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Coating Innovations
for Electronics

TI TECHNICAL INFORMATION

TI 15/20: Selection criteria for conformal coatings and casting compounds used for LED protection

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Light emitting diodes (LEDs) are used in a growing number of applications and will replace conventional light sources in more and more areas. Depending on the purpose of later use it is indispensable to insulate the assembly by a conformal coating material which leaves the optical properties of the LEDs unaffected despite a possible coverage.

Depending on the type of application, conformal coatings or casting compounds may be used to protect printed circuit boards assembled with LED components. Basically, conformal coatings and casting compounds are different as from their thickness applied: while conformal coatings are mostly 1-pack materials, casting compounds usually come as 2-pack systems.

Owing to the drying and/or wetting mechanisms of conformal coatings, their dry layer thickness is limited to a maximum of 100 µm; in case of thick film coatings, the typical layer thickness should not exceed 300 µm. Casting compounds, on the other hand, can theoretically be applied in any unlimited thickness which enables a far better protection and a wider variety of applications.

Materials for the coating of LEDs

ELPEGUARD® conformal coatings and thick film coatings

ELPEGUARD® conformal coatings are available in colourless and fluorescent adjustments. One of the advantages of fluorescent adjustments is their visibility under UV light which allows to distinguish coated from non-coated areas. This way, the coating result can be checked for completeness in an easy and reliable manner.

When choosing a fluorescent conformal coating one must consider, however, that LEDs also emit in the UV-A range and that a colour shift may result therefrom. In addition, the exposure to UV radiation (sunlight) is likely to fade the fluorescent colouring. For this reason, the fluorescent conformal coatings should be tested for its suitability by carrying out pre-trials.

Conformal coatings of the series ELPEGUARD® SL 1800 FLZ/& (and ELPEGUARD® SL 1307 FLZ/&)

The conformal coatings of the series **ELPEGUARD® SL 1800 FLZ/&** and **ELPEGUARD® SL 1307 FLZ/&** are physically drying coating materials based on acrylate resins which dry through solvent evaporation. For this reason, the drying time is quite short. Acrylate resins are known for their ease of handling, while they offer good electrical insulation properties under moisture, besides their hydrolysis resistance and a good aging and yellowing resistance.

The conformal coatings of the series **ELPEGUARD® SL 1800 FLZ/&** are modern coating systems characterised by excellent flexibility even at very low temperatures down to -65 °C [-85 °F]. The tests were carried out on the conformal coatings of the **ELPEGUARD® SL 1307 FLZ/&** series, but due to the same resin base they are also largely valid for the products of the **ELPEGUARD® SL 1800 FLZ/&** series.

Thick film coatings of the series ELPEGUARD® Twin-Cure® DSL 1600 E-FLZ

The conformal coatings of the series **ELPEGUARD® Twin-Cure® DSL 1600 E-FLZ** are UV curing thick film coatings based on a copolymerisate of polyurethane (UR) and polyacrylate (AR). Curing is achieved via two chemical cross-linking mechanisms of different time lengths which complement each other: UV curing and humidity curing. UV curing by means of appropriate UV lamps is essential; once this step is completed, the conformal coating offers a loadable protection level in accordance with the electrical insulation properties.

In shadow areas, the product cures through a reaction with air humidity which also enables cross-linking underneath components. In general, one benefit of UV curing coatings is their rapid processability. Furthermore, this product is characterised by its mechanical and chemical resistance.

From the series **ELPEGUARD® Twin-Cure® DSL 1600 E-FLZ**, primarily the thick film coating **ELPEGUARD® Twin-Cure® DSL 1600 E/500** is most suitable for lighting electronics applications thanks to its high transparency and yellowing resistance.

ELPEGUARD® silicone thick film coatings

Largely independent from the structure and the cross-linking method (addition/condensation or UV cross-linking), silicones feature several unique properties compared to other organic plastic materials. They offer very good dielectric properties, besides a high resistance to temperature and chemicals, as well as a high weathering and UV resistance.

Silicone thick film coatings of the series ELPEGUARD® DSL 1706 FLZ

Solvent-free, colourless and condensation-cross-linking, the 1-pack silicone thick film coatings of the series **ELPEGUARD® DSL 1706 FLZ** already cross-link at room temperature while separating alcohol.

ELPECAST® casting compounds

ELPECAST® casting compounds of the series Wepuran VT 3402 KK

Owing to their extremely high transparency along with very good yellowing resistance, the **ELPECAST®** casting compounds of the series **Wepuran VT 3402 KK** based on polyurethane resins (UR) are used in lighting electronics and sensor technology, especially for applications where high demands are placed on optical properties, such as the potting/encapsulation of LEDs or optical sensors. The **ELPECAST®** casting compounds of the series **Wepuran VT 3402 KK** are distinguished by a very good weather resistance, outstanding UV light stability and a good temperature stability. Moreover, they offer a very high optical transparency with low optical attenuation and are resistant against water, moisture, condensation water and many chemicals, lyes, acids and oils.

ELPECAST® Casting compound Wepesil VT 3602 KK

Its temperature stability of 150 °C and the very high transparency make **ELPECAST®** casting compound **Wepesil VT 3602 KK** which is based on silicone resins (SR) an ideal solution for lighting electronics applications, in particular when high power LEDs shall be coated. Even when applied in thick layers and/or under a high permanent temperature load, it displays a high transparency over the entire visible range of wavelength, besides an excellent yellowing resistance. The **ELPECAST®** casting compound **Wepesil VT 3602 KK** is well-suited because of its high elasticity, the extremely high thermal stability and the very low volume shrinkage, or shrinkage pressure, especially when complex electronic components are potted which are sensitive to temperature and shocks (e.g. sensors or glass diodes). Within the curing process, only low heat is generated, and during operation, material tensions under thermal shocks are limited due to its elasticity.

Climatic tests

Outdoor applications such as signal lamps, information panels etc. are exposed to all kinds of weather conditions. The products we have developed do not only serve the purpose of protecting against environmental impacts, but they also provide solutions to meet high functional demands such as high transparency or light diffusion.

In order to make a statement on the suitability of coating materials for optical applications, various test methods are applied, such as the “85/85 test” or the dewing test (condensation water test).

As one of the basic requirements, no failure of the LEDs must be generated by climatic loading. Besides this, yellowing resistance is another essential demand. It is possible to compare coating materials by their yellowing degree after climatic loading.

After all tests were conducted, it was established that no LED was affected in terms of functionality.

However, to make a general statement on yellowing resistance, the results of the climatic tests have been stated below.

For all tests, strips were coated/encapsulated with Cree high power LEDs of the type XPG-2. The test strips were fixed on anodised aluminium U profiles by means of customary double-sided tape.

The photos below show the respective conformal coating against a reference sample. All coating materials tested display an excellent yellowing resistance, which, however, is not clearly recognisable due to reflections in the photos.

Dewing test (condensation water test)

Figure 1: Climate chamber for condensation water test

In the frame of the condensation water test, condensing humidity is simulated that one would find in the tropical climate. By loading the coating with condensation water, osmotic processes are triggered, meaning that water-soluble components cause water to accumulate which may, amongst others, delaminate the coating material from the substrate.

For this test, the climate chamber is filled with distilled water and the test room is tempered to 40 °C [104 °F] by heating up the water, so that a relative humidity of approx. 100 % is reached. After 72 hours of climatic loading at 350 or 500 mA, the functioning of the LED strips is tested and the strips are visually assessed.

Figures 2 and 3 show the test specimens after a condensation test (72 hours at 40 °C [104 °F] and 100 % R.H.).

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Figure 2: ELPEGUARD® conformal coatings after the condensation water test

Figure 3: ELPECAST® casting compounds after the condensation water test

85/85 Test (85 °C/ 85% R.H.)

Figure 4: Climate chamber for conducting the 85/85 test

In case of the so-called 85/85 test, high air humidity and high temperature are simulated while the boards are kept in ramp-formed storage. This test is performed under severe climatic conditions, as it is common in the automotive industry.

For these tests, a multi-step programme was applied:

- 1 day at 35 °C [95 °F] / 90 % R.H.
- 3 days at 65 °C [149 °F] / 90 % R. H.
- 3 days at 85 °C [185 °F] / 85 % R. H.
- 1 day 25 °C [77 °F] / 50 % R. H.

Then the sensitivity against humidity of the coating material and the LEDs underneath, or the assembly, is tested under severe test conditions against humidity which are common in the automotive industry.

After the ramp-formed temperature storage with a simultaneous current of 350 mA or 500 mA applied, the LED strips were tested for their proper functioning and visually assessed.

Figure 5: ELPEGUARD® conformal coatings after the 85/85 test

Figure 6: ELPECAST® casting compounds after the 85/85 test

Thermal shock test

Figure 7: Climate chamber for temperature cycle tests (TCT)

Within thermal shock tests or thermal cycling tests (TCT), coatings are exposed to both thermal and mechanical loads. Such temperature cycle loads are likely to cause embrittlement, cracking and coating delamination which cannot be detected directly by electrical measuring.

The test specimens are stored alternately in a “cold” (here: -40 °C) and a “hot” (here +85 °C) chamber for a defined period of time. As a general rule, 252 cycles of 30 min each are chosen.

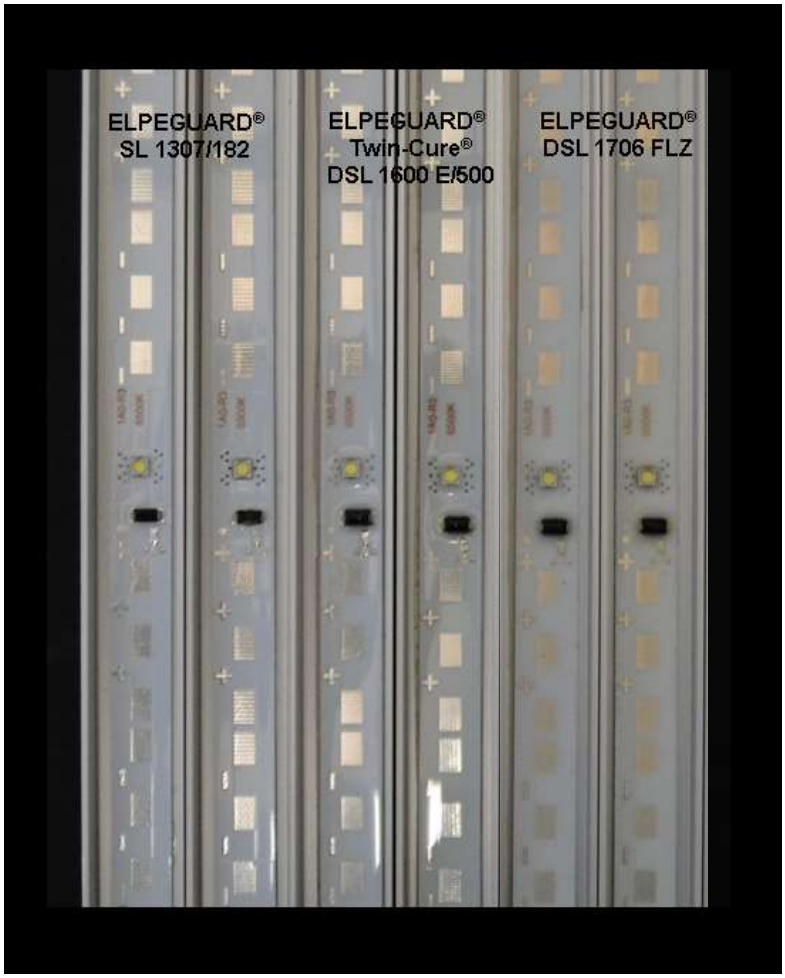

Figure 8: ELPEGUARD® conformal coatings after TCT

Figure 9: ELPECAST® casting compounds after TCT

Fields of application

Selection chart

Application \ Product name	Conformal coating **ELPEGUARD® SL 1800 FLZ (SL 1307/182)**	Thick film coating **ELPEGUARD® Twin-Cure® DSL 1600 E/500**	Silicone thick film coating **ELPEGUARD® DSL 1706 FLZ**	ELPECAST® casting compound **Wepuran VT 3402 KK-NV**	ELPECAST® casting compound **Wepesil VT 3602 KK**
Coating of LEDs, e.g. in display panels					
Coating of high power LEDs					
Use under high humidity and high temperatures					
Outdoor use					
Use under condensation					
Underwater use					
Flame class UL 94	V-0	V-0		HB*	
Temperature and yellowing resistance under thermal load					

* VT 3402 KK-NV-SV-HB

very good (very well suited)	good (well suited)	moderate (moderately suited)	not suited

Protective coating of LEDs / high power LEDs

With many types of assemblies, potting is not possible since there is no frame or housing, or the weight is important. In view of protecting an assembly against condensation, conformal coatings are a good alternative. In case of constant condensation with water, silicone thick film coatings ensure excellent protection. For the protection of LED panels to be mounted, for example, in display panels various products have proven themselves:

- ELPEGUARD® SL 1800 FLZ/& (SL 1307 FLZ/&)
- ELPEGUARD® Twin-Cure® DSL 1600 E/500
- ELPEGUARD® DSL 1706 FLZ

Encapsulation of high power LEDs

High electric power generates high temperatures when high power LEDs are applied. While conformal coatings are stable to yellowing over a large temperature range, there are certain limits for UR casting compounds when applied at high temperatures. Therefore it is recommended to use silicones if permanent temperature loads exceed 90 °C [194 °F].

- ELPECAST® Wepesil VT 3602 KK

Operation at high temperatures along with high humidity

Loading with high temperature (> 40 °C [104 °F]) and high humidity (R. H. >70 %) is considered to be a great challenge for the conformal coating.

By the process of hydrolysis, the polymer compound is split up in the presence of water. The typical effects of a hydrolytic polymer degradation include, besides discolouring of the coating layer, the softening of the film, tackiness, peel-offs, formation of bubbles or wrinkles and even a dissolution of the coating film. With progressive loading, discolouring is noticed which is due to the inevitable concurrent oxidation processes that are triggered by atmospheric oxygen.

UR systems are generally attacked in such cases. A simultaneous presence of organic solvents, acids or oils may be an additional load on the materials. For this reason, we do not recommended to use conformal coatings or casting compounds in saunas or steam baths.

Due to their chemical composition, hydrolysis is not enabled with silicone-based systems; thus silicone conformal coatings and casting compounds are stable to a great extent under such loads (high temperature along with high humidity).

- ELPECAST® Wepesil VT 3602 KK
- ELPEGUARD® DSL 1706 FLZ

Underwater applications

For a long-term operation of electronic components under water it is essential to provide a special protection; conformal coatings are no longer sufficient for this type of application. By choosing a casting compound, one can achieve sufficient protection for a permanent operation under water.

- ELPECAST® casting compounds of the series Wepuran VT 3402 KK
- ELPECAST® casting compound Wepesil VT 3602 KK
- ELPEGUARD® DSL 1706 FLZ

Processing instructions

Below you will find a short description of the methods that can be applied for processing conformal coatings and casting compounds, and of the equipment available.

There is a major difference between conformal coatings and casting compounds as to the layer thickness that is required or enabled for application. The thickness of conformal coatings films is distinctly limited by their drying and curing mechanism, while the thickness of casting compounds, from a theoretical point of view, is almost unlimited because of their crosslinking mechanism. The latter are usually solvent-free and independent of crosslinking partners such as atmospheric oxygen, humidity or UV light.

The technical data sheets below give a detailed description of what must be observed for processing:

AI	Application information AI 1/1 ”Processing instructions for ELPEGUARD® conformal coatings (thin film coatings)“
AI	Application information AI 1/2 ”Processing instructions for the ELPEGUARD® thick film coatings of the series Twin-Cure®“
AI	Application information AI 3/1 “Processing instructions for the casting compounds of the series Wepuran VT 3402 KK“
TI	Technical information TI 15/2 ”Selection criteria and processing instructions for casting compounds”
TI	Technical information TI 15/3 “Protective measures when using chemicals including lacquers, casting compounds, thinners, cleaning agents“
TI	Technical information TI 15/10 “Processing of 2-pack systems“
TI	Technical information TI 15/18 “Handling of silicones“

Processing of conformal coatings

Depending on the coating system, conformal coatings can be processed either by brushing, dip coating or spraying, e.g. by selective coating units. For this purpose, different viscosity adjustments are available. In general, an even and not too thick layer of 20-50 µm dry layer thickness on a plane surface should be strived at when processing conformal coatings. Thick film coatings (such as **ELPEGUARD® Twin-Cure® DSL 1600 E/500**) are generally solvent-free and can also be applied in high layers.

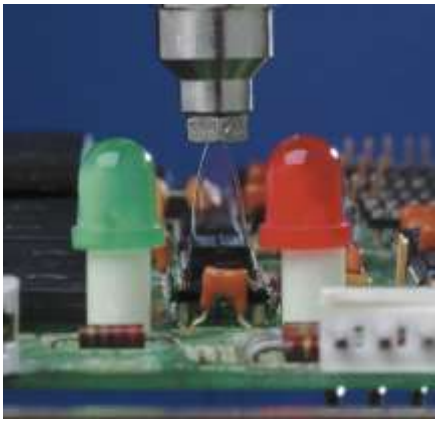

Figure 10: Selective coating
(Source: Nordson ASYMTEK)

Processing of casting compounds

2-pack casting compounds are processed in three steps:

- Preparation of the individual components
- Mixing (and evacuating) of the components
- Potting

In order to enhance the processing reliability, in particular when using casting compounds with short pot lives, we recommend to use automatic mixing and dosing equipment which makes you independent from the processing time (pot life). If the compound is processed manually, evacuation by means of an desiccator is indispensable once the components have been mixed. To achieve optimum final properties, casting compounds should be applied with a layer thickness of at least 2-3 mm on top of the LED. This will ensure, for example, a better protection in underwater applications.

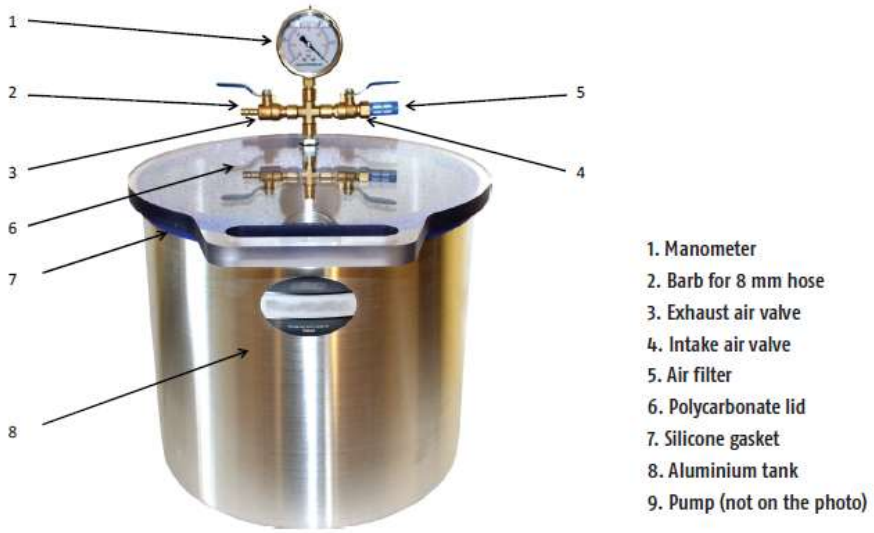

Figure 12: "Bubble-free" desiccator

Handling of silicone-containing conformal coatings and casting compounds

When using silicone-containing and silicone-free products simultaneously, defects such as dewettings may occur in the processing of the silicone-free products. For this reason, one must ensure that the workplace/work tools are kept separately, in order to avoid the contamination of these different systems, e.g. through contaminated work tools.

Economic efficiency analysis

Especially for conformal coatings, the resulting dry layer thickness is dependent on the application method that was chosen. In practise, dry layer thicknesses of 20-50 µm will result for the conformal coating **ELPEGUARD® SL 1307,** for example. On the other hand, one would pot the **ELPECAST®** casting compound **Wepuran VT 3402 KK-NV** based on layers of 2-3 mm, for example, in order to achieve the best possible final properties. In consequence, material consumption will be distinctly higher.

The table below gives an overview of the economic benefits and drawbacks for the coating materials presented.

Product name	Conformal coating **ELPEGUARD® SL 1800 FLZ (SL 1307/182)**	Thick film coating **ELPEGUARD® Twin-Cure® DSL 1600 E/500**	Silicone thick film coating **ELPEGUARD® DSL 1706 FLZ**	ELPECAST® Casting compound **Wepuran VT 3402 KK-NV**	ELPECAST® Casting compound **Wepesil VT 3602 KK**
Processing method	Automatic selective coating unit			2-K mixing and dosing equipment or evacuation necessary	
Typical layer thickness on LED	20-50 µm	100-200 µm		2-3 mm, theoretically unlimited	
Material consumption kg/m²					
Relative cost per m²	1	3	5	43	74
VOC content					
Process time when curing	1-2 h at RT	UV and moisture curing	45 min at RT (50% RH)	24 h at RT	24 h at RT

Very economical	economical	less economical

Example of how to calculate the theoretical consumption

Consumption of **ELPEGUARD® SL 1307 FLZ/182** per m^2 (dry layer thickness approx. 50 µm, equivalent to a wet layer thickness of approx. 200 µm):
0,02 cm * 10000 cm^2 = 200 cm^3
ρ = 1.00 g/cm^3
1.00 g/m^3 * 200 cm^3 = **200 g**

Consumption of **ELPEGUARD® DSL 1600 E/500** per m^2 (dry layer thickness approx. 200 µm):
0.02 cm * 10000 cm^2 = 200 cm^3
ρ = 1.06 g/cm^3
1.06 g/m^3 * 200 cm^3 = **212 g**

Consumption of **ELPECAST® Wepuran VT 3402 KK-NV** per m^2 (layer thickness of approx. 5 mm):
0.5 cm * 10000 cm^2 = 5000 cm^3
ρ = 1.09 g/cm^3
1.09 g/m^3 * 5000 cm^3 = **5450 g**

Conclusion

The calculations above show that the actual consumption of certain products varies distinctly when the typical dry layer thickness is observed.

Besides the pure material consumption, the acquisition cost of the equipment (coating-drying-curing) should be considered in an economic efficiency analysis. Depending on the manufacturer and the application method, these costs may vary considerably.

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