Commercialization of Military & Space Electronics - Conference

Commercial Off-The-Shelf (COTS) Program
Using Nondestructive Methods (C-SAM) for COTS PEMs Screening and Qualification

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AGENDA:

- C-SAM Inspection
- Failure Mechanisms/Studies
- C-SAM Screening Method
- Test Data
- Reject Criteria/Failure Analysis
- Other Work
- Summary

The work was performed at Jet Propulsion Laboratory California Institute of Technology under contract to the National Aeronautics and Space Administration
C-SAM Inspection Characteristics:

- Nondestructive Method
- Ultrasound Signal
- Ceramics, Plastics, Metals
- Voids, Cracks, Delamination, Anomalies, Defects, Disbonds
- Relatively inexpensive
- Cheap Reliability Insurance
Possible Failure Mechanisms from PEM Delamination Based on Independent Studies:

- Stress-induced passivation damage over the die surface
- Wire bond degradation due to shear displacement
- Accelerated metal corrosion
- Die attach adhesion
- Intermittent electricals at high temperature
- Popcorn cracking
- Die cracking
- Device Latch Up
Eight Independent Studies on C-SAM Delamination /Reliability:

- Failure Criteria for Inspection Using Acoustic Microscopy After Moisture Sensitivity Testing of Plastic Surface Mount Devices; Alcatel Bell, Texas Instruments, Philips Semiconductor
- A Case Study of Plastic Part Delamination; ITT Aerospace/Communications
- The Application of Scanning Acoustic Microscopy to Control Moisture/Thermal Induced Package Defects; Texas Instruments
- C-SAM Analysis of Plastic Packages to Resolve Bonding Failure Mode Mis correlations; Texas Instruments
- On the Role of Adhesion in Plastic Packaged Chips Under Thermal Cycling Stress; Siemens
- Relation Between Delamination and Temperature Cycling Induced Failures in Plastic Packaged Devices
- Correlation of Surface Mount Plastic Package Reliability Testing to Nondestructive Inspection by Scanning Acoustic Microscopy; Texas Instruments
- The Mystery of the Cracked Dice; Analog Devices
Popcorning Failure Mechanism from Internal Moisture

C-SAM Inspection Points for delamination which can accelerate entry of moisture/collection
C-SAM Finds Hidden Defects

HIDDEN DEFECTS IN IC PACKAGES (PLASTIC) CAN AFFECT RELIABILITY

Die-attach material serves three functions: attach die to die substrate, conducts heat away from die, and absorbs some internal stresses.
C-SAM is Included in JPL’s Full Part Level Screening

COTS++ Plastic Infusion Critical Screening Flow
(Tailored for Project application/mission requirements)
# COTS++ Upscreening Rejects by Part Type & Vendor

<table>
<thead>
<tr>
<th></th>
<th>Amplifier- A</th>
<th>ADC- B</th>
<th>ADC2-B</th>
<th>DC-DC Con.-C</th>
<th>Voltage C-A</th>
<th>S.Regulator-B</th>
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<tbody>
<tr>
<td><strong>DPA:</strong></td>
<td>0/4</td>
<td>1/8</td>
<td>TBD</td>
<td>0/4</td>
<td>0/4</td>
<td>0/4</td>
</tr>
<tr>
<td><strong>Incoming:</strong></td>
<td>0/78</td>
<td>n/a</td>
<td>4/79</td>
<td>1/78</td>
<td>0/80</td>
<td>8/80</td>
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<tr>
<td><strong>C-SAM:</strong></td>
<td>3/78</td>
<td>38/78</td>
<td>9/75</td>
<td>16/77</td>
<td>5/80</td>
<td>0/80</td>
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<tr>
<td><strong>Temp Cycle:</strong></td>
<td>0/78</td>
<td>10/78</td>
<td>0/75</td>
<td>3/77</td>
<td>0/80</td>
<td>3/72</td>
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<tr>
<td><strong>Burn-In:</strong></td>
<td>0/78</td>
<td>3/68</td>
<td>0/75</td>
<td>0/74</td>
<td>0/80</td>
<td>9/69</td>
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<tr>
<td><strong>QCI:</strong></td>
<td>0/10</td>
<td>0/10</td>
<td>0/10</td>
<td>0/10</td>
<td>0/10</td>
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<td><strong>Total:</strong></td>
<td>3/78</td>
<td>51/78</td>
<td>TBD</td>
<td>20/78</td>
<td>5/80</td>
<td>20/80</td>
</tr>
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</table>
LOT by LOT Test Results:

Results are package/vendor assembly dependent. Failed lots were replaced and retested.

Lot sizes range from 15-30 parts each.

<table>
<thead>
<tr>
<th>Part Type</th>
<th>Manufacturer</th>
<th>Yield</th>
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<tbody>
<tr>
<td>NPN Transistor 1</td>
<td>A</td>
<td>83%</td>
</tr>
<tr>
<td>Switching Diode</td>
<td>A</td>
<td>0%</td>
</tr>
<tr>
<td>NPN Transistor 2</td>
<td>A</td>
<td>100%</td>
</tr>
<tr>
<td>Zener Diode</td>
<td>A</td>
<td>50%</td>
</tr>
<tr>
<td>NPN Transistor 3</td>
<td>A</td>
<td>100%</td>
</tr>
<tr>
<td>Op-Amp 1</td>
<td>B</td>
<td>87%</td>
</tr>
<tr>
<td>Op-Amp 2</td>
<td>C</td>
<td>0%</td>
</tr>
<tr>
<td>Op-Amp 3</td>
<td>C</td>
<td>7%</td>
</tr>
<tr>
<td>Phase Detector</td>
<td>D</td>
<td>100%</td>
</tr>
<tr>
<td>MMIC</td>
<td>E</td>
<td>40%</td>
</tr>
</tbody>
</table>
C-SAM Rejects (JPL examples): (Devices with >> 10% delamination in critical areas are suspect and are rejected)

*Delamination is not evident because of die top coating used by the manufacturer. (e.g. C-SAM limitation)
C-SAM Delaminations Confirmed by Failure Analysis: (JPL examples):

A. Die attach void at the heat sink surface
B. Bubble exists from Mylar tape near pin 5
C. Delamination and lack of adhesion between die and heat sink

Definitive results were found on six suspect problem areas submitted for analysis.
IC defect descriptions are now identified in J-STD-035 (Acoustic Microscopy for NonHermetic Encapsulated Electronic Components)

Source: Sonoscan Inc.
A New Failure Characterization Study
is Underway Utilizing Plastic Part C-SAM Rejects

Objectives:

• Identify C-SAM reject parts by criteria(s)
• Measure Material Properties including sonic test, IR, X-ray
• Apply extreme temperature cycle stresses
• Repeat Material Properties Measurements including C-SAM at different intervals
• Identify all failure mechanisms and risk rate C-SAM rejects
A Failed Chip Scale Board Assembly is under investigation utilizing C-SAM inspection on components/board

Objectives:
- Identify component delaminations
- Identify board layer delaminations
- Make correlation to CSP package thermal cycle failures
  - CTE Mismatch
  - Package Proximity and Location on Board
  - Ball Bond Size and Location
Summary:

• Some reported concerns/risks anticipated with using PEMs having evidence of delamination can be minimized and possibly eliminated with nondestructive AMI (acoustic microscopy imaging).

• JPL’s existing screening flows for PEMs incorporates AMI 100% to enhance the reliability of parts used by JPL Projects when PEMs are the only choice available.

• Further investigations/studies are being conducted on individual components and board assemblies using AMI analysis. This information will provide more understanding of the correlation between delamination and component/ board failure mechanisms.
JET PROPULSION LABORATORY
Electronic Parts Engineering Office

Additional information can be found at:

http://cots.jpl.nasa.gov