Reliability of Interconnects in LED Lighting Assemblies Utilizing Metal Clad Printed Circuit Boards
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Agenda

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2. Motivation
3. Interconnect Reliability
4. Solder Joint Testing
5. Test Results
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Introduction
Henkel at a glance

- 140 years old, German based, family owned company
- Close to 50,000 employees, over €18B in sales
- 3 divisions: Laundry & Home Care, Beauty Care and Adhesive Technologies
  - Specific division focused on solutions for Electronics applications

![Diagram of electronics components and materials used in LED lighting assemblies utilizing metal clad printed circuit boards.]
Motivation
Why using MCPCB in a LED assembly?

• LED performance is highly influenced by junction temperature
  • LED lifetime depends on junction temperature of the die
  • LED brightness depends on junction temperature of the die
  • LED Color shift depends on junction temperature of the die

• Various ways to achieve this:
  • FR4 with filled vias
  • FR4 with Cu-inlays
  • Ceramic boards
  • MCPCB

Proper thermal management is a must
**Motivation**

Interconnect Reliability

- Interconnect failure is an open circuit, not a short
- This causes all of the lights in series with the failed interconnect to go out.
- More significant than a single point source due to a short
- Warranties of 5 year or more are common in high reliability applications like street lighting, so the interconnect is crucial.
Interconnect Reliability
What happens

Different expansion/contraction with temperature swings

Stress Relief via Strain in:
- Solder Joint
- Dielectric

Ceramic submount
CTE ~ 5 ppm/K

PCB CTE (ppm/K)
- Stainless Steel ~ 12
- Copper ~ 16
- Aluminum ~ 25
Interconnect Reliability

The Result

Reliability of Interconnects in LED Lighting Assemblies Utilizing Metal Clad Printed Circuit Boards
Most interconnect reliability / fatigue failures occur where there is local plastic deformation. They are initiated at a void, discontinuity, or stress concentration and grow through plastic deformation.

Interconnect Reliability
Fatigue Relationships

• $\Delta D =$ the cyclic damage term. Generally: the lower the better

\[
\Delta D = \frac{F \cdot L_D \cdot \Delta \alpha \cdot \Delta T}{h}
\]

• $F$: correction factor $0.7 > F > 1.2$, generally
• $L_D$: distance to centerline or neutral plane
• $\Delta \alpha$: difference in CTE between package and substrate
• $\Delta T$: maximum and minimum temperatures in thermal cycle
• $H$: solder joint thickness

Source: Engelmaier, Pb-free solder creep-fatigue reliability models updated and extended; Global SMT& Packaging, 9/2009. pg 36-37
Solder Joint Testing

Test parameters

- Copper and Aluminum based boards with different dielectric materials
- Circuit pattern as shown
- Finished with Electroless Nickel Immersion Gold
- 3 solders evaluated
  - Low Creep (Henkels 90iSC)
  - Standard (SAC 305)
  - Low melt (140C)
- Solder was stenciled using a 125 micron laser cut stencil with a 10% reduction in aperture size
- Populated with Luxeon Rebel
- Solder was reflowed as shown in air with standard reflow cycle
- Thermal Cycle the assembly
- Apply 3 V at the pads and look for light at cycling intervals
Solder Joint Testing
Test results

Comparison of Thermal Cycle on Solder Joint Reliability (aluminum)

-40 to 100°C, 15 min dwell
-40-125°C, 30 minute dwell
Solder Joint Testing
Test results

Comparison of MCPCB Substrate on Solder Joint Reliability

Fraction parts with light on vs. Thermal Cycles

- Red dots: Aluminum based MCPCB
- Gray dots: Copper based MCPCB
Solder Joint Testing

Test results

Comparison of Solder on Solder Joint Reliability

Fraction parts with light On

Thermal Cycles

- SAC 305
- 90iSC
- Low melt alloy
Solder Joint Testing
Test results

Comparison of MCPCB Dielectric Modulus on Solder Joint Reliability

Fraction parts with light On

Thermal Cycles

- Standard Modulus
- 1/2 standard modulus
- 1/4 standard modulus
Solder Joint Testing
Test results - Conclusions

• Solder joint reliability can be improved by:
  • Minimizing the temperature swing
  • Minimizing CTE Mismatch
    • Select Copper base v. Aluminum
  • Strain absorption of dielectric
  • Strain absorption of solder
Interconnect Reliability
What can Henkel do?

Relative Performance of Solder Joint Reliability of Thermal Clad Products

- ASL-1 SAC 305 aluminum 75
- IMS 1 90iSC aluminum 75
- IMS 2 SAC 305 aluminum 75
- IMS 1 SAC 305 aluminum 75
Conclusions

• Reliability of LED lighting solutions is key to continuing large scale adoption

• Interconnects can play a significant role in the reliability of LED assemblies in applications with thermal cycling requirements

• Solder joint reliability is determined by
  • Quality of solder joints
  • Solder types
  • Substrate materials
  • Part geometry
  • Thermal Cycles
Questions?
Thank you!

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