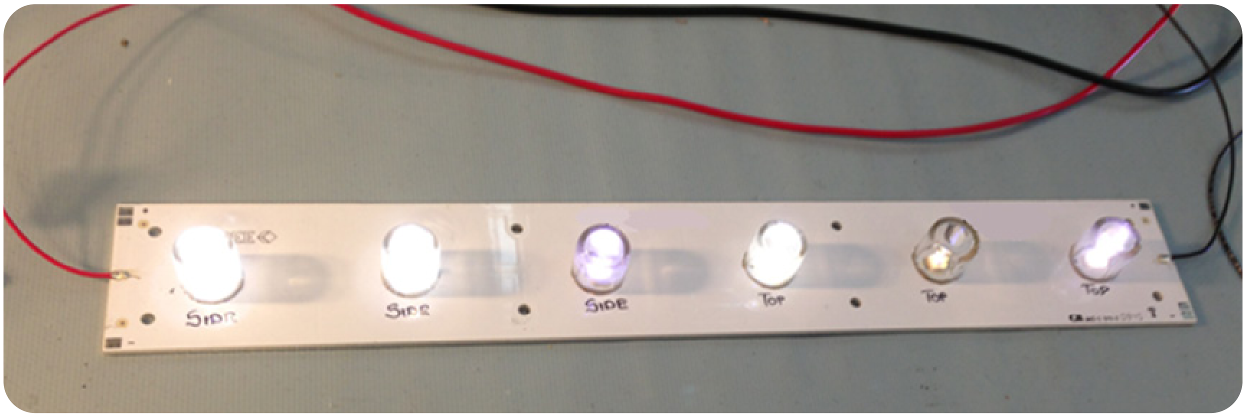


Figure 15: Chemical compatibility test board in operation

Chemical Compatibility Test Procedure

To determine whether a material is chemically compatible with the XLamp LED product family, a chemical compatibility test should be completed for each MX-6, XP-E, XR-E and XHP50 component. To determine material compatibility with a single product such as an XP family LED, only the XP test need be completed. The following test must be performed to evaluate a material for chemical compatibility..

1. Place the material under test on top of three of the six total LED components on the chemical board. Label the board near the component to identify the material located on top of the LED's dome.
2. Place the same material under test at the base of two LED components and label this near the LED as the proximity test. Be sure to place the material at the base of the LED where it is soldered to the circuit board while being careful to keep the material from making contact with the LED dome.
    a. For materials present but not contacting the LED, such as gaskets, place the sample on the board next to the LED.
3. The last LED component will remain untouched as the experimental control.
4. Seal the LED components under test with a glass cap using the included thermal adhesive. The appropriate seal can be made by applying a small bead of adhesive around the base of the glass cap, then slightly rotating the cap while pushing it to the board.
5. Wire the leads to the circuit board and power the LED components with a constant-current driver or power supply, specific to the components under test.
    a. 350 mA at approximately 18 VDC for MX-6 and XR-E components
    b. 700 mA at approximately 18 VDC for XP-E components
    c. 700 mA at approximately 72 VDC for XHP50 components
6. Photograph the LEDs before the test.

7. Run the test for at least six weeks, or 1,000 hours. After one week, initial results should be visible. After six weeks, tests should be conclusive.

8. Photograph the LEDs after the test. These photographs can be compared to the photographs taken before the test to best make determinations about VOC-based discoloration.

Evaluation

Cree LED recommends taking photographs before and after testing so that results may be directly compared to initial conditions. Monitor the variation in color and light intensity for each component to determine whether a material is compatible with XLamp LED products. Evaluating small changes in these components at 350 mA or 700 mA is nearly impossible due to the high quantity of light emitted from the devices. If possible, lower the drive current close to 1 mA to allow direct viewing of the LED within the component package with the naked eye. This enables thorough evaluations of the silicone dome, phosphors, and chip condition (such as charring).

If the LED encapsulant discolors during testing, try removing the glass cap and continuing the test to see if the discoloration diminishes. This secondary test can verify compatibility in applications that do not require the LED to be in a sealed environment.

Provide Post-Test Information to Cree LED

For the benefit of the SSL industry, Cree LED strives to maintain the most accurate information and highest standards concerning all aspects of design and manufacture of solid-state lighting systems. We are eager to receive the results of the materials tested and this information will be added to our materials database and be reflected in future versions the list of materials in the Appendix. Provide this information to the local Cree LED Field Application Engineer.

Please include the following information about the original fixture:

- Type of LED tested
- Material trade name (e.g., “Super Glue”)
- Active chemicals as listed on the packaging or material safety data sheet (MSDS)
- Type of circuit board and soldering process utilized
- Forward current (I_F), solder-point temperature (T_S) and ambient temperature (T_A) of circuit board and system
- Test duration
- Pictures of affected LEDs

Optional information, but very helpful:

- Differences in luminous flux or peak intensity
- Differences in color (CCx, CCy or u’, v’)
- Amount of lumen recovery after cap removed

Chemical Compatibility Test Kit Availability

Henkel, a major manufacturer of materials for use in electronics, has worked with Cree LED to develop a chemical compatibility reference guide for LEDs. This guide, based on test results from the Cree LED chemical compatibility test kits, covers threadlockers, general bonding, potting compounds, and lens bonding and sealing products that have been found in testing to be compatible with LEDs. Additionally, to help the whole SSL industry with this LED chemical compatibility challenge, Cree LED has made chemical compatibility test sets available for purchase directly from Mouser Electronics. These test kits can be a surrogate for any of Cree LED's various LED types.

CONCLUSION

VOCs emitted from materials used in the construction of LED-based SSL systems can penetrate the silicone lenses and encapsulants of LEDs. These VOCs in the silicone can discolor when exposed to heat and high photonic energy of an LED. The result can produce significant loss of light output or color shift from an LED. Proper material selection for the SSL design and venting of the enclosure or secondary lens assemblies reduces the risk of chemical compatibility issues in SSL luminaire systems. Compatibility testing of the materials selected for the assembly of the SSL system can help ensure the long-term high performance of lighting-class LED designs.

HELPFUL LINKS

Henkel AG & Co., KGaA	na.henkel-adhesives.com/Cree LED-compatibility-21209.htm
Mouser Electronics, Inc.	www.mouser.com

APPENDIX

Following are tables of base materials and commercial products that are often found in electronic and electrical devices along with Cree LED's assessment of the viability of the substance in SSL luminaire construction. Be sure to consult the local Cree LED Field Application Engineer for the most current information concerning chemical compatibility.

Table 4 lists the results of chemical compatibility tests including specific tests passed and failed for each product tested.

Table 4: Detailed chemical compatibility test results

Commercial Product	Type	Direct Contact Test - Passed	Direct Contact Test - Failed	Proximity Test - Passed	Proximity Test - Failed
3M® Novec® 1710	Coating	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
3M Novec 1908	Coating	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
3M Novec 2702	Coating	XP-E XR-E		XP-E XR-E	
3M Novec 2708	Coating	MX-6 XP-E	XR-E	MX-6 XP-E XR-E	
AIT Solarbloc™ SC7050-UVB	Coating	XP-E XR-E		XP-E XR-E	
Aquanox® A4241	Cleaner	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Aquanox A4625B Plus Booster 20	Cleaner	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Cool-Bond™ PSA-3NC	Thermal adhesive tape pads	MX-6 XR-E	XP-E	MX-6 XR-E	XP-E
Cool-Bond PSA-3TC	Thermal adhesive tape pads	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Cool-GapFill™ TT G4	Thermal interface material	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Cool-Grease™ ZXM	Thermal grease	XP-E	XR-E	XP-E	XR-E
Cool-Pad CPR7153	Thermal interface material	XP-E		XP-E	
DELO® DualBond® AD340	Adhesive	XP-E		XP-E	
DELO DualBond AD4950	Light/humidity adhesive	XP-E		XP-E	
DELO DualBond OB749	UV/light/heat adhesive	XP-E		XP-E	
DELO-Duopox® AD821	Epoxy resin		XP-E	XP-E	
DELO-Duopox AD840	Epoxy resin		XP-E	XP-E	
DELO Katiobond® OB642	UV/light epoxy adhesive	XP-E		XP-E	
DELO Katiobond OB678	UV/light epoxy adhesive	XP-E		XP-E	
DELO Monopox® MK040	Heat epoxy		XP-E	XP-E	
DELO Monopox MK045	Heat epoxy	XP-E		XP-E	
DELO PhotoBond® 4494	UV/ light acrylate adhesive	XP-E		XP-E	
DELO PhotoBond AD494	UV/light acrylate adhesive	XP-E		XP-E	

* Many of these chemicals and compounds are acceptable (OK) in XLamp LED-based luminaire and lamp designs. However, Cree LED advises against the use of any chemicals or materials that have been found or are suspected to have an adverse affect on device performance or reliability. The results obtained and listed are specific to the test method, volume and material applied and environmental conditions under which it was performed. To verify compatibility, Cree LED recommends that all chemicals and materials be tested in the specific application and environment for which they are intended to be used. These lists are provided for informational purposes only and are not a warranty or endorsement.

Commercial Product	Type	Direct Contact Test - Passed	Direct Contact Test - Failed	Proximity Test - Passed	Proximity Test - Failed
DELO PhotoBond GB368	UV/light acrylate adhesive	XP-E		XP-E	
DELO PhotoBond PB437	UV/light acrylate adhesive	XP-E			XP-E
DELO PUR 9895	Polyurethane adhesive		XP-E	XP-E	
Dow Corning® 3-8259 RF	Silicone foam	MX-6 XR-E	XP-E	MX-6 XP-E XR-E	
Dow Corning DC 744	Sealant & adhesive	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Dow Corning EA-2626	Adhesive	MX-6 XR-E	XP-E	MX-6 XP-E XR-E	
Dow Corning EA-2900	Sealant & adhesive	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Dow Corning EA-9189 H	Adhesive	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Dow Corning SE 1700	Adhesive	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Dow Corning SE 1720	Sealant & adhesive	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Dow Corning SE 9120	Adhesive	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Dow Corning TC 1800	Adhesive	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Dow Corning TC-5080	Thermal grease	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Dow Corning TC-5351	Thermally conductive compound	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Dow Corning TC-5622	Thermally conductive compound	MX-6 XR-E	XP-E	MX-6 XP-E XR-E	
Dow Corning TC-5625C	Thermal grease	MX-6 XR-E	XP-E	MX-6 XP-E XR-E	
H.B. Fuller EH9642	Adhesive			MX-6 XP-E XR-E	
H.B. Fuller FH3911 A/B	Potting			MX-6 XP-E XR-E	
Kyzen® A4241	Cleaner	XP-E		XP-E	
Kyzen A4625	Cleaner	XP-E		XP-E	
Liqui-Bond® EA 1805 (Munich)	Adhesive			XP-E	
Loctite® 0151™	Epoxy	MX-6	XP-E	MX-6 XP-E	

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Commercial Product	Type	Direct Contact Test - Passed	Direct Contact Test - Failed	Proximity Test - Passed	Proximity Test - Failed
Loctite 2046™	Threadlocker food grade		MX-6 XP-E XR-E	MX-6	XP-E XR-E
Loctite 242®	Threadlocker (methacrylate)		MX-6 XP-E XR-E		MX-6 XP-E XR-E
Loctite 2422™	High temp threadlocker		MX-6 XP-E XR-E		MX-6 XP-E XR-E
Loctite 246™	Threadlocker	XP-E	MX-6 XR-E	MX-6 XP-E XR-E	
Loctite 248™	Threadlocker (methacrylate)		MX-6 XP-E XR-E		MX-6 XP-E XR-E
Loctite 249™	Threadlocker		MX-6 XP-E XR-E	MX-6	XP-E XR-E
Loctite 263™	Threadlocker	MX-6	XP-E XR-E	MX-6	XP-E XR-E
Loctite 266™	Threadlocker (methacrylate)		MX-6 XP-E XR-E		MX-6 XP-E XR-E
Loctite 268™	Threadlocker		MX-6 XP-E XR-E	MX-6	XP-E XR-E
Loctite 3090™	Instant adhesive	MX-6	XP-E	MX-6	XP-E
Loctite 3092™	Cyanoacrylate	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Loctite 3105™	UV acrylic	MX-6 XP-E (cured)	XP-E (uncured)	MX-6 XP-E (cured)	XP-E (uncured)
Loctite 3106™	UV acrylic	MX-6 XP-E		MX-6 XP-E	
Loctite 3145™	Epoxy	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Loctite 315™	No mix acrylic - TIM		MX-6 XP-E	MX-6 (cured) XP-E (cured)	MX-6 (uncured) XP-E (uncured)
Loctite 3165™	Epoxy	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Loctite 3173™	Polyurethane	MX-6	XP-E XR-E	MX-6	XP-E XR-E
Loctite 3184™	Polyurethane	MX-6	XP-E XR-E	MX-6	XP-E XR-E
Loctite 3321™	UV acrylic	MX-6 (cured)	MX-6 (uncured) XP-E	MX-6 (cured)	MX-6 (uncured) XP-E
Loctite 3336™	UV epoxy	MX-6 XP-E		MX-6 XP-E	
Loctite 3341™	UV acrylic	MX-6 XP-E		MX-6 XP-E	
Loctite 3364™	Polyurethane	MX-6 XR-E	XP-E	MX-6 XR-E	XP-E

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Commercial Product	Type	Direct Contact Test - Passed	Direct Contact Test - Failed	Proximity Test - Passed	Proximity Test - Failed
Loctite 3494™	UV acrylic	MX-6	XP-E	MX-6	XP-E
Loctite 3525™	UV acrylic	MX-6	XP-E	MX-6	XP-E
Loctite 3526™	UV acrylic	MX-6 XP-E		MX-6 XP-E	
Loctite 3542™	Hot melt polyurethane resin	MX-6	XP-E	MX-6	XP-E
Loctite 3553™	UV acrylic (indigo)	MX-6 XP-E		MX-6 XP-E	
Loctite 384™	No-mix acrylic		MX-6 XP-E		MX-6 XP-E
Loctite 3922™	UV acrylic	MX-6 XP-E		MX-6 XP-E	
Loctite 3936™	UV acrylic	MX-6 XP-E (cured)		MX-6 XP-E (cured)	
Loctite 3972™	UV acrylic	MX-6 XP-E		MX-6 XP-E	
Loctite 3979™	UV acrylic	MX-6	XP-E XR-E	MX-6	XP-E XR-E
Loctite 3981™	Epoxy	MX-6 XP-E		MX-6 XP-E	
Loctite 4090™	Cyanoacrylate/epoxy	MX-6 XP-E		MX-6 XP-E	
Loctite 4311™	UV cyanoacrylate	MX-6 XP-E		MX-6 XP-E	
Loctite 435™	Cyanoacrylate		MX-6 XP-E XR-E		MX-6 XP-E XR-E
Loctite 454™	Cyanoacrylate		MX-6 XP-E XR-E		MX-6 XP-E XR-E
Loctite 455™	Cyanoacrylate	MX-6	XP-E	MX-6 XP-E	
Loctite 460™	Instant adhesive	MX-6 XP-E		MX-6 XP-E	
Loctite 5031™	UV silicone	MX-6 XP-E		MX-6 XP-E	
Loctite 5050™	UV silicone	XP-E (cured) XR-E (cured)	MX-6 XP-E (uncured) XR-E (uncured)	MX-6 XP-E (cured) XR-E (cured)	XP-E (uncured) XR-E (uncured)
Loctite 5088™	Silicone (neutral cure)				
Loctite 5091™	UV silicone	MX-6 (cured) XP-E (cured) XR-E (cured)	MX-6 (uncured) XP-E (uncured) XR-E (uncured)	MX-6 (cured) XP-E (cured) XR-E (cured)	MX-6 (uncured) XP-E (uncured) XR-E (uncured)
Loctite 5092™	Silicone	MX-6 XP-E		MX-6 XP-E	
Loctite 5510™ Clear	Modified silane (MSP)	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Loctite 5510™ White	Modified silane (MSP)	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Loctite 5512™	Modified silane (MSP)	MX-6 XP-E		MX-6 XP-E	

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Commercial Product	Type	Direct Contact Test - Passed	Direct Contact Test - Failed	Proximity Test - Passed	Proximity Test - Failed
Loctite 5570™ White	Modified silane (MSP)	MX-6	XP-E	MX-6 XP-E	
Loctite 5590™	Modified silane (MSP)	MX-6 XR-E	XP-E	MX-6 XP-E	
Loctite 5600™	Silicone	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Loctite 5604™	Silicone	MX-6 XR-E	XP-E	MX-6 XP-E XR-E	
Loctite 5611F™	Silicone	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Loctite 5611S™	Silicone	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Loctite 5620™	Silicone	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Loctite 5623™	Silicone	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Loctite 5640™	Silicone	MX-6 XP-E		MX-6 XP-E	
Loctite 5900™	Silicone	MX-6	XP-E XR-E	MX-6	XP-E XR-E
Loctite 7386™	No mix acrylic - TIM		MX-6 XP-E	MX-6 (cured) XP-E (cured)	MX-6 (uncured) XP-E (uncured)
Loctite 7809FR™	Polyamide hot melt		MX-6 XP-E	MX-6	XP-E
Loctite 7901™	Hot melt	MX-6	XP-E XR-E	MX-6	XP-E XR-E
Loctite AA 3038™	Adhesive	MX-6	XP-E	MX-6	XP-E
Loctite AA 315™	Adhesive		MX-6 XP-E		MX-6 XP-E
Loctite CR 4300™	Casting resin		MX-6 XP-E	MX-6	XP-E
Loctite CR 6127™	Casting resin		MX-6 XP-E	MX-6	XP-E
Loctite E-05MR™	Epoxy	XR-E	MX-6 XP-E	XP-E XR-E	MX-6
Loctite E20-HP™	Epoxy	MX-6 XR-E	XP-E	MX-6 XR-E	XP-E
Loctite E-30CL™	Epoxy	MX-6 XR-E	XP-E	MX-6 XP-E XR-E	
Loctite E-40EXP™	Epoxy	MX-6 XR-E	XP-E	MX-6 XP-E XR-E	
Loctite E-40HT™	Epoxy	MX-6 XR-E	XP-E	MX-6 XP-E XR-E	

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Commercial Product	Type	Direct Contact Test - Passed	Direct Contact Test - Failed	Proximity Test - Passed	Proximity Test - Failed
Loctite E-60NC™	Epoxy	XP-E MX-6	XP-E	MX-6 XP-E XR-E	
Loctite E-90FL™	Epoxy	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Loctite EA 9483™	Transparent epoxy adhesive		MX-6 XP-E		MX-6 XP-E
Loctite EA 9496™	Potting		MX-6 XP-E	MX-6 XP-E	
Loctite EA 9497™	Adhesive	MX-6	XP-E	MX-6 XP-E	
Loctite H3300™	Methylmethacrylate (MMA)		MX-6 XP-E XR-E	MX-6	XR-E XP-E
Loctite H5004™	Methylmethacrylate (MMA)	MX-6 XR-E	XP-E	MX-6 XR-E	XP-E
Loctite Hysol® 232™	Hot melt		MX-6 XP-E XR-E	MX-6 XP-E	XP-E
Loctite Si 100™	Thermal paste	MX-6	XP-E	MX-6 XP-E	
Loctite Si 113™	Adhesive	MX-6 XP-E		MX-6 XP-E	
Loctite Si 5088™	Sealant & adhesive	MX-6	XP-E	MX-6	XP-E
Loctite Si 5616™	Sealant & adhesive	MX-6 XP-E		MX-6 XP-E	
Loctite Stycast® EE 8200/EB 363	Potting		MX-6 XP-E	MX-6	XP-E
Loctite Superflex® Non-Corrosive RTV	Silicone	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Loctite Technomelt® 232	Hot melt		MX-6 XP-E XR-E	MX-6 XR-E	XP-E
Locite U-05FL™	Polyurethane		XP-E XR-E	MX-6 XR-E	XP-E
Loctite U-09FL™	Polyurethane	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Loctite UK 1366™	Polyurethane	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Peters ELPEGUARD® DSL 1706 FLZ	Conformal coating	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Peters ELPEGUARD® SL 1307 FLZ/2	Conformal coating	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Peters ELPEGUARD® SL 1397	Conformal coating	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Peters ELPEGUARD® TWIN-CURE® DSL 1600 E/500	Conformal coating	MX-6 XP-E	XR-E	MX-6 XP-E	XR-E

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Commercial Product	Type	Direct Contact Test - Passed	Direct Contact Test - Failed	Proximity Test - Passed	Proximity Test - Failed
Pur-Fect Lok® 34-858A	Polyurethane resin hot melt (AT product)	MX-6	XP-E	MX-6 XP-E	
SoftFace®	Thermal interface material			MX-6	
Stycast 5952	Silicone (TIM)	MX-6	XP-E	MX-6 XP-E	
Stycast 5954	Silicone (TIM)	MX-6	XP-E	MX-6 XP-E	
Sur-Cool® GNTPB 150V	Thermal interface material	MX-6 XP-E		MX-6 XP-E	
Sur-Cool GNTPB 300V	Thermal interface material	MX-6 XP-E		MX-6 XP-E	
Sur-Cool SFR 150V	Thermal interface material	MX-6 XP-E		MX-6 XP-E	
Sur-Cool USVO	Thermal interface material	MX-6 XP-E		MX-6 XP-E	
Technomelt® PA 678	Adhesive		MX-6 XP-E	MX-6	XP-E
Technomelt PA 7878	Hot melt		MX-6 XP-E	MX-6	XP-E
Techspray® 2120	Coating	MX-6 XHP50		MX-6 XHP50	
Techspray® 2125	Coating	MX-6 XHP50		MX-6 XHP50	
Teroson MS 939	Sealant & adhesive		MX-6 XP-E	MX-6 XP-E	
Teroson MS 9399	Adhesive		MX-6 XP-E	MX-6 XP-E	
Wepuran VT 3402 KK-ALU	Coating		MX-6 XP-E XR-E		
Wepuran VT 3402 KK-NV	Coating	MX-6	XP-E XR-E	MX-6 XR-E	XP-E
Wepuran VT 3402 KK-NV-HE	Coating		MX-6 XP-E XR-E		
Wepuran VU 4444/31 SB-WB	Coating	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Wepuran VU 4447/51	Coating	MX-6 XP-E XR-E		MX-6 XP-E XR-E	
Wepuran VU 4490/31	Coating	MX-6 XP-E XR-E		MX-6 XP-E XR-E	

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Table 5 and Table 6 present information from past versions of this document (up to Revision 5C, August, 2016). These tables present information from chemical compatibility tests that did not follow the same testing and reporting procedures outlined in the Chemical Compatibility Test Procedure section on page 11. An issue is defined to be a significant loss of light output or color shift in the light from an LED. The tables are provided as a courtesy to any customer considering using these products. Cree LED recommends that all chemicals and materials be tested in the specific application, environment, and conditions for which they are intended to be used.

Table 5: Base material compatibility (legacy)

Base Material	Type	OK In XLamp LED Designs*	Outgas Tested	Issues Found◊	Issues Suspected
Acetic acid	Acid				Yes
Acrylic rubber	Rubber/plastic seal				Yes
Acetone	Manufacturing material			Yes	
Acrylonitrile butadiene styrene (ABS)	Structural plastic	Yes			
Ammonia	Alkaline				Yes
Benzene	Solvent				Yes
Butadiene rubber	Rubber/plastic seal				Yes
Butyl rubber	Rubber/plastic seal				Yes
Chlorinated polyethylene	Rubber/plastic seal				Yes
Chlorobutyl	Rubber/plastic seal				Yes
Chlorosulphonated rubber	Rubber/plastic seal				Yes
Cyanoacrylate	Sealant & adhesive		Yes	Yes	
DCA SCC3	Coating/potting	Yes	Yes		
Dichloromethane	Solvent				Yes
Epichlorhydrin	Rubber/plastic seal				Yes
Gasoline	Solvent				Yes
Graphite gasket	Thermal compound	Yes	Yes		
Halogenated hydrocarbons (containing F, Cl, Br elements)/miscellaneous			Yes		Yes
HT902	Coating/potting	Yes	Yes		
Hydrochloric acid	Acid				Yes
Isopropyl alcohol (IPA)	Cleaning agent	Yes	Yes		
Methyl ethyl ketone (MEK)	Solvent				Yes
Methyl isobutyl ketone (MIBK)	Solvent				Yes
Mineral spirits	Solvent				Yes
Nitric acid	Acid				Yes
Non-silicon thermal grease	Thermal compound	Yes	Yes		
Petroleum	Oil/lubricant				Yes
Polycarbonate (PC)	Structural plastic	Yes			
Polyethylene	Rubber/plastic seal	Yes			
Polypropylene (PP)	Structural plastic	Yes			
Polystyrene (GPPS)	Structural plastic	Yes			
Potassium hydroxide	Alkaline				Yes
Silicone oil	Oil/lubricant				Yes

◊ Cree LED recommends avoiding the use of these chemicals and products in XLamp LED designs. Harmful effects have been found and verified when using them.

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Base Material	Type	OK In XLamp LED Designs*	Outgas Tested	Issues Found◊	Issues Suspected
Sodium hydroxide	Alkaline				Yes
Sulfuric acid	Acid				Yes
Tetracholoromethane	Solvent				Yes
Tetradecylamine					Yes
Thermal transfer grease (silicone based)	Thermal compound	Yes	Yes		
Thermal transfer tape (with or without adhesives)	Thermal compound	Yes	Yes		
Toluene	Solvent				Yes
Trimethylhexamethylene diamine					Yes
Xylene	Solvent				Yes

Table 6: Commercial product compatibility (legacy)

Commercial Product	Type	OK In XLamp LED Designs*	OK In XLamp LED Proximity	Outgas Tested	Issues Found◊
3M Scotch-Weld™ DP105	Adhesive	Yes	Yes	Yes	
3M Scotch-Weld DP190 epoxy adhesive (polymeric diamante, kaolin)	Sealant & adhesive	Yes	Yes	Yes	
3M Scotch-Weld DP460	Adhesive	Yes	Yes	Yes	
Arctic Silver®	Thermal epoxy	Yes	Yes	Yes	
Baiyun SMG533	Coating/potting	Yes	Yes	Yes	
Bostik® ISR 70-03	Adhesive	Yes	Yes	Yes	
Dow Corning 1-2577	Coating/potting	Yes	Yes	Yes	
Dow Corning 1-4105	Conformal coating	Yes	Yes	Yes	
Dow Corning 3165	RTV adhesive sealant	Yes			
Dow Corning 3-1744	Coating/potting	Yes	Yes	Yes	
Dow Corning 3-1944	RTV	Yes	Yes	Yes	
Dow Corning 3-1953	Conformal coating	Yes	Yes	Yes	
Dow Corning 7091	Coating/potting	Yes	Yes	Yes	
Dow Corning 7096	Coating/potting	Yes	Yes	Yes	
Dow Corning 7097 + Dow Corning TC-5625	Coating/potting	Yes	Yes	Yes	
Dow Corning 734 silicone sealant	Coating/potting	Yes	Yes	Yes	
Dow Corning CN-8760	Silicone encapsulant		Yes		
Dow Corning EA-2800	RTV	Yes	Yes	Yes	
Dow Corning MS-1002	Moldable silicone		Yes		
Dow Corning MS-2002	Moldable white reflector silicone	Yes			
Dow Corning RTV-3145	Adhesive	Yes	Yes	Yes	
Dow Corning SE-4485	Thermally conductive silicone adhesive	Yes			
Dow Corning SE-4486	Thermal adhesive	Yes	Yes	Yes	
Dow Corning SE-9184	Thermal adhesive	Yes	Yes	Yes	
Dow Corning SE-9185	Silicon adhesive	Yes	Yes	Yes	

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Commercial Product	Type	OK In XLamp LED Designs*	OK In XLamp LED Proximity	Outgas Tested	Issues Found◊
Dow Corning SE-9186	Silicone Adhesive	Yes			
Dow Corning Sylgard® 160	Potting	No	No		
Dow Corning TC-4015	RTV	Yes	Yes	Yes	
Dow Corning TC-4025	Thermal compound	Yes	Yes	Yes	
Dow Corning TC-5121	Thermal compound	Yes	Yes	Yes	
Dymax Multi-Cure® 9-20557	Conformal coating	Yes	Yes		
Huitian 9311T	Coating/potting	Yes	Yes	Yes	
Huitian HT-932TP	Coating/potting	Yes	Yes	Yes	
Humiseal® 1B51NS	Conformal coating	Yes	Yes	Yes	
Humiseal 1B73	Conformal coating	Yes	Yes	Yes	
Humiseal 1C49LV	Conformal coating	Yes	Yes	Yes	
Humiseal 1H20AR1/S	Conformal coating	Yes	Yes	Yes	
Humiseal UV40	Conformal coating	Yes	Yes	Yes	
Iso Elektra IsoPur K760	Coating/potting	Yes	Yes	Yes	
Karl Schupp PUR277 UV	Coating/potting	Yes	Yes	Yes	
Liyao KY-1312	Coating/potting	Yes	Yes	Yes	
Loctite 542	Adhesive	Yes	Yes	Yes	
Loctite Hysol LC9481	Adhesive	Yes	Yes	Yes	
Loctite Hysol LC9489	Adhesive	Yes	Yes	Yes	
Loctite Superflex RTV Non-Corrosive	Sealant & adhesive	Yes	Yes	Yes	
Loctite UK 1366 B10	Adhesive		Yes	Yes	
Lord® 6148S	Conductive adhesive	Yes	Yes	Yes	
Lord Circalok® 6150	Epoxy adhesive			Yes	Yes
Lord MD-161	Conductive adhesive			Yes	Yes
Lord MG-133	Thermal grease	Yes	Yes	Yes	
Lord MT-125	Thermal adhesive			Yes	Yes
Lord SC-309	Silicone gel	Yes	Yes	Yes	
Lord TC-404	Thermal grease	Yes	Yes	Yes	
LZ6704	Coating/potting	Yes	Yes	Yes	
Parabond®	Adhesive	Yes	Yes	Yes	
Permacol 5706	Adhesive	Yes	Yes	Yes	
Shat-R-Shield	Coating/potting	Yes	Yes	Yes	
Shinetsu x-832 and 350-3 two-part optical coupler (silicone)	Adhesive	Yes	Yes	Yes	
Specialty Coating Systems – Parylene	Coating/potting	Yes	Yes	Yes	
Star Technologies 4050T	Adhesive	Yes	Yes	Yes	
Super Glue	Sealant & adhesive			Yes	Yes
TechSpray Turbo-Coat™ acrylic conformal coating (2108-P)	Coating/potting	Yes	Yes	Yes	
Toray silicone SE 9176 RTV	Adhesive	Yes	Yes	Yes	

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