Reliability Testing of Medical Electronic Circuits using IST

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What is IST

- IST = Interconnect Stress Testing
- Determines Overall Reliability of PCB’s
- Powerful and Flexible Reliability Tool
- Objective Test Results
- Reproducible Test Results
- Automated - Set It and For Get It
- Complies to IPC TM 650 2.6.26
- Industry Wide Acceptance
How Does IST Work?

- Uses an IST Coupon that is the Same Configuration as the Board
- Thermal Cycles by Electrically Heating the Test Coupon
- Continuously Measures Resistance of Circuits During Heating
- 10% Increase in Resistance is a Failure
- Heating Stops within Seconds of a Failure
- This Allows for Failure Location of the Most Damaged Via Using a Thermal Camera

Material Testing

- With the Advent of RoHS – Material Damage
- IST coupon are design with Capacitance Circuits
- Measure the Capacitance of a the Coupon
- Capacitance is Measured Before, After Precon and End of Test
- Greater than a -4% Change in Capacitance is Material Damage
- IST Tests the Circuits (copper) and the Material (dielectric)
Z Axis Expansion

Case Study – Three Fabricators

- This was for a Major Medical OEM
- The device is an internal ECG and Defibrillator
- This is a sequential laminated eight layer design
- Interconnections - microvias and buried vias.
- The PWB is made of polyimide
- The IST coupon design used is a SL08022
- This coupon is tested at 210°C
- The test is for 500 cycles
- A 10% increase in resistance is a failure
- Delamination is a failure
Case Study – Design SL08022

- The coupon is an SL08022 – four circuits
- The power circuit P is a buried via on layer 4/5
- The sense circuit S1 is microvias on layers 1/2 and 7/8
- The sense circuit S2 is microvias on layers 2/3 and 6/7
- The sense circuit S3 is microvias on layers 3/4 and 5/5
- This coupon is tested at 210°C
- This coupon does not have capacitance circuits
Case Study – Three Fabricators

- Fabricator One had no failures and no delamination after testing 80 coupons
- Fabricator Two had one power circuit failure and 6 coupons with delamination after testing 10 coupons
- Fabricator Three had 18 power circuit failures out of 18 coupons

Case Study – Fabricator 1

- The first fabricator has no failures after testing 500 cycles at 210°C, on 80 coupons
- There was no delamination
Case Study – Fabricator 1

- The second fabricator had one failure out of 10 coupons
- There was delamination in 6 coupons

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<tr>
<th>COUPON</th>
<th>P1</th>
<th>% S1</th>
<th>S1</th>
<th>% S1</th>
<th>S2</th>
<th>% S2</th>
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Mean: 500, S1: 0.048, S2: 0.048, S3: 0.024

Case Study – Fabricator 2
Case Study – Fabricator 2

[Images of electronic components and circuit boards]

Case Study – Fabricator 2

[Images of electronic components and circuit boards]
Case Study – Fabricator 3

- The third fabricator had 18 power circuit failures out of 18 coupons – mean cycles to failure 112
- There was no delamination

<table>
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<th>Coupon</th>
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<th>P1 Sense</th>
<th>S1 %</th>
<th>S1 Sense</th>
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Mean    112  10  101  1  127  1  109  1
StDev   70.6 0.0 75.1 1.3 72.1 1.2 64.7 1.2
Min     0   0   0   0   -1.5 0   -1.5 0
Max     273 10 273 5.2 273 2.8 213 2.8
Range   273 0 273 5.2 273 4.3 213 4.3
Coef Variation 62.8% 74.2% 56.6% 59.4%
Case Study – Three Fabricators

- Fabricator One was approved after qualification
- Fabricator Two changed the material and process and qualified on subsequent tries
- Fabricator Three after a few more tries withdrew from consideration
- The fabricators are now monitored using two IST coupons per lot
- The OEM has never had a circuit board failure

Failure Location

- Testing Stops at 10% Increase in Resistance
- The Failed Circuit is not Open
- The Failed Circuit can be Heated with a Small Amount of Current
- While Being Heated the Failed Circuit is Observed with a Thermal Camera
- The Most Damaged Circuits Shows as a Hot Spot
- Thermo-graphic Camera allows the Identification of the Most Damaged Interconnection
Failure Location

Microvia Separation
Microvia Barrel Crack

Microvia Corner Crack
Microvia/Buried Via Lifted Cap

Barrel Crack – Metal Fatigue
Knee Crack

Interconnect Separation
Delamination

- IST Coupon Design Critical to Measurement Sensitivity
- Validation of Product Construction / Material Dk
- Measurements Taken Before & After IST Thermal Cycles
- Changes in Capacitance Signify Delamination
- Capability Confirmed, Test Protocol Established/Available
Construction Profile

Material Damage
Adhesive Delamination

Cohesive Failure
Reliability Testing of Medical Electronic Circuits using IST

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Additional Information

- The following slides are offered here for additional information about the IST process

IST Process

- Select or Have Design the Correct Test Vehicle (Coupon)
- Fabricate a Coupon with Appropriate Attributes
- Prescreen Resistance & Capacitance and Select a Test Sample
- Precondition – Simulate Assembly and Rework
- Capacitance after Preconditioning for Material Damage
- Test Coupons by Thermal Cycling to Failure
ISTA Process

- Plot Damage Accumulation
- Capacitance at End of Test to Determine Material Damage
- Determine the Circuit Failure Location (Thermal Camera)
- Cross Section Perform Failure Analysis for the Root Cause
- Determine Observed and Latent Failure Modes
- Evaluate Data and Draw Conclusions

Thermal Profiles
IST Hardware and Software

- **Hardware - IST Testing Machine**
  - Eight Individually Controlled Test Heads
  - Automated – Preconditioning and Testing
  - Requires Clean, Controlled Environment

- **Software**
  - Automated Control of Heating and Cooling
  - Continuous Measurements of Environment and Product
  - Automated Report Generation
  - Automatic Safety Controls (Watch Dog, Emergency Shutoff)
IST Testing

- Automated Testing Protocol
- Operator Independent
- Coupons Have Two or More Circuits
  - “Power, Sense 1, Sense 2, Sense 3”
- Ohmic Heating of Coupon - Tight Control
- Coupons are Heated for 3 Minutes +/- 3 Seconds
- Coupons Preconditioned to
  - Simulate Assembly (3X) and Rework (6X)
  - Tin/Lead 230°C, Lead Free 245°C or 260°C
- Testing to Any Temperature – 150°C to 260°C Typical
- Convection Cooling to Ambient – Approx 2 min.

IST Testing

- Resistance is Measured Continuously on Each Circuit
- 10% Increase in Resistance is Considered a Failure
- Data is written to various files for automatic reporting
Test Coupon

- The Coupon Must Reflect the Critical Attributes of the PWB
  - Coupon Reflects Thickness and Layer Count
  - Copper Weights used in the Construction
  - Holes Sizes that includes the Smallest Hole Size
  - Surface Finish that is Appropriate
  - Grid size
  - Construction
  - Designs are Required for Each Level of Technology
- All Above is Established by the Customers Requirements

Test Coupon

- The Line width is the One Variable that is adjustable by IST Design
  - Line Width is Determined by IST Coupon Design Requirements
  - Power Circuit Line widths are Adjusted to Assure the Resistances are Optimized for Heating Efficiency
  - The Sense Circuit Line Widths are Adjusted to Assure the Maximum Sensitivity
Thermal Expansion

- Test to 150°C (Microvia 190°C) +
- Test in Three Minutes +/- Three Seconds
- Cooling in Approximately Two Minutes
- Determines Relative Reliability
- Allows Ranking of Process, Materials etc.
- Uses Standard and Weibull Statistical methods
- Tests the Interconnect and PTH integrity at The Same Time
Test Temperatures

- Performance and Baselines = 150°C
- Microvias = 190°C
- Flex Circuits are Tested at 210°C
- Polyimide = 220°C
- Survivability Testing Tin Lead = 230°C
- Survivability Testing Lead Free = 260°C
- Preconditioning Tin/Lead Assembly = 230°C
- Preconditioning Lead Free = 245°C or 260°C
- Acceleration Testing Typically 150°C, 160°C and 170°C
- Test Temperatures Can Be Adjusted as Required

IST Methodology

- Rejection Criteria is a 10% Increase in Resistance
- A 10% Resistance Established by Military Specifications
- Failures can happen abruptly, or progressively
- Failures can occur on the sense or power circuit
- Material Damage is a Rejection Criteria
- Material Damage is Based on Capacitance (-4%)
Plot of Damage Accumulation

- Plot of Damage Accumulation at 150°C
- Resistance at Temperature for Each Cycle
- Damage is caused by cracks in copper
- Damage is Express as Increase in Resistance
- A 10% Increase is a Failure = Top of Graph
- Review – Onset, Slope, Acceleration etc.
- Sense Circuit Shows Typical Wear Out
- Power Circuits Shows Typical Acceleration
Minimum Cycle by Industry

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