

Preventing LED Failures caused by corrosive Materials

Application Note

Introduction

Nowadays LED components are used in a wide variety of application areas and are therefore exposed to a crossfire of influences and environmental conditions. In the automotive industry for example LEDs in lighting systems are exposed to extreme conditions such as vibration, variations in temperature, humidity and others.

In order to evaluate possible consequences, LEDs were examined regarding standard and user-specific criteria and operating conditions.

LEDs from OSRAM Opto Semiconductors are exposed to gases according to the EN 60068-2-60 Method 4 test (e.g. @ 25°C & 75%rH, 200ppb SO₂, 200ppb NO₂, 10ppb H₂S, 10ppb Cl₂, 21days). Following this test-cycles, the LEDs do not show any damage or degradation.

This brief application note will point at some extreme conditions which could influence the lifetime of LED components.

Design of SMT LEDs

Most surface mounted technology (SMT) LEDs consist of a leadframe with a molded housing. A die is glued or soldered to the leadframe to create one contact of the LED. The die is electrically connected to the second contact pin of the LED's leadframe with a bond wire.

Finally the LED is casted with a transparent encapsulation to protect the die and wire bond.

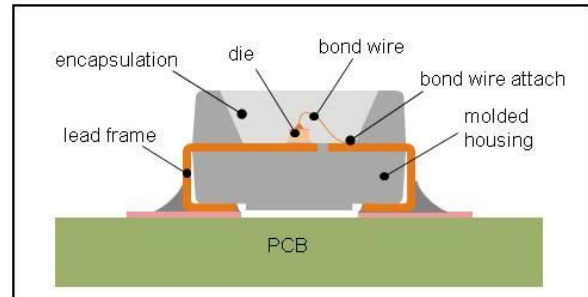


Figure 1: Typical structure of a SMT LED package

Figure 1 shows the basic structure of a SMT LED package mounted on a PCB.

Silicones are frequently used for the transparent encapsulation. Silicones possess a high optical transparency, favorable mechanical properties and superior thermal and radiation stability. For example, the maximum operating temperature can be extended to more than +125 °C.

Special care has to be taken because silicone is permeable for gases. Gases can vary from being harmless to highly aggressive.

LED in a System Environment

In general, the LED is mounted together with mechanical, electrical, optical and thermal conductive components in a system housing required to protect the array against outside environmental conditions and to allow the specified function.

The LED is part of this system and can now be exposed to new differing environmental conditions compared to its original qualification. Due to the proximity of various components and materials in such a system, those environmental conditions are mainly originating from the system itself and may vice versa affect the function and reliability

of single components of the system, including the LED.

Especially at higher temperatures aggressive substances from materials like foam pads, rubber sealing, anti vibration pads, or thermal conductive pads but also others can evaporate.

These substances may not only get into contact with the surface of the LED but can also diffuse through the silicone encapsulation and could finally contaminate the die, bond wire and leadframe.

However the critical materials are not only confined to a final system. As it has been confirmed such kind of materials can also be found in machines' or stopovers of the production line. In this case a damage of the LED components can be observed already prior to the real system setup.

Example Sulfur Contamination

Even though any harmful substances should be avoided in proximity of electronic components in general, in the recent past some customers experienced corrosion issues. These were always linked to a very high concentration of sulfur in proximity to the LEDs. Although the design and reliability of the system rests with the system manufacturer, this chapter is intended to gather the experiences reported by various sources to support the design of corrosion free systems:



Figure 2: Picture of a SMT LED with silicone resin

It has been reported that e. g. H_2S can evaporate especially from rubber-like materials, if no special focus is put on low sulfur content or low evaporation properties of these materials.

These sulfur compounds can corrode for example the silver plating of the leadframe which finally may result in destruction of the electrical contact between leadframe and wire bond or die bond.

Figure 2 shows an original finished LED product just after the manufacturing process. The shining surface of the leadframe can be seen.

In comparison, Figure 3 shows a LED which was mounted in a H_2S containing system. This LED was exposed to a micro climate containing sulfur compounds.



Figure 3: View of a SMT LED with blackish leadframe pads

The permanent presence of such micro climate causes a diffusion of the sulfur-containing gases through the silicone and a reaction with the leadframe plating. The plating turns black due to formation of silver sulfide, which can easily be noticed by visual inspection.

In general heat, humidity and light among others are able to accelerate such a corrosive process. However, if the H_2S concentration is very high (f.i. due to a high evaporation rate and restricted volume of the containing system), the main influence factors can be limited to concentration level and temperature.

Such high concentrations can result in growing corrosion, in the case shown in Figure 4 the surface is homogenously discolored.

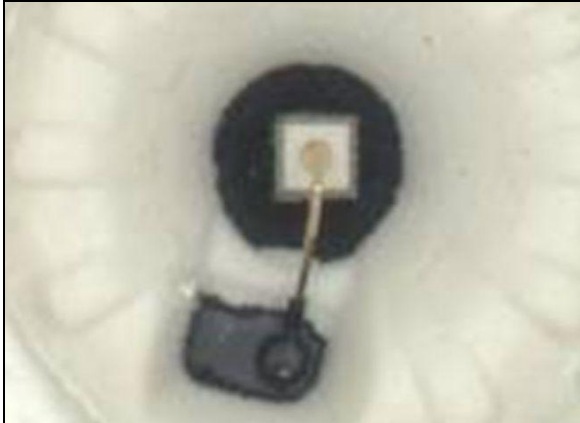


Figure 4: Detailed view on LED with corroded leadframe surface

Since our LEDs withstand the corrosive gas test according to EN 60068-2-60 method 4 with 10ppb (parts per billion) H₂S without any damage or visual change, it leads to the conclusion that the concentrations leading to corrosion inside the LED must be magnitudes higher.

In fact, studies show that corrosion becomes visible at concentrations greater 100ppb.

Based on experiments, it can be concluded that the concentration present if contaminated rubber is used can be significantly more than 10ppm (parts per million).

The verification via SEM and EDX analysis illustrates the effect of the corrosion. As can be seen in Figure 5 the sulfur-containing compound reacts with the leadframe surface to form silver sulfide. In extreme cases the corrosion can damage the connection between the wire and the leadframe and can

result in a lifted wire - respectively open contact.

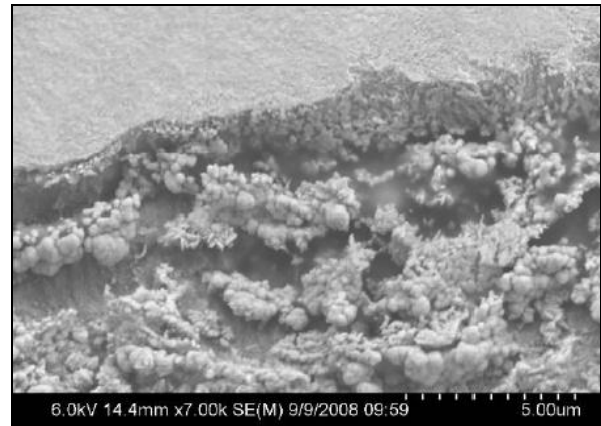


Figure 5: SEM picture of the corroded Ag-surface (silver sulfide)

Solutions

1) The first and most obvious solution to avoid corrosion of electronic components (such as LED) is to avoid corrosive or harmful atmosphere in the vicinity of the components.

Not only the silver leadframe of LEDs can be affected, also any copper, even coated e.g. with a NiAu layer, on printed circuit boards could be affected for example.

Figure 6 shows a detail of an IMS-PCB which was exposed to a corrosive sulfur atmosphere. During the test (1500h @15ppm H₂S) the red highlighted area of the surface was covered with an adhesive tape. As can be seen the unprotected contacts especially the Cu layer are affected by the sulfur (layer construction 35µm Cu, 6µm Ni, 0.1µm Au).

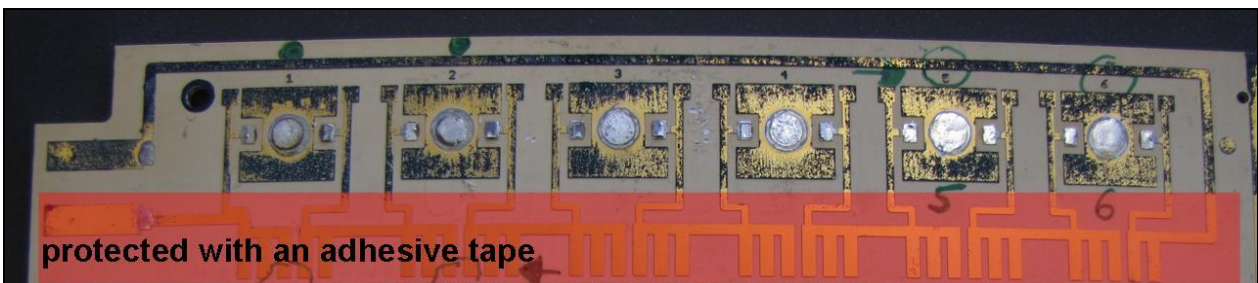


Figure 6: Example of an IMS PCB with corroded Cu material

In case of rubber, peroxide cross-linked materials are available on the market as alternative to sulfur cross-linked versions.

If materials evaporating corrosive substances can not be avoided in vicinity of the LEDs, OSRAM Opto Semiconductors offers solutions with robustness improved LEDs.

2) If the silicone properties - stability against temperatures $>125^{\circ}\text{C}$ and high stability against radiation of short wavelength light - are not required, epoxy casted LEDs can be used.

Epoxy is not permeable for gases such as H_2S and therefore provides protection of the LED. Epoxy casted LEDs are also fully automotive qualified (AEC-Q101), are even in use longer than silicone casted LEDs and thus a useful alternative in many cases.

3) For applications in which the specific silicone properties are essential OSRAM Opto Semiconductors offers a variety of silicone casted LEDs with the leadframe plated with gold instead of silver. The gold plating is more stable against corrosion by H_2S .

However, it must be pointed out, that any electronic device including LEDs with high corrosion stability may be destroyed by long-term influence of H_2S at high concentration levels.

The information which specific LED product shows improved corrosion properties can be found in the corresponding datasheet. LEDs with increased stability contain the reference "Improved corrosion robustness" or "Superior corrosion robustness".

Conclusion

Using a LED with silicone encapsulation and silver plated leadframe requires a careful analysis of all materials used in the application or in the vicinity of the application for any harmful, gaseous and corrosive materials or substances.

Please ensure that gaseous or corrosive materials or substances are not used in assembly and applications.

The following list shows some examples which in some cases may be the source of corrosive substances, especially H_2S :

Actual cases known:

- Elastomers vulcanized with sulfur

Other theoretical sources:

- contaminated PCB material
- solder resist
- stop-off lacquer
- paper and paperboards
- an industrial environment with high sulfur or sulfide concentration

OSRAM Opto Semiconductors highly recommends using sulfur free materials in proximity of electronic components, including LEDs.

In order to avoid evaporation from rubber seals, for example peroxide cross-linked elastomers could be applied instead of the sulfur cross-linked types.

On LED level, as shown in this Application Note, OSRAM Opto Semiconductors is offering products with improved robustness for corrosive environments. The relevant information can be found in the datasheet of the LED product.

However, even robustness improved LEDs may suffer corrosion if exposed to extreme conditions.

For further information and support please contact OSRAM Opto Semiconductors.

Authors: Norbert Häfner, Michael Brandl, Andreas Stich

ABOUT OSRAM OPTO SEMICONDUCTORS

OSRAM, Munich, Germany is one of the two leading light manufacturers in the world. Its subsidiary, OSRAM Opto Semiconductors GmbH in Regensburg (Germany), offers its customers solutions based on semiconductor technology for lighting, sensor and visualization applications. Osram Opto Semiconductors has production sites in Regensburg (Germany), Penang (Malaysia) and Wuxi (China). Its headquarters for North America is in Sunnyvale (USA), and for Asia in Hong Kong. Osram Opto Semiconductors also has sales offices throughout the world. For more information go to www.osram-os.com.

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