Application Note

Guides on
Chemical Compatibility

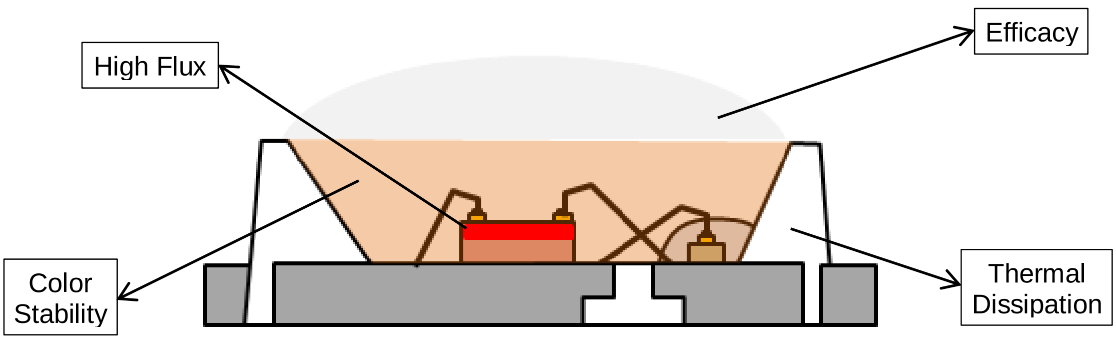
SAMSUNG

1. Introduction

Lightings are exposed to various atmospheric conditions that may affect expected product lifetime. Lighting fixtures therefore have to be carefully designed to avoid contamination by unwanted pollutants. While some form of encapsulation, such as silicone coating or lens is present in LED packages for physical protection, an LED luminaire is still susceptible to penetration of gaseous components from the surroundings (humidity, inorganic oil vapors, toxic gases, etc.). Corrosion, oxidation and VOC contamination are some examples of chemical interactions that can occur between these penetrated gas elements and the material assembled on the complete LED fixture. Common types of failure modes that accompany these chemical interactions include reduced luminous flux, decrease in intensity of lighting and degradation of color stability.

This application note outlines the failure mechanisms associated with chemical contamination, presents case study based on field failures and provides basic guidance on chemical compatibility test for Samsung LED products.

2. Overview of LED Structure



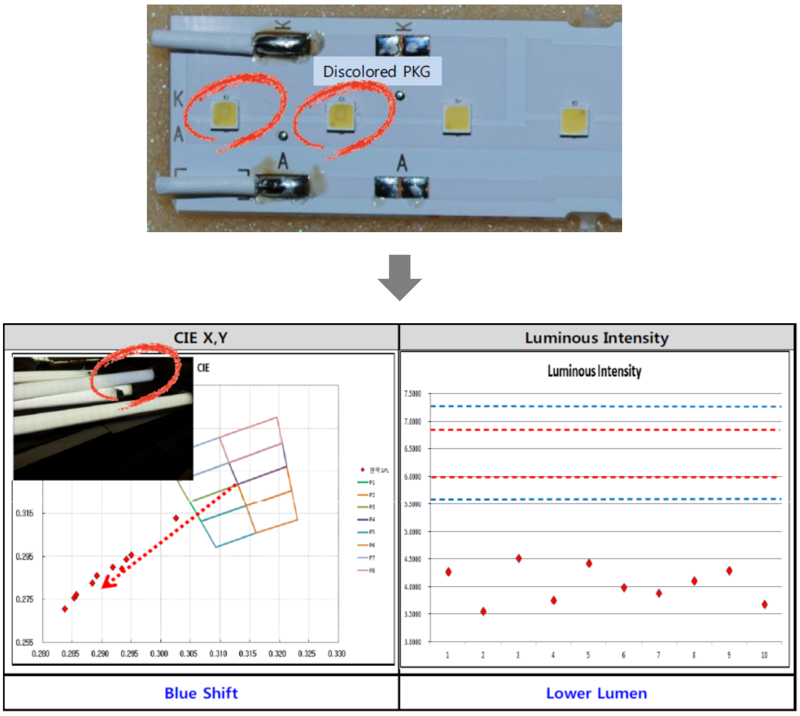
An LED package is primarily composed of chip, phosphor, lead frame and encapsulation. Chip – also referred to as die – emits light; yellow phosphor covers the LED chip, convert blue light into white light. The lead frame is present to support package structure, to provide thermal dissipation, and to promote light output efficacy. Silicone encapsulation provides mechanical protection, with its elasticity and absorption of thermal stress.

Table below outlines the possible sources of contaminants that may lead to discoloration of different components within LED structure.

Discoloration	Possible Sources · Mechanisms
Silicone encapsulant	Volatile Organic Compounds (VOCs) / Carbonization
Ag lead frame	Sulfurization / Flux residue / Process solvents / Organic additives
Pre-mold	Pre-mold fume / Organic additives
Die adhesive, lens	VOCs / Carbonization

3. Chemical Failure Mechanisms

Exposure to inappropriate chemicals during module/fixture assembly, delivery process, and in the field environment, may lead to reactions that cause discoloration failures and could further result in the degradation of luminous flux, shifts in chromaticity (CCx and CCy) and drift in the correlated color temperature (CCT).

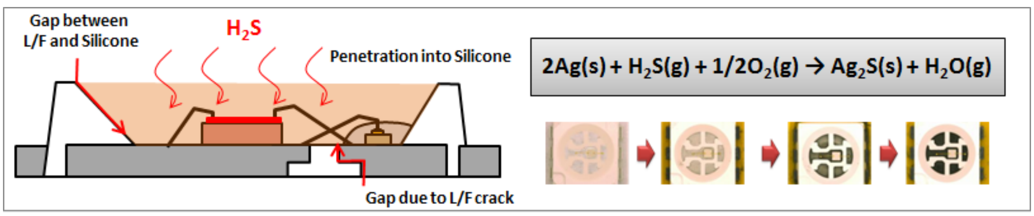


- Corrosion (Sulfurization)

1) Generation: potential contamination sources emit reactive sulfur gas or sulfuric compounds into the atmosphere (*potential sources: corrugated box, vulcanized rubber stoppers in testing chambers, PC materials, organic rubber components in fixtures, solder cream, etc.*)

2) Migration: sulfur elements penetrate into the LED packages through the silicone encapsulant itself, or via the interface between silicone and the lead frame

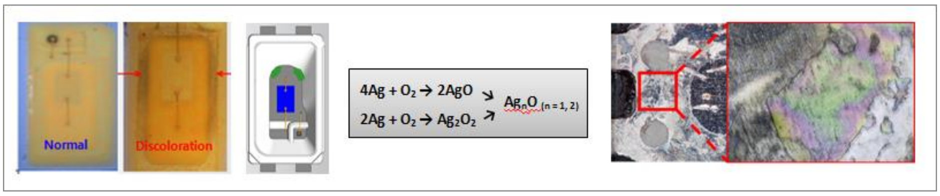
3) Chemical Reaction: penetrated H_2S gas comes into contact with the Ag layer and forms a non-electro-conductive silver sulfide (Ag_2S)
→ Side effects of the new **Ag_2S** compound are degradation of luminous flux, color shift and color change of Ag layers



- Oxidation: oxidation of Ag lead frame when exposed to moisture, reflector fume and flux at high temperature and humidity

  1) Oxygen gas present in ambient moisture or flux penetrate into the LEDs through the interface between L/F and mold

  2) Oxidized Ag (Ag_nO) on the lead frame surface moves to Silicone encapsulant → discoloration at the interface and L/F

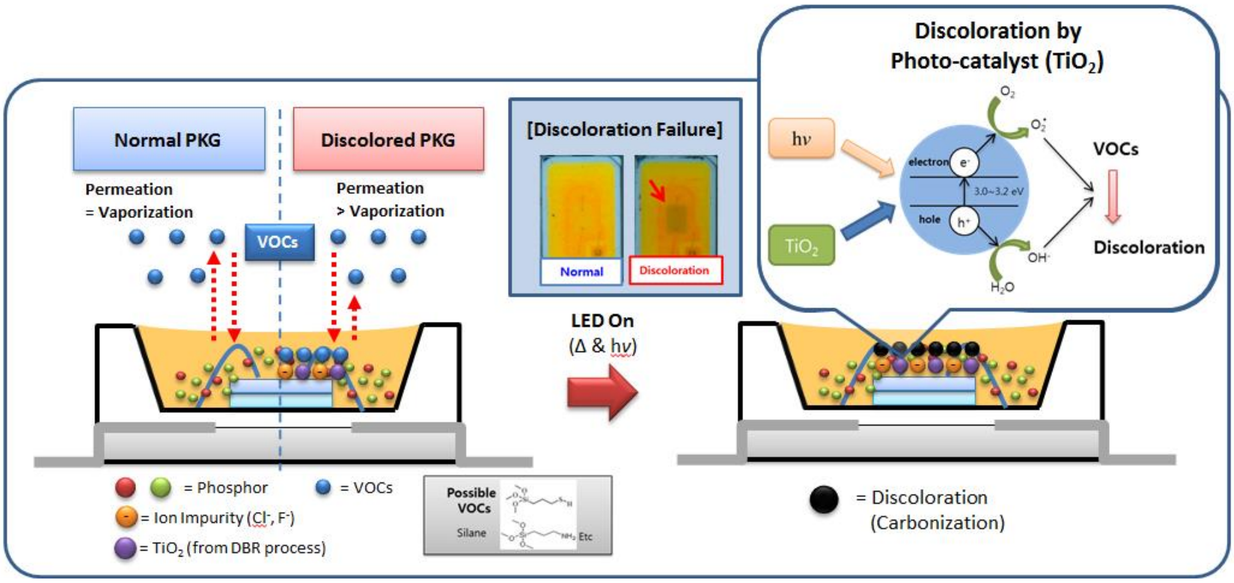


- VOC contamination

  1) Low-molecular (hydroxyl-/benzene-/vinyl-/stearate-/amide-) VOCs are present in the ambient surroundings

  2) VOCs penetrate into the LEDs and occupy the free spaces within the siloxane chain

  3) VOCs react when exposed to heat and photonic energy and results in LED discoloration that lead to flux degradation and chromaticity shift



4. Design Suggestions

All organic materials are potential sources of gaseous chemicals. Therefore careful selections of materials for components such as resin, silicone, interface bonding material, solder cream, etc. is crucial in designing LED lighting structures to avoid unwanted chemical reactions taking place within LED products. In addition, heat and humidity – levels of which are determined by the field environment and the operating conditions – are critical factors that influence the rate of reaction. Hence, LED lighting should be designed in ways that minimize the chances of outgassing and limits the accumulation of the outgassed chemicals.

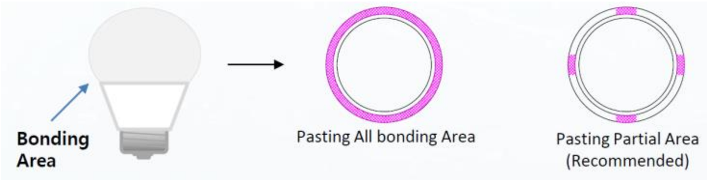
➢ Factors that affect reaction rate in LED products

1) Operating current: higher input current leads to elevated current density, which then causes temperature rise of the LED chip.
2) Ts temperature: most organic materials vaporize even at very low temperatures.
3) Thermal dissipation: when every part of the fixture is well-fitted during the assembly process, thermal conduction is high. (VOCs penetrate into LED packages through gas-permeable encapsulant, which also means they may move out of the LED when there is enough space for diffusion. If the lighting fixture is not so tightly sealed, it allows VOCs to freely ventilate out to the atmosphere.)

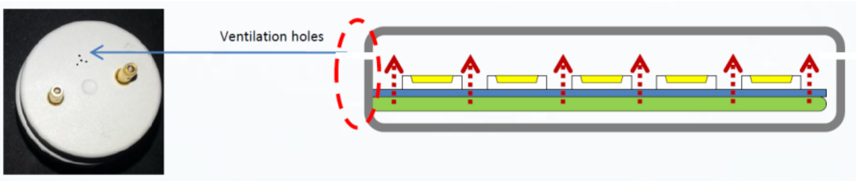
Based on these factors, lighting fixtures built with the following considerations: **appropriate operation current**, **low Ts temperature**, imperfect sealing to promote **high thermal dissipation**; are less likely to face chemical contamination failures.

➢ Design Suggestion Examples

- Adhesives for bulb cover
  Adhesives applied in parts that satisfy sufficient bonding force, is recommended when bonding the cover onto the bulb, rather than applying them on the entire connection area. Extremely tight sealing of the adhesives on the entire area increases the likelihood of VOC trapping inside the light bulb.



- Ventilation holes
  Presence of ventilation holes in lighting fixtures allows circulation of air, thereby allowing the reduction of temperature and thus decreasing the VOCs density within the set.



5. VOCs Compatibility Test

To prevent chemical interference with LED performance, Samsung recommends a preliminary compatibility test on Samsung LED boards to simulate potential outgassing effects of the chemical materials planned for use with the LEDs.

Suggested Testing Procedures:

Step 1: Prepare the chemical compounds that will be used with the LEDs.

Step 2: Paint the chemical materials on top of, and around the LEDs.

Step 3: Apply adhesives on the bottom of glass vial; place it on top of the LED. Keep an airtight environment to observe accelerated effects of the chemicals.

Step 4: When the vial is completely sealed to cover the LED and an airtight environment is created, turn the LEDs on with a constant supply of the representative driving current.

Step 5: Carry out the test for more than 1,000 hours (≈ 6 weeks), monitoring and taking notes on the changes observed in the visual appearance, in regular intervals.

For the test, tight sealing of the cover glass onto the PCB is recommended for the observation of accelerated effects of chemical materials. After aging at different operating conditions (ex. Temperature, operating current and testing periods), carry out visual inspection and measure the luminous flux to see if the applied chemicals have a potential contamination effect.