CHEMICAL GUIDE OF LED COMPONENT

Lighting Marketing Team
SAMSUNG Electronics LED Business

SAMSUNG ELECTRONICS
LED Business

Index

1.1 Sulfurization, Chloridization (or Tarnishing) in LED

1.1.1 Mechanism

In case of manufacturing LED lighting, it is important to check a chemical compatibility with applied materials or environment.

Therefore, Samsung products have a possibility of chemical compatibility to materials of components. Particularly, discoloration by sulfur, chloride and their compound should come from Ag coated lead-frame part.

So, we would like to give an explanation about specific causes and penetration route of that phenomenon below table 1.

Discoloration Example	The Material of Cause	Primary Source	Penetration Route
Ag_2S	Sulfur & sulfur compound	Organic Rubber, Corrugated Paper, Solder Cream	① Penetrate the Encapsulant (Silicone) itself ② Interface between Lead-frame and Reflector
AgCl	Chloride & chloride compound	FR1(PCB), NH_4Cl	

Table 1. Type & Cause of Ag Coated Lead-frame Discoloration

Discoloration by penetration of sulfur or chloride into LED can be explained by Figure 1.

It indicates two kinds of main penetration routes mentioned in table 1.

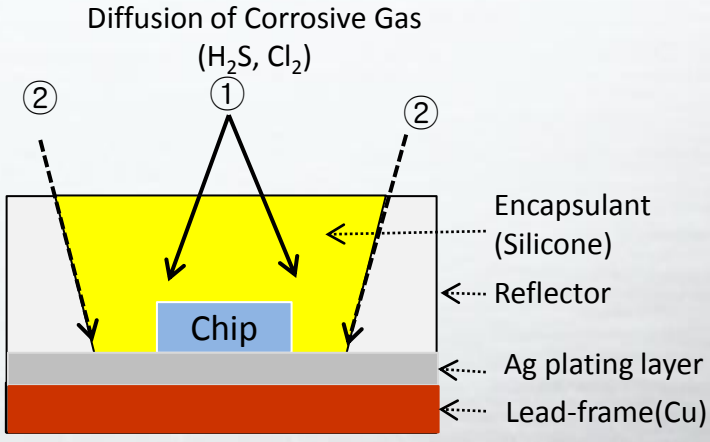


Fig 1. Penetration Route

1.1 Sulfurization, Chloridization (or Tarnishing) in LED

1.1.1 Mechanism

As mentioned previously, when compounds like Ag_2S and AgCl are made by sulfulrization or chloridization, the area around chip will turn into black color. You can see examples in Fig. 2

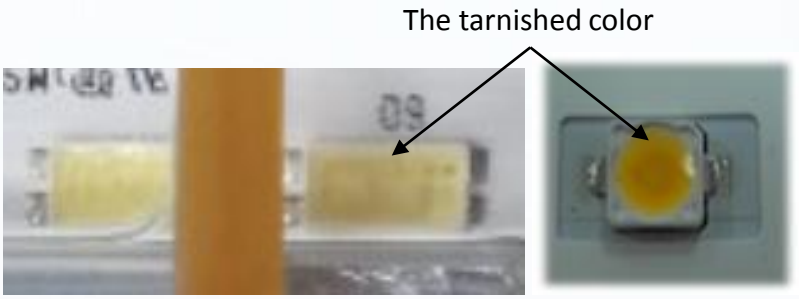


Fig 2. Appearance of discoloration in LED PKGs

In these cases, LED component or LED lightings can result in the unexpected properties as like below

- Degradation of luminance or luminous flux
- Color shift (change of CCx, CCy and CCT)

1.1 Sulfurization, Chloridization (or Tarnishing) in LED

1.1.2 Case study

The Improper handling of LED component by user can generate discoloration phenomenon associated with sulfurization or chloridization (tarnishing). In this application note, we try to help our customers to avoiding unnecessary trial and error by suggesting some guidance.

First, if an organic rubber including sulfur is used for the storage of LED component, it can give in the discoloration of LED component.

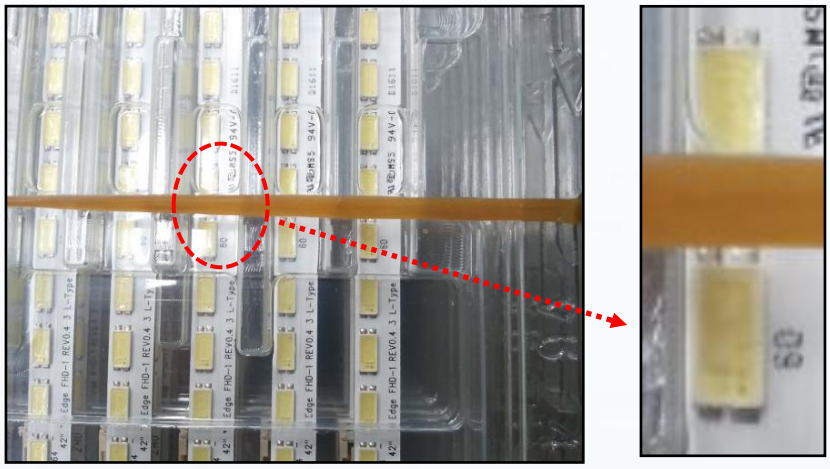


Fig 3. Discoloration of LED lead frame by Organic Rubber

For second case, it needs very attention in the storage of a LED pkgs or their component. If LED pkgs and lighting products are stored in or on corrugated paper, It can make the lead frame of LED pkgs discolored.

Fig 4. Discoloration by corrugated paper

1.1 Sulfurization, Chloridization (or Tarnishing) in LED

1.1.2 Case study

Users' working place and testing environment can also be a important factor to sulfurization or chloridization(tarnishing). Like pictures below, the unclean testing chamber or working place with wet floor can give chances of discoloring LED component.

Unclean testing chamber

Working place with wet floor

Fig 5. The examples of potential origin of contaminant in the working places

1.1 Sulfurization, Chloridization (or Tarnishing) in LED

1.1.3 Guide (for storage)

We would like to provide a guidance about storage method of LED lighting products after SMT process for users. Please refer to the following pictures and explanations.

Fig 6. Recommended storage method

1. Use the PP or PET Tray(Corrugated Paper Tray Is Not Allowed)
2. Insert the Silica Gel into Tray
3. Block contamination of Sulfur from the Outside(Use the Anti-static Vinyl)

As shown in table 2, we would like to introduce the best and alterative storage methods. Especially for outbox material, we highly recommend PP as an outbox. But If users have to take corrugated paper box as an outbox, the contents of sulfur must be less than 850ppm.

Name	Best	Alternative
Tray	PP (Polypropylene)	PET (Polyethylene terephthalate)
Envelope (bag)	Aluminum bag (for Moisture Barrier Bag)	PE (Polyethylene)
Out Box	PP (Polypropylene)	Corrugated paper box (Sulfur Less than 850ppm)

Table 2. Recommended materials for storage

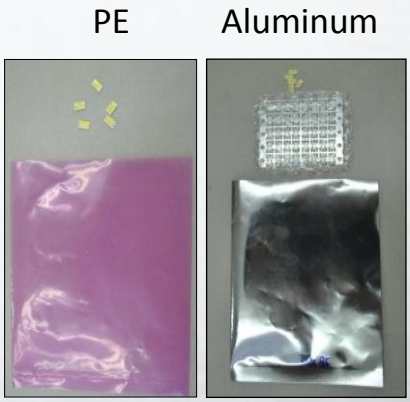


Fig 7. Envelope (Bag)

1.1 Sulfurization, Chloridization (or Tarnishing) in LED

1.1.3 Guide (for selection of PCB materials)

For manufacturing LED lighting, the chemical stability of various PCB materials was evaluated at an elevated temperature of 280℃. Because the variation of mass in PCB shows the chemical reaction of PCB material at an elevated temperature.

The large mass loss of PCB indicates the weak chemical stability at an elevated temperature. FR1 is not suitable for LED lighting because the reduction ratio of mass is higher(up to 25%) than CEM1 and FR4 at a high temperature as shown in table 3. The lost material was turn out to be the high contents of Cl from IC analysis.

According to EDX analysis of FR1, Cl was also included more than 30,000ppm.

Test / Condition		CEM1	FR4	FR1
TGA (Thermo-gravimetric Analysis)	The Mass Reduction from Initial State (Room Temp. ~ 280℃)	4%	< 1%	25%
IC (Ion Chromatography)	The Cl Quantity Has Eluted by Water (Unit : mg/PCB)	-	-	69.4
Conclusion	- CEM1 & FR4 PCB : Thermo-stability is Good. - FR1 PCB : Weight Loss → Plenty of Gas and Cl is Detected → Not Suitable for LED Component			

Table 3. The Effect of Chloridization with PCB Materials

1.2 Discoloration by VOCs in LED

1.2.1 Phenomenon

Volatile organic chemicals(VOCs) can make the fast degradation of luminous flux in LED lightings.

This phenomena should locally occur in physically closed system, which means space without air movement. The operation of LED should lead to elevate temperature in close system. In two conditions, the volatile organic chemicals can vaporize and diffuse in the system.

This diffusion of VOCs can affect normal operation in LEDs. The bulbs in below figure 8 show the discoloration of LED in bulbs and the inner surface of itself.

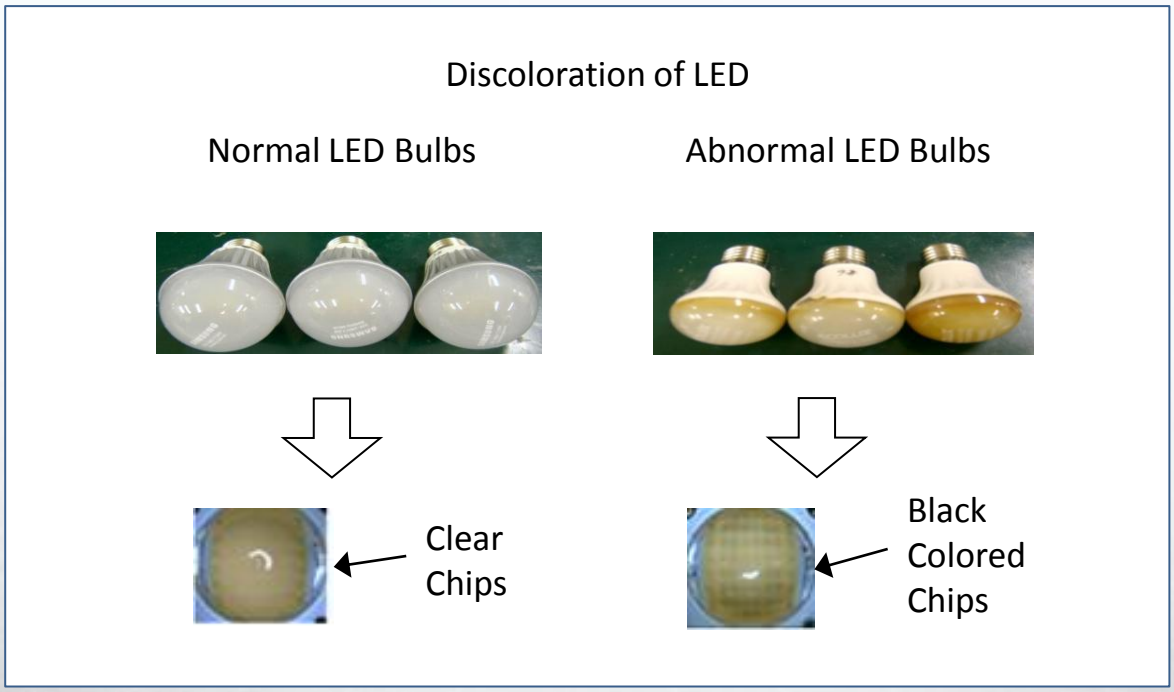


Fig 8. Discolored Bulbs and LED by VOCs

1.2 Discoloration by VOCs in LED

1.2.2 Cause

VOCs have a adverse effect on LED component by conditions and process as follows.

1. Generation of VOCs

VOCs(volatile organic compounds) possibly can generate from the silicone encapsulant itself and other materials, such as glue(sealing material), conformal coating, O-ring and potting materials.

2. Enveloped in Closed system (Sealed system without air movement)

In any sealed system, the vapor of VOCs can diffuse in entire closed system.

3. Diffusion of VOCs

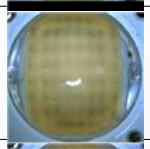
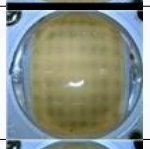
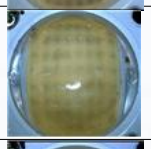
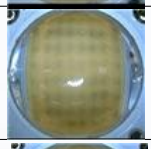
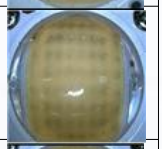
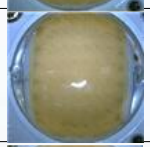
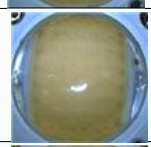
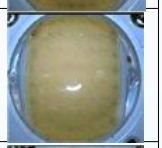
VOCs can diffuse into the silicone encapsulant of LED, which should result from the weak binding force between molecules. And the free space within silicone is helpful to the diffusion of VOCs. The weak binding energy and the free space is related with cured silicone. This means the more gas-permeable state. The black color just on the surface of LED chip is where the highest temperature.

1.2 Discoloration by VOCs in LED

1.2.3 Reversibility

In case of discoloration by VOCs, LED can be recovered by change in environment to open system(It is called reversibility). The discoloration in LED can disappear during the normal operation in ambient atmosphere(below table). It seems that VOCs can outgas from the inside of encapsulant. The reversible reaction should demonstrate that VOCs could not chemically react with any parts in LED.

You can see a recovery of LED components when operated removing cover for a week.

	SPL1#	SPL2#	SPL3#	SPL4#	SPL5#
0h					
24h					
48h					
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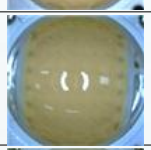
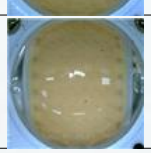
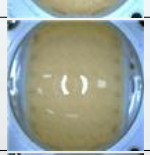
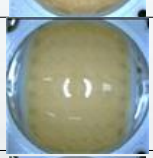
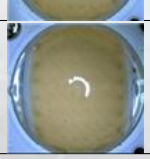
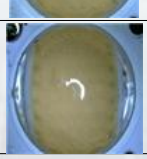
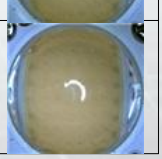
96h					
120h					
144h					
168h					

Table 4. Recovery of Appearance in Discolored LED

1.2 Discoloration by VOCs in LED

1.2.4 Guide

Minimizing factor of contamination is important. Discoloration phenomenon is mainly generated by gas from surrounding materials. Especially epoxy used as adhesive(sealing) material easily make LED component discolored than silicone material. Fig 9 means epoxy is easily transformed than silicone and Fig 10 shows discoloration when epoxy adhesive is used at bulb application.

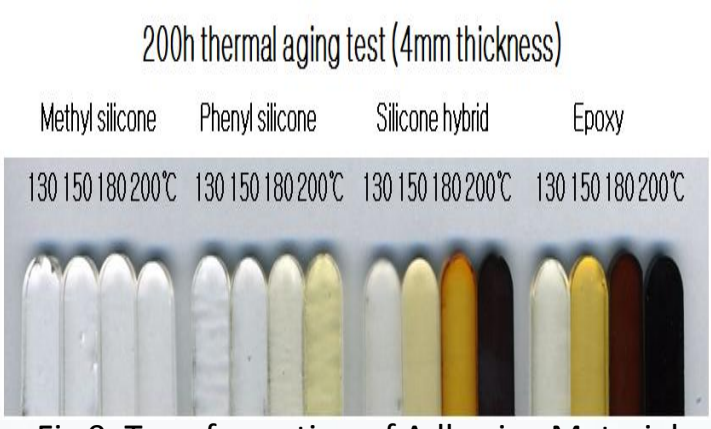


Fig 9. Transformation of Adhesive Materials in Accordance with Temperature

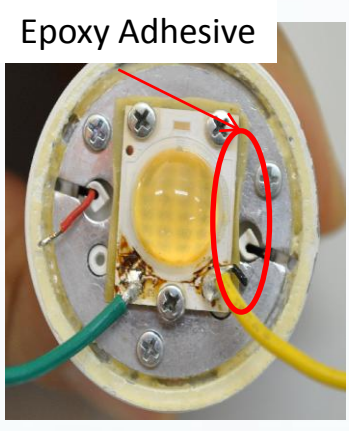


Fig 10. Example of Using Epoxy Adhesive

So, we highly recommend users to use silicon affiliated adhesive in minimum quantity.

When the soldering is done for combining wire to PCB. The use of flux(rosin) in solder paste can make LED discolored by thermal and lighting acceleration factor. So, It would be better to clean a residual flux with IPA(Isopropyl Alcohol) after soldering .

Fig 11. Overuse of Solder paste

1.2 Discoloration by VOCs in LED

1.2.4 Guide for Bulb Design

When users design LED lighting product, it is important to get open system for free air ventilation to avoid discoloration and outgas VOCs (contamination materials on LED) easily. For example, at the time of using adhesive for cover, please make secure open system as shown below.

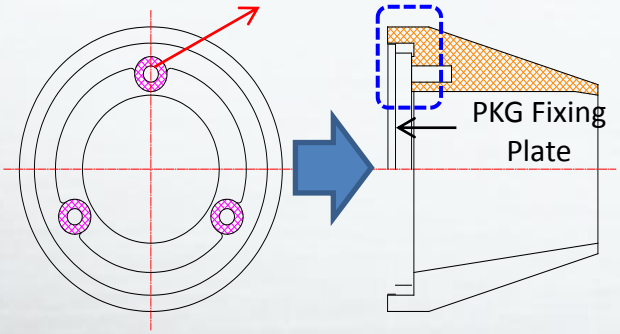
Full Dotting
(Not Recommended)

Partial Dotting
(Recommended)

Fig 12. Means Recommended to Fix Cover

In order to prevent contamination and VOCs from outgas with the increase of temperature, the large contact area between fixing plate and case have to be needed for efficient heat dissipation.

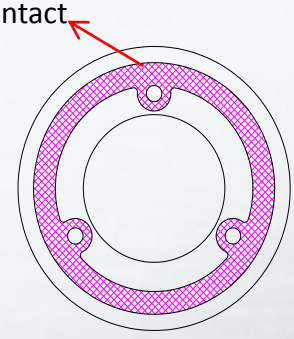
• Worst Design
- Small Contact Area(Only 3 Points)



Side View

(Not Recommended)

• Good Design
- Area Contact



(Recommended)

Fig 13. Fixture Design Recommended to Dissipate Heat

2.1 Injurious Chemicals to Encapsulant Silicone in LED

Chemicals in the below table shouldn't be used in manufacturing lightings with Samsung pkgs. These chemicals should lead to degradation of properties and life span.

Category	Chemical Name
Solvent	Toluene
	Xylene
	Benzene
	Chloromethane
	Chloroform
	Ethyl Acetate
	Butyl Acetate
	Acetone
	MEK
	MIBK
Acid	HCl
	H_2SO_4
	HNO_3
Alkali	KOH
	NaOH
	LiOH
	$Ca(OH)_2$
Oil	Diesel Oil
	Petroleum
	Hydro Carbons

Table 5. Injurious Chemicals to Silicone

3. Revision History

Date	Revision History
2013.02.20	New Version