Preventing LED Failures Caused by Corrosive Materials & Chemical Contamination

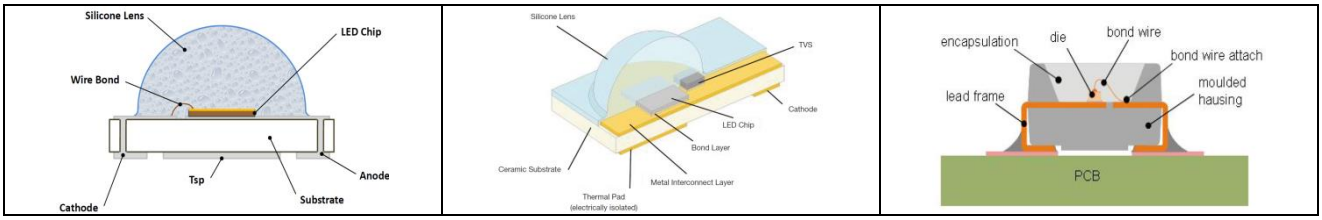
Introduction

Industry leading producers of LEDs including high power LEDs, monitor the return of parts deemed to have failed (or exhibit reduced performance) in operation. Common failure modes include; Thermal overstress, electrical overstress and inhibited performance or failure due to an influence of an external Chemical.

This paper is intended to provide some level of guidance when considering the influence of chemicals and other compounds used in the assembly and construction of LED based lamp luminaire or system.

Construction of LEDs

LEDs are often constructed using a clear encapsulant either as a means of protecting the light emitting die or as a primary lens. Figures 1, shows different construction.



Courtesy of Cree *Courtesy of Philips Lumileds* *Courtesy of Osram*

Fig 1

The most common encapsulant used is based around a silicone compound.

LEDs in a System Environment

Depending on the application LEDs may be mounted together with mechanical, electrical, optical and thermal conductive components in a system housing to protect against the outside environmental conditions and to create the specified function. In some cases and to achieve an ingress protection rating (IPxx), or other forms of protection, an LED may well be enclosed in an air tight environment.

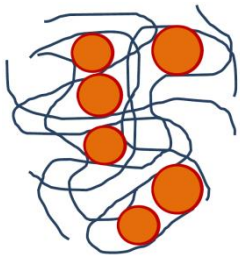
Contamination

Silicone encapsulants may be made using a Si-O-Si-O-Si-O chain (SiO)n as the basic structure. The silicone used in a number of LED domes is highly gas permeable. Oxygen and volatile organic compound (VOC) gas molecules can diffuse into the dome.

Some VOCs and chemicals may react with the silicone dome of LEDs to produce discoloration and surface damage which may affect the total light output. Some VOCs may not chemically react with silicone material directly but may diffuse into the silicone and oxidize during the presence of heat or light. It is important to note that the level of silicone permeability increases with temperature so at

higher temperature more VOCs may diffuse into the silicone and/or evaporate out from the silicone.

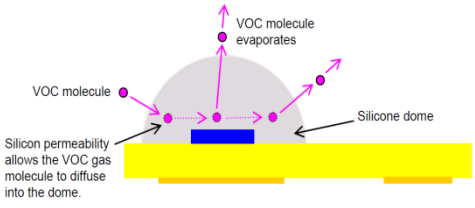
Consideration needs to be given to whether LEDs are enclosed in an “air tight” environment or not. For example, in an “air tight” environment, some VOCs introduced may permeate and remain in the silicone dome. Under heat and “blue” light, the VOCs inside the dome may partially be oxidized and create a silicone discoloration particularly on the surface of the LED where the flux energy is the highest.

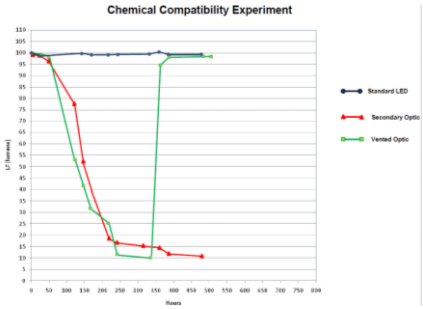


Courtesy of Cree

Fig 2

The volatile hydrocarbons occupy free spaces within the silicone chains (Fig 2.). The resulting effect is discolouration (turning brown) and reduced light emitted from the LED





Courtesy of Philips Lumileds

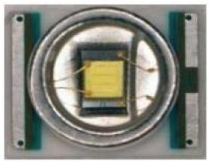
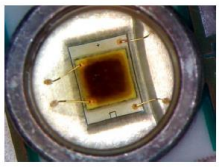
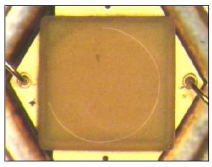
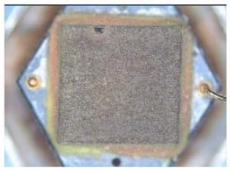
Courtesy of Cree

Fig 3

In the air rich or “open” air environment the VOC has a chance to leave the area (driven by the normal air flow). Transferring the devices which were discoloured in the enclosed environment back to “open” air may further oxidize the contamination and may restore the original optical properties of the LED dome.

An additional source of contamination includes Sulphur (Sulfur) compounds such as Hydrogen Sulphide (H2S). It has been reported that H2S can evaporate especially from rubber-like materials, such as O rings and gaskets (Elastomers vulcanized with sulfur). To further clarify Sulphur contamination is mainly of concern with silicone encapsulated LEDs that have silver coated lead frames.

Examples of Chemical contamination

Good **Bad** **Good** **Bad**

Courtesy of Cree *Courtesy of Philips Lumileds*

Fig 4

Potential Sources of Contamination

There are materials (glues, conformal coatings, etc) used in the construction of luminaires that emit volatile hydrocarbons and other volatile substances.

Among the materials to use with caution include:

- Conformal coatings
- Adhesives
- Gaskets and o-rings
- Solder fluxes

Chemicals that should be avoided as they may directly react with the silicone material:

Chemical Name	Normal use
Hydrochloric acid	Acid
Sulphuric acid	Acid
Nitric acid	Acid
Acetic acid	Acid
Sodium hydroxide	Alkali
Potassium hydroxide	Alkali
Ammonia	Alkali
MEK (Methyl Ethly Ketone)	Solvent
MIBK (Methyl Isobutyl Ketone)	Solvent
Toluene	Solvent
Xylene	Solvent
Benzene	Solvent
Gasoline	Solvent
Mineral splits	Solvent
Dichloromethane	Solvent
Tetracholorometane	Solvent
Castor oil	Oil
Lard	Oil
Linseed oil	Oil
Petroleum	Oil
Silicone oil	Oil
Halogenated hydrocarbons (containing F, Cl, Br elements)	Misc
Rosin flux	Solder flux

In testing, one manufacturer has found the following chemical to be harmful. The recommendation is not using these chemicals anywhere in an LED system. The fumes from even small amounts of these chemicals may damage the LEDs.

Chemicals that might outgas aromatic hydrocarbons (e.g., toluene, benzene, xylene)
Methyl acetate or ethyl acetate (i.e., nail polish remover)
Cyanoacrylates (i.e., “Superglue”)
Glycol ethers (including Radio Shack® Precision Electronics Cleaner - dipropylene glycol monomethyl ether)
Formaldehyde or butadiene (including Ashland PLIOBOND® adhesive)
Dymax 984-LVUF conformal coating
Loctite Sumo Glue
Gorilla Glue
Clorox bleach
Clorox Clean-Up Cleaner spray
Loctite 384 adhesive
Loctite 7387 activator
Loctite 242 thread locker

Note: these lists are not exhaustive and manufacturers should be consulted for the latest information.

Conclusion & Summary

Volatile hydrocarbons and other volatile substances can outgas from some materials. These volatiles will diffuse through the silicone encapsulant used in LED construction and cause discoloration.

Care in the selection of materials must be taken when designing and building LED based products including luminaires. A luminaire that includes consideration of these points during design should experience no problems due to chemical contamination throughout life.

Additionally if encapsulation of the LEDs is necessary, the producer may wish to allow enough ventilation/out-gassing time before sealing the fixture.

The designer and producer should consult their LED supplier and seek guidance on the known contaminants and as importantly, fully qualify all materials used, prior to placing their product on the market.

Even when using the best LED’s available in the world, the use of incompatible materials can cause unexpected and severe issues.

Luminaire producers should qualify compounds and components. Providing a “safe list” is problematic.

Credits

Philips Lumileds Lighting, Cree Inc., Osram Opto Semiconductors