ANSYS Solutions to Electronic Component and Board Reliability

Fluid Dynamics  Structural Mechanics  Electromagnetics  Systems and Multiphysics

Ansys Inc.
What this presentation will cover

• Overview

• Section 1 : Chip-Package Interconnect Reliability (Underfilled Solder Bumps)

• Section 2 : Solution to 3D Packaging Challenges

• Section 3 : Board Level Reliability

• Section 4 : ANSYS Solutions for Board Level Design
Overview

• Thermo-Mechanical Analysis

Import/Create Geometry

Geometry can be imported from CAD software

Link Geometry->Icepak

Apply basic settings, solver settings and boundary conditions in Icepak
Solve the Model in Icepak

Link Geometry with Structural

Share the geometry with structural

Link Icepak setup with Structural

Share setup from Icepak
Solve for stress
Overview

- Engineering solutions of Chip & Package & Board Level
Section 1: Chip-Package Interconnect Reliability
(Underfilled Solder Bumps)
Flip Chip Process Steps

Step I: Silicon, solder bump and substrate bond at reflow temperature (>180 C)

Step II: Cool down from 180 C to room temperature

Step III: Underfilling, cure at 150 C, Cool to room temperature

Step IV: Lid attach/encapsulation at ~120C, cool down to room temp

Step V: Ball attach & reflow at > 180C,
Simulation Challenges

- Process steps include attachment on warped Geometry
- Attach happens at stress free state
- Stress build due to cool down
- CTE input with ref. temp alone is insufficient to capture this pre-stress effect

- ANSYS Solution involves the use of element birth and death technique
  - Element Birth and death is a powerful technique that allows new materials to be introduced into the model
  - In their deformed, but stress free state
Deformation Result

Warpage before Lid attach (120C).

Warpage after lid attach and cool down (20C)
Element Birth & Death Method

Steel Panel 1

Steel Panel 2

Seam Weld

Heat Transfer

Thermal Deformation

Project

Model (B4, C4)
- Geometry
- Part
- Coordinate Systems
- Connections
- Mesh
- Named Selections

Transient Thermal (B5)
- Initial Temperature
- Analysis Settings
- Convection
- Temperature

Commands (APDL)
- Commands (APDL) 2
- Commands (APDL) 3
- Commands (APDL) 4
- Commands (APDL) 5
- Commands (APDL) 6
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Section 2 : Solution to 3D Packaging Challenges
3D Packaging Challenges

Delamination

Fracture due to TSV, BEOL feature CTE mismatch With Silicon

Solder Joint Reliability

Die Thinning, microbumps, new Materials & associated processed Makes delamination a non-trivial challenge
Thermo-Mechanical Fracture Modes In Sillicon with TSV

Generic Classification

Thermo-mechanical Fracture Modes applicable to TSV (CTE (cu) ~ 17, CTE (Si) ~ 2; Ref Temp ~ 120 (electro plating) (Lu et al)

DT > 0, R- Crack due to tensile mode

DT < 0, C- Crack due to tensile mode

Interfacial, Shear mode @ any DT

Tensile mode @ DT<0
Fracture Mechanics Models

- Stress Intensity factor Calculations
  - Suited for linear material behavior

- Energy release rate using J-integral calculations
  - Applicable to non linear material models also

Delamination Modeling

- Cohesive Zone Modeling (CZM)
3-D Packaging and the Multi-Scale Challenge
Multi-Scale Modeling Using Sub-Modeling

Full Model

Sub Model
Section 3 : Board Level Reliability
• Reliability challenges at the package – board interface (solder joints)
  – Reliability is dependent on board design as well as package design
    • Low Cycle Fatigue (LCF) due to Thermo Mechanical cycling
    • High Cycle Fatigue (HCF) due to vibration

• Board Level
  – Board mounting, stiffening, heat sink retention
Fatigue Approach

- Two basic fatigue analysis methods
  - stress-life (SN) uses calculated elastic stresses and empirical stress vs. cycle fatigue curves
    - applicable to high cycle fatigue
      - greater than 100,000 cycles for metals
  - strain-life (EN) uses elastic-plastic strains and Strain Life Relation Equation
    - elastic-plastic strains can be directly calculated or predicted from elastically calculated strains
    - applicable to low and high cycle fatigue
Summary Flowchart of CAE Fatigue Analysis

Fatigue Approach

Strain-Life (EN) Stress-Life (SN)

Rainflow cycle counting
Miner’s rule damage accumulation

total number of cycles to failure (life)
Board Level Solder Joint Reliability (Low Cycle fatigue)
Board Level High Cycle Fatigue of Column Grid Array

- High Frequency Vibration can be simulated using random vibration or harmonic analysis

- Random Vibration analysis and S-N curve for the solder joints may be used for life prediction
Board Level High Cycle Fatigue of Column Grid Array

Cycles to Failure

my_cycles = 1.446e+005
Section 4 : ANSYS Solutions for Board Level Design
Internal faces of all six holes fixed
Heat Sink Retension

Compliant Joint
• Static structural analysis helps determine board pre-stresses due to retention
  – Board flexure due to static loading

• Vibration natural frequency should be higher than the frequencies encountered during the life of the electronics
Random Vibration Analysis

- Time vs. Acceleration input for vibration analysis can lead to time consuming transient analysis.

- Random Vibration analysis using Power Spectral Density (PSD) input is computationally efficient for linear systems.
Shock Response Analysis

- Avionics, automotive and military electronics experience sudden acceleration (shock)
- Such systems can be simulated in time domain
- Linear as well as non-linear material models can be used in flexible dynamics analysis
Q and A

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