Ansys

CASE STUDY /

Ansys Reliability Engineering Services Team Identifies Root Cause of Failure for Electronics Manufacturer

"A combination of design review and simulation allowed us to determine what was causing the solder joint failure and provide our customer with detailed recommendations on how to prevent the failure from reoccurring."

Mike Howard

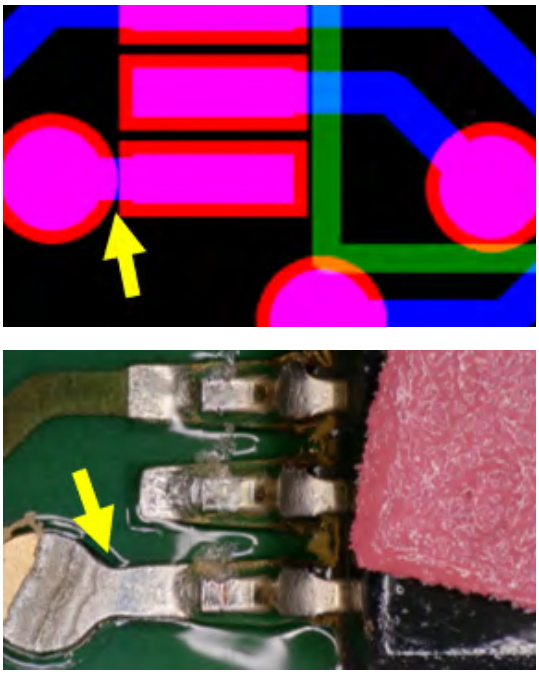
Reliability Engineering Services Manager / Ansys

CASE STUDY

The Ansys Reliability Engineering Services (RES) team (formerly DfR Solutions) was contacted by a leading electronic instrument manufacturer to determine why their printed circuit board assemblies (PCBAs) were experiencing early solder fatigue failure during thermal cycling. Ansys RES used a combination of design review and simulation to determine the root cause of failure & provide actionable mitigation strategies.

Technology Used

- Ansys Mechanical
- Design Review



Insufficient solder mask dam (top image) led to solder wicking into the via (bottom image) and a low volume solder joint under the corner lead

Engineering Solution

Approach: Step 1 — Design Review of PCBAs

Ansys RES experts performed a design review covering derating risks,

electro-static discharge (ESD) rating, vias, panelization, solder mask dams, conformal coating, the manufacturing process, and the stackup properties for the laminate, including the coefficient of thermal expansion (CTE), conductive anodic filament CAF resistance, and glass transition temperature (Tg). Two items were flagged by the design review as potential reliability issues:

1) The conformal coat properties

2) The solder mask dams

An examination of the datasheet for the one-component urethane material used as the conformal coat raised a concern that the coating might be passing through its Tg during the thermal cycling process. Near Tg, the CTE of the conformal coating changes more rapidly than the Young's modulus, meaning the conformal coat has both high CTE and stiffness concurrently. Therefore, thermal cycling events which pass through the Tg are prone to cause damage in the electronic components.

Upon visual examination of the PCBAs, the conformal coating also appeared to be much thicker than the nominal 2 mils recommended for this type of coating process. Both the transition through the Tg and the large thickness were flagged in the design review as potential contributors to the solder fatigue failure.

Secondly, the design review also noted that some solder mask dams between pads and vias were less than the minimum recommended value of 0.1 mm. The insufficient solder mask dams led to solder bridging over the gap, reducing the volume of solder in critical solder joints.

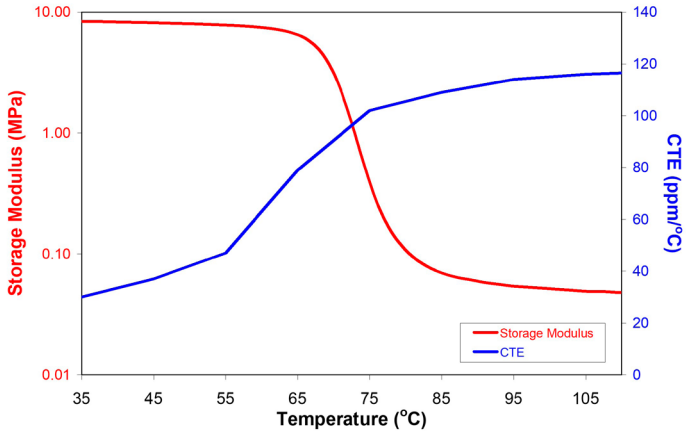


Image from Polymer Science and Technology, Chapter 4:
Thermal Transitions in Polymers, Robert Oboigbaotor Ebewele, CRC Press, 2000

Approach: Step 2 — Finite Element Analysis Simulation

The RES team next performed finite element analysis (FEA) simulation of the PCBA's solder system using **Ansys Mechanical** simulation software to quantify the effect of both the conformal coat and insufficient solder volume on the reliability of the assembly. In thermal cycling (a low cycle fatigue failure), the creep work accumulated in each cycle is used to predict when failure will occur. In Ansys Mechanical, this translates to using the nonlinear creep work as the metric to determine solder life. **Comparing simulation results for a non-conformally coated (baseline) PBCA and a conformally coated PCA revealed that the conformally coated version experiences more nonlinear creep work accumulation in the solder joint for a given thermal cycle.**

The simulation revealed a drastic increase in nonlinear creep work when the conformal coating was present. Converting the nonlinear creep work to a characteristic life using the Syed model*, the characteristic life prediction of the baseline PCA is nearly 8x higher than the conformally coated PCBA.

For verification that decreasing coating thickness would improve the reliability of the component, the Ansys RES team performed a simulation with reduced conformal coat thickness. T**he simulation predicts that reducing the thickness of the conformal coating significantly (down to 3 mils, which is still more than the 2 mil recommended thickness) improved the characteristic life of the solder joint.** When the conformal coat does not completely underfill the component, then the life of the component nears the life of the package when no conformal coat is applied. This is because the air gap allows the conformal coat to expand freely without imparting stresses in the solder joint.

The RES team also performed simulations of a poor-quality solder joint to reflect the solder leakage due to insufficient solder mask dams. **They found that a solder joint with a reduced heel fillet can result in a 4x loss in predicted life for this component in this thermal environment.**

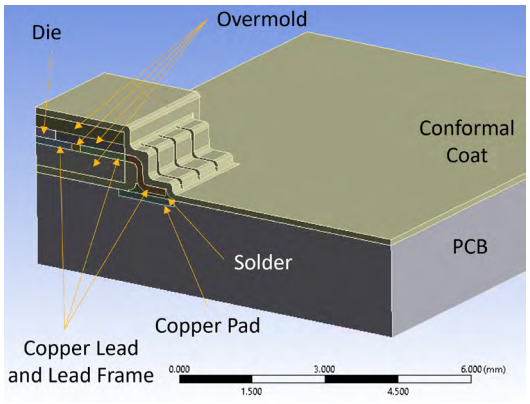
/ Recommendations & Solutions

Recommendation 1: Decrease the volume of the conformal coating applied:

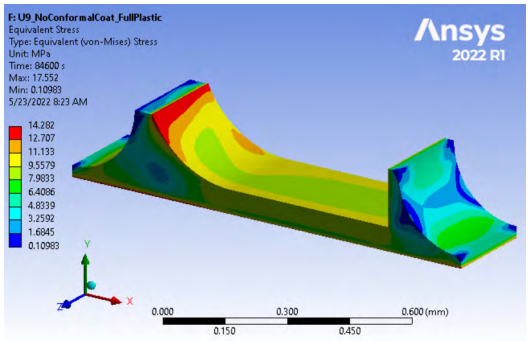
- A new application method, like an automated spray system, could improve the life of the PCBA by aiding in controlling the thickness of the coating.
  - The typical coating thickness for a urethane coating is 2 mils
- Physical characterization of the conformal coat is necessary to exactly quantify the harmful effect it is having on the PCBA's reliability.
  - The simulations performed assumed material properties for the conformal coat based on similar materials and the manufacturer's data sheet. However, the Tg, and the corresponding modulus and CTE on either side of the Tg, is critical to exactly quantify the deleterious effect the conformal coat is having on the PCBA's reliability.

Recommendation 2: Increase the solder mask dams to reduce the likelihood of solder defects

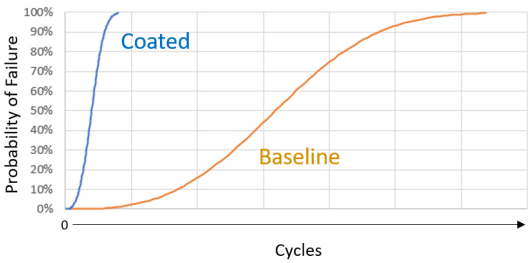
- Confirm that all solder mask damns meet the minimum gap of 0.1 mm, which should improve the solder volume in the critical solder joints.



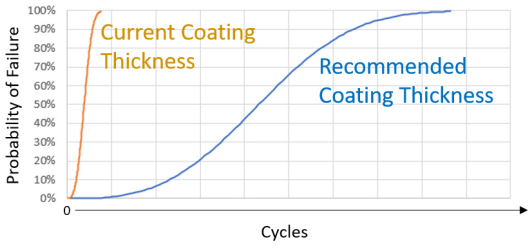
Quarter symmetric finite element model of a typical gullwing leaded package with conformal coat completely filling the air gap between package, lead, and board



Simulation results: sample solder joint equivalent stress contour



The probability of failure curves, assuming a 2-parameter Weibull failure distribution with β=3, show the conformal coat is highly damaging to the system



The probability of failure curves, assuming a 2-parameter Weibull failure distribution with β=3, show that using the recommended conformal coat thickness would greatly improve the reliability of the component

Interested in working with the Ansys RES team? Get in touch with us.

**Accumulated creep strain and energy density based thermal fatigue life prediction models for SnAgCu solder joints, 2 004 Proceedings. 54th Electronic Components and Technology Conference, doi: 10.1109/ECTC.2004.1319419*

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