Hybrid inspection and assembly process related challenges

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Introduction

Whether we are evaluating the overall integrity of a Multi-chip Module (MCM) or Hybrid during pre-cap inspection or post-cap as a result of a failure, the industry generally relies on the Military Standards. Two primary documents outline the Inspection Criteria and overall Hybrid performance specifications, which are categorized into classes.

- MIL-STD-883: Test Method for Microcircuits
  - Test Method 2017: Defines materials and workmanship visual inspection Criteria.
- MIL-PRF-38534: Performance Specification
  - Defines general performance characteristics.
  - Quality Control programs / protocol.
  - Allows flexibility to implement commercial “best practice”, while meeting the intended use and performance in Military applications.

This presentation includes examples of process related non-conformances, that could have detrimental effects on performance

Hybrid Classes Per MIL-PRF-38534; Ref. Sect. 1.3

Classes are defined as Quality Assurance Levels:

- **Class K** Highest Quality / Reliability level: Intended for space applications.
- **Class H** High Quality / Reliability level: Intended to meet/exceed military applications.
- **Class G** Lower Quality / Reliability level: Meets class H performance, with lowered operating temperature range (-40°C to +85°C). Suitable for use in military applications. May require additional qualification testing.
- **Class E** Defined Quality / Reliability level: Based on other classes (K, H or G), with specific exceptions taken as defined in the acquisition and/or item product specification document. Requires additional qualification tests for the intended environment.
- **Class D** Supplier specified Quality / Reliability level: A reduced operating temperature range (0°C to 70°C). Supplier defines performance, quality levels, test flow and interprets inspection criteria.

COTS Devices for IT, Telecom, Civil Communications fall into the E & D classes

Defines Quality levels and performance criteria for all classes of MCM / Hybrid devices

Class D Tolerable Exceptions & Non-conformances

When applying Inspection Criteria in MIL-STD-883 TM 2017

Tolerable Items:

- Minor probe marks on inactive substrate or traces that don't impact functionality OR create organic / metallic debris.
- Leads, ribbons, wires or devices that have been contacted during assembly / tuning / rework processes that ***DO NOT impact functionality***. *Subjective!*
- Excess conductive / non-conductive die / substrate squeeze out that ***DOES NOT*** reduce conductor spacing.
- Die / Component alignment or orientation that ***DOES NOT*** affect functionality or reliability. There should be placement & orientation consistency between units and lot runs.
- Small amounts of non-conductive / conductive material that is affixed in place in an inactive area of the cavity. Similar to J-STD-001 inspection criteria (Classes 1-3). *Subjective!*

We will review how the standards are interpreted for Classes E & D, specialty and general-purpose COTS Devices

Class D Tolerable Exceptions & Non-conformances

When applying Inspection Criteria in MIL-STD-883 TM 2017

Non-conforming Items:

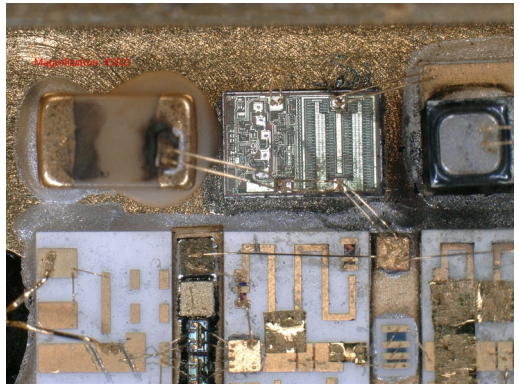
- Major probe marks on substrate, traces, die, components that may impact functionality and creates loose organic / metallic debris.
- Leads, ribbons, wires or devices that have been significantly impacted / deformed during assembly, tuning, rework processes that ***can impact functionality***. Proximity to ground, adjacent wire intersections, missing bond wires, defective bonds etc.
- Conductive / non-conductive die / substrate squeeze out which reduces conductor spacing, creates shorts, displaces other devices.
- Die / Component alignment or orientation that affects functionality or reliability. placement & orientation consistency between units and lot runs.
- Non-conductive / conductive material that is not affixed ***ANY*** area of the cavity.
- Any other issues related to die / components or substrate that indicate material non-conformance

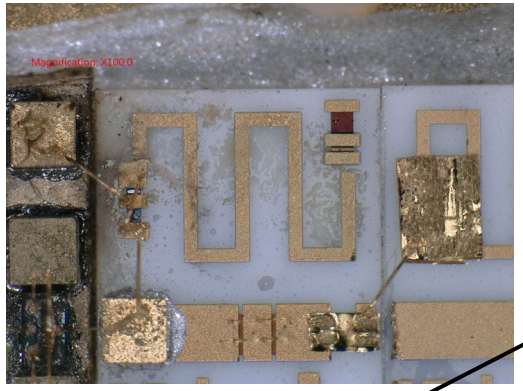
We will review how the standards are interpreted for Classes E & D, specialty and general-purpose COTS Devices

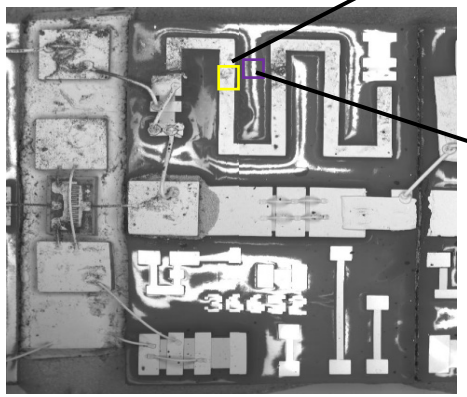
Example: COTS RF Amplifier, Findings (Post-Cap Analysis)

- **Primary issue:** Hybrid is epoxy sealed (non-hermetic) were subjected to CCA wash causing contaminant intrusion
- Hybrid supplier stated components should not be subjected to wash!

Organic Wash Contaminates inside cavity



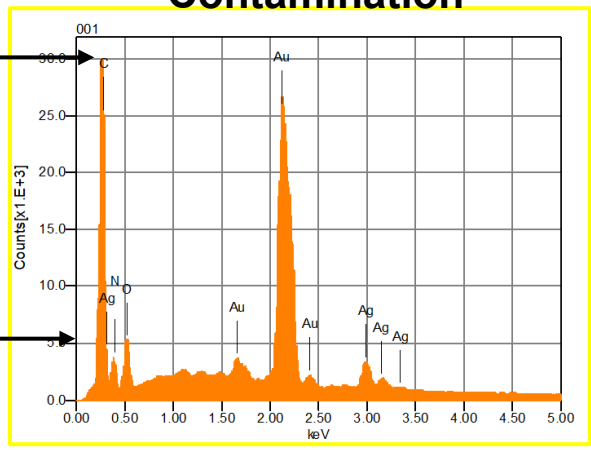




Contamination

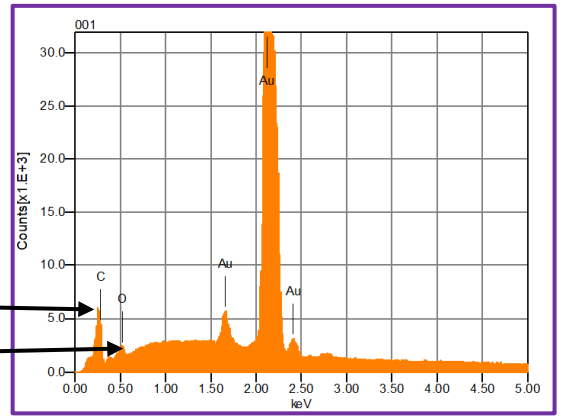
Carbon (C)
~6X increase

Oxygen (O)
~5X increase



Clean

Carbon (C)
Oxygen (O)



SEM analysis confirmed contaminants were Wash Intrusion Residues

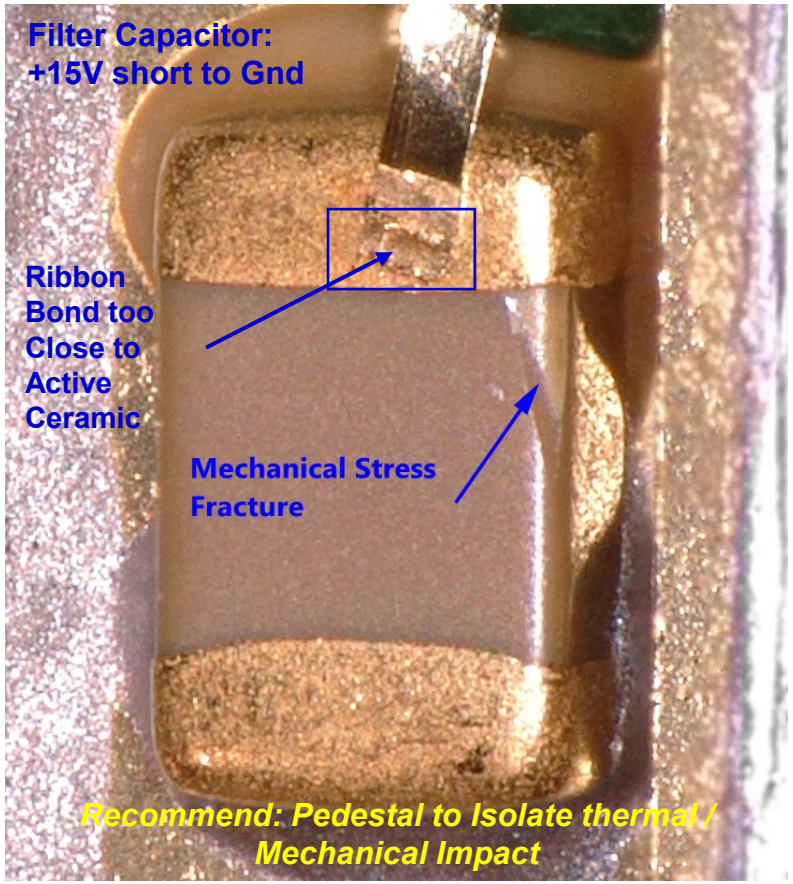
A population of failed RF amps were analyzed for: Low gain, No Gain & Insertion loss

Images Owned by RTX Corporation

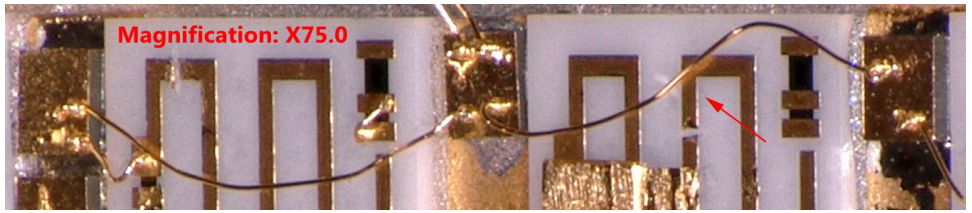
Example: COTS RF Amplifier, Findings (Post-Cap Analysis)

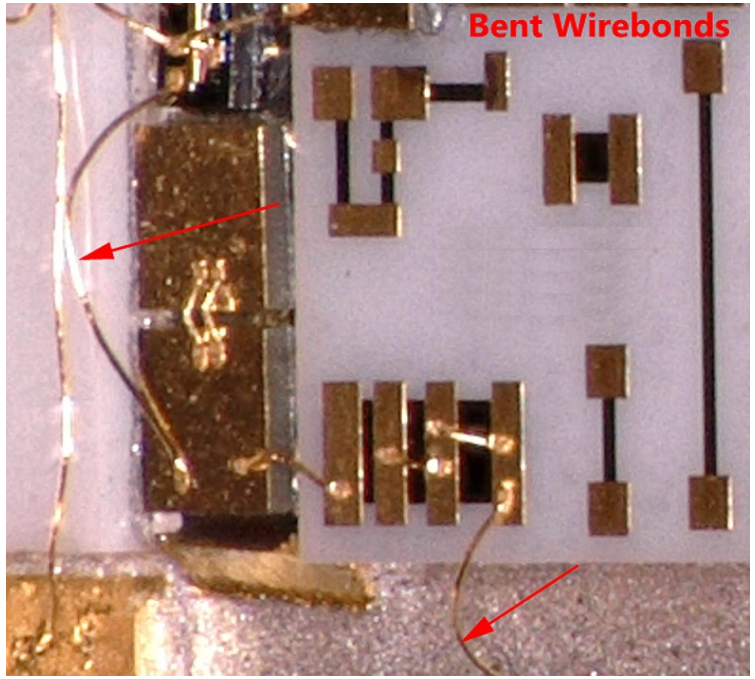
– Follow on analysis showed other failures were attributed to supplier assembly process defects.

Ribbon Bond Stress Fractures, <u>Several units</u>



Lack of Long wire Staking & Disturbed Wire Bonds





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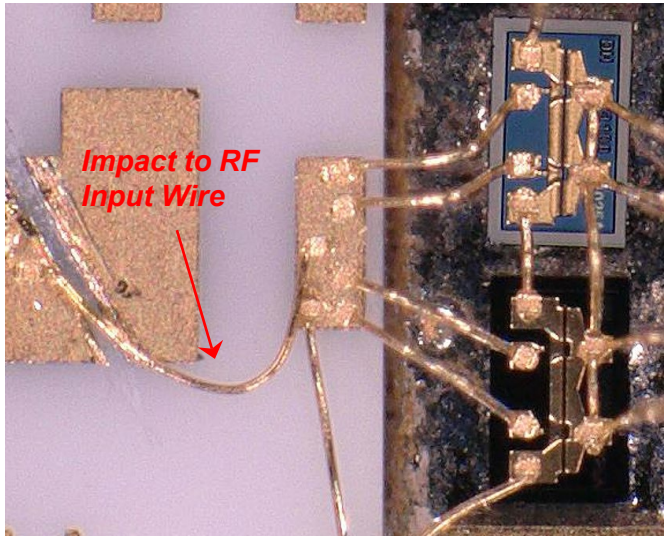
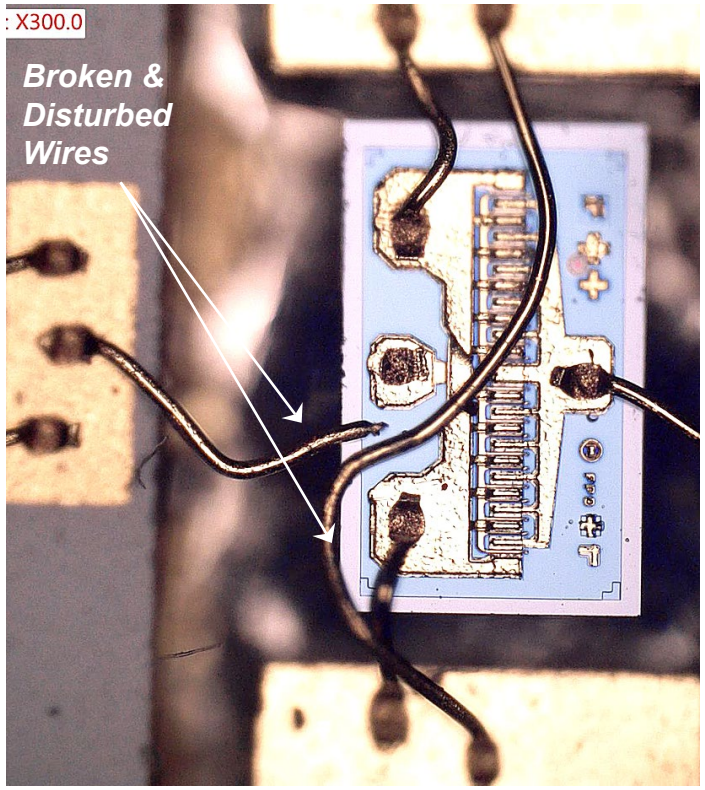
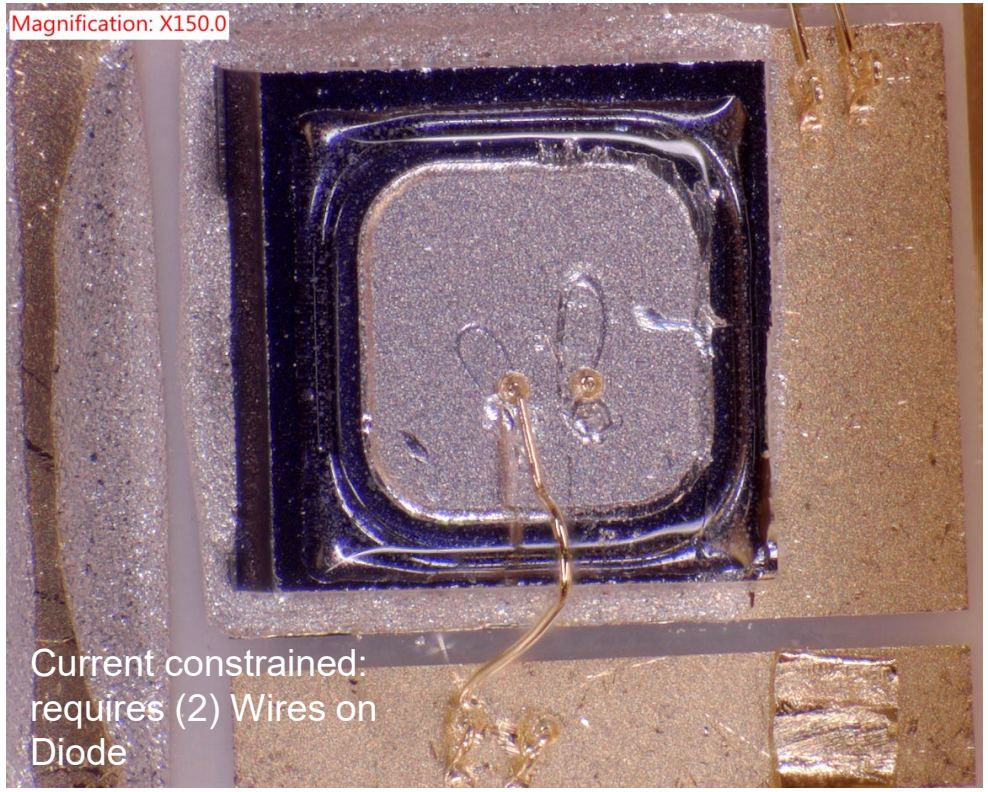
Disturbed & Broken Wire bonds due to impact





Missing Bond wire (Should be 2)



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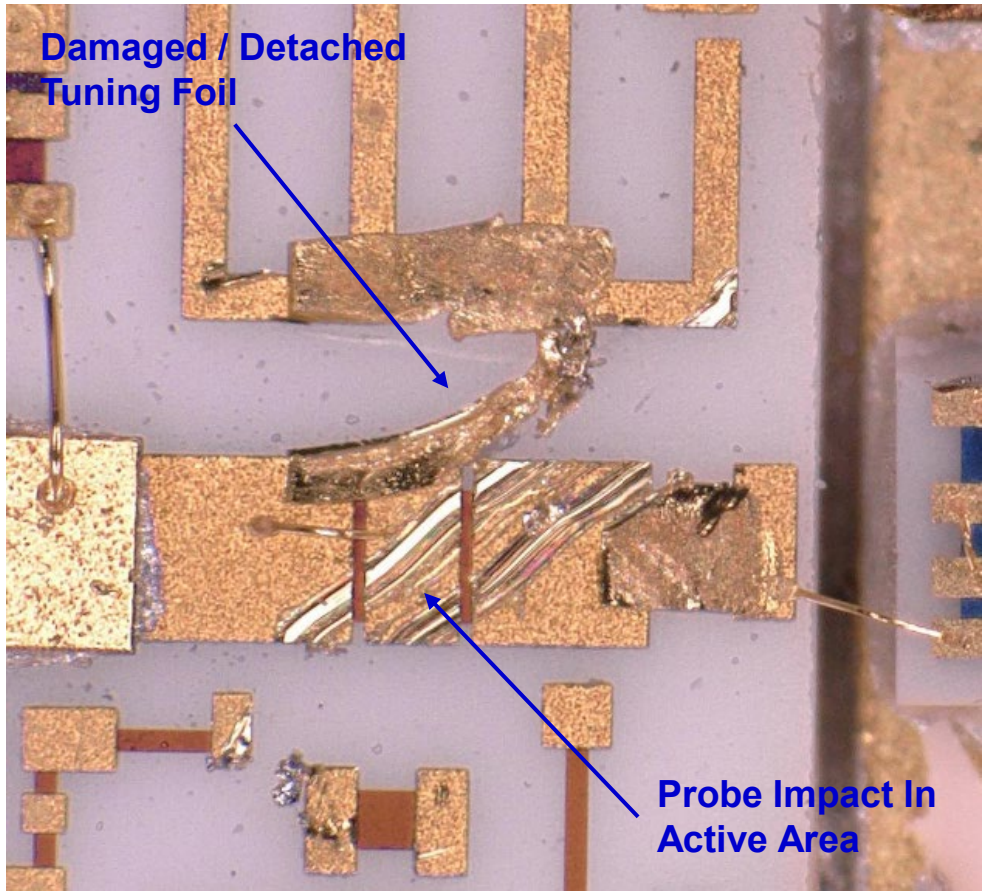
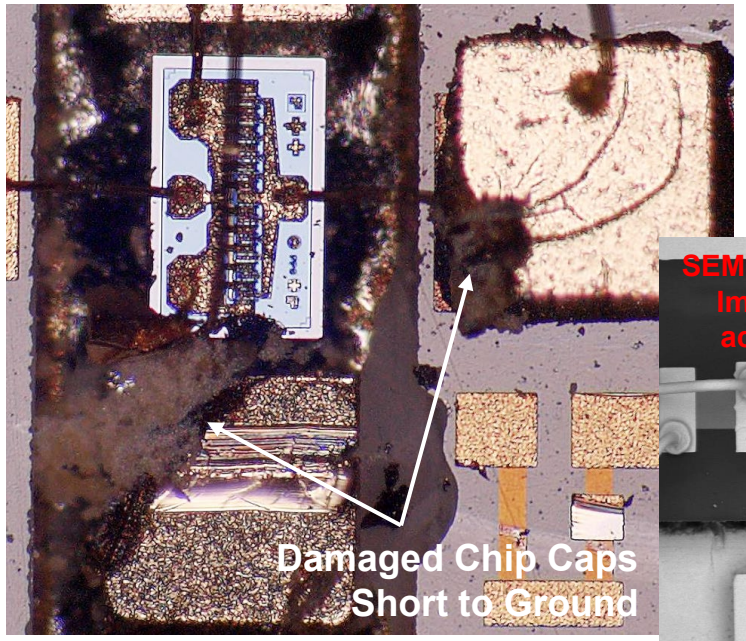
Example: COTS RF Amplifier, Findings (Post-Cap Analysis)

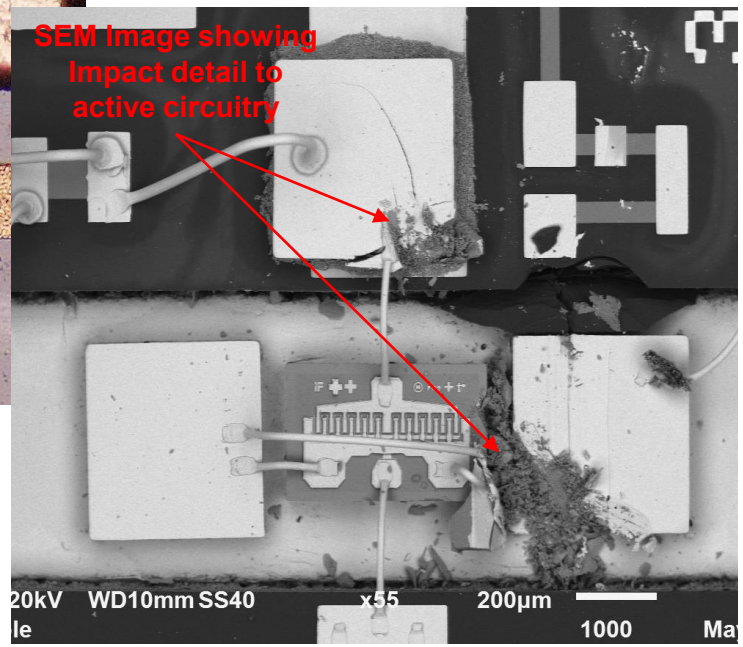
– Follow on analysis showed other failures were attributed to supplier assembly process defects.

Probe Impact in active areas; detached foils



Impact to Components & Die





A population of failed RF amps were analyzed for: Low gain, No Gain & Insertion loss

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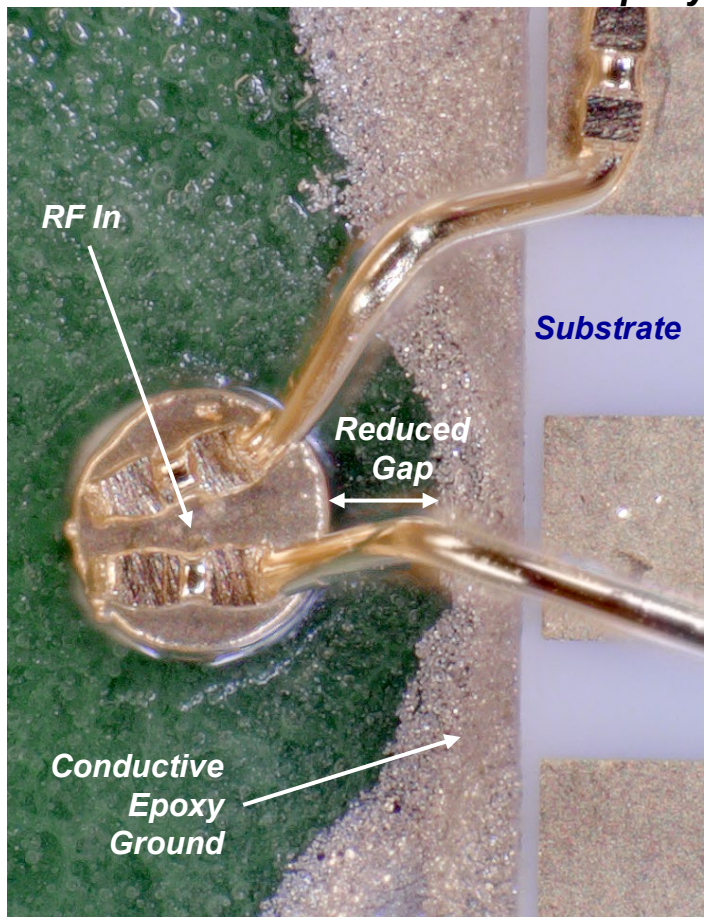
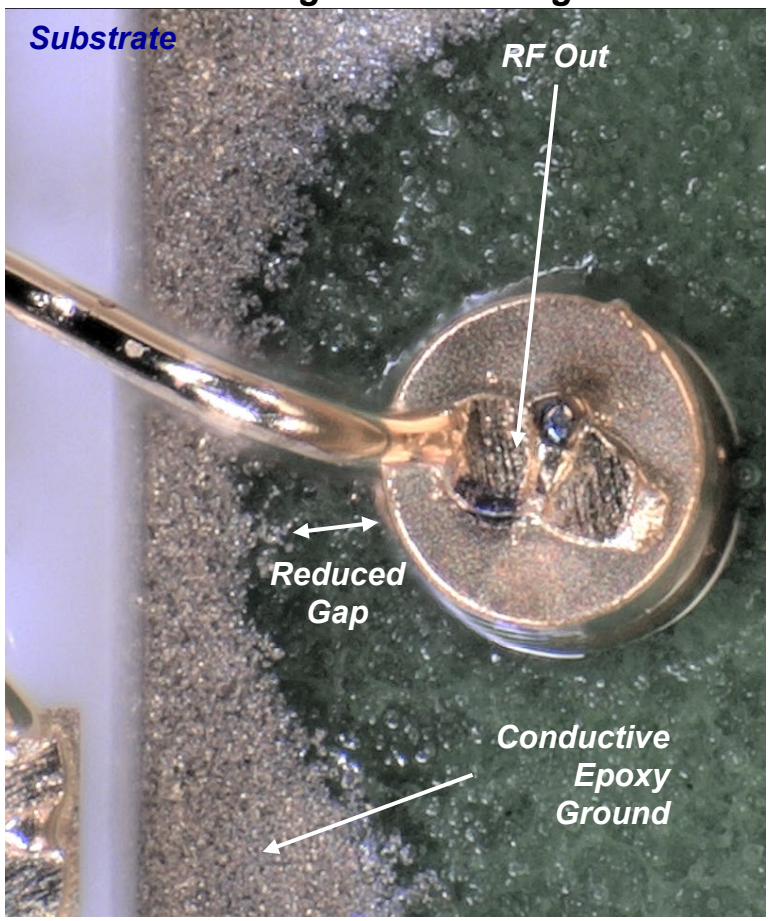
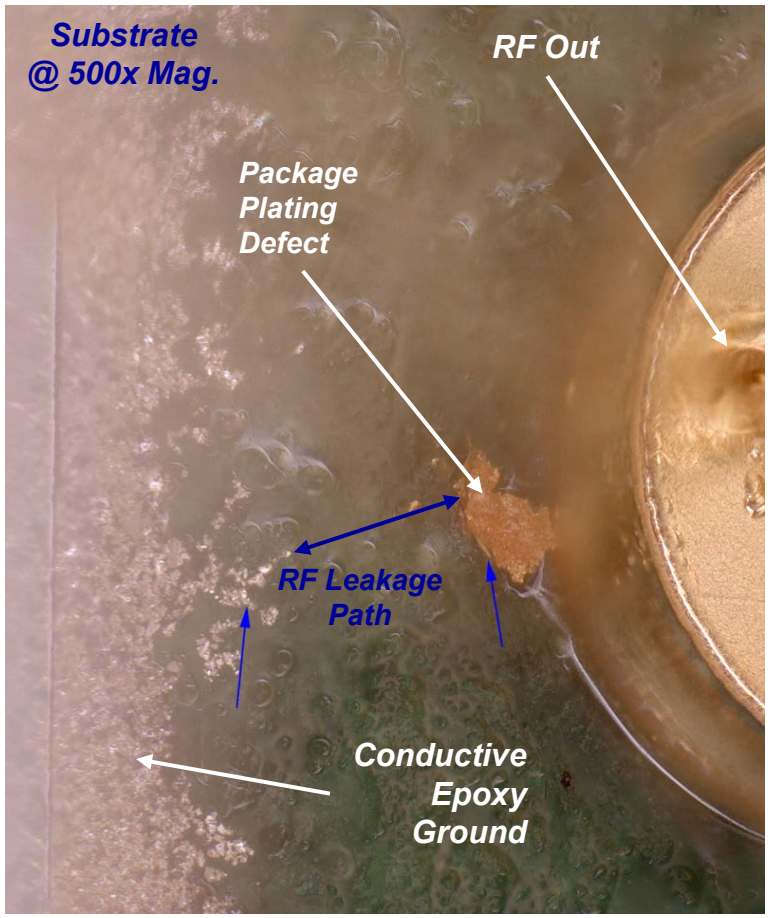
Example: COTS RF Amplifier, Findings (Post-Cap Analysis)

– Follow on analysis showed other failures were attributed to supplier assembly process defects.

Excess Epoxy and Substrate Alignment leading to Insertion Loss & Low Gain







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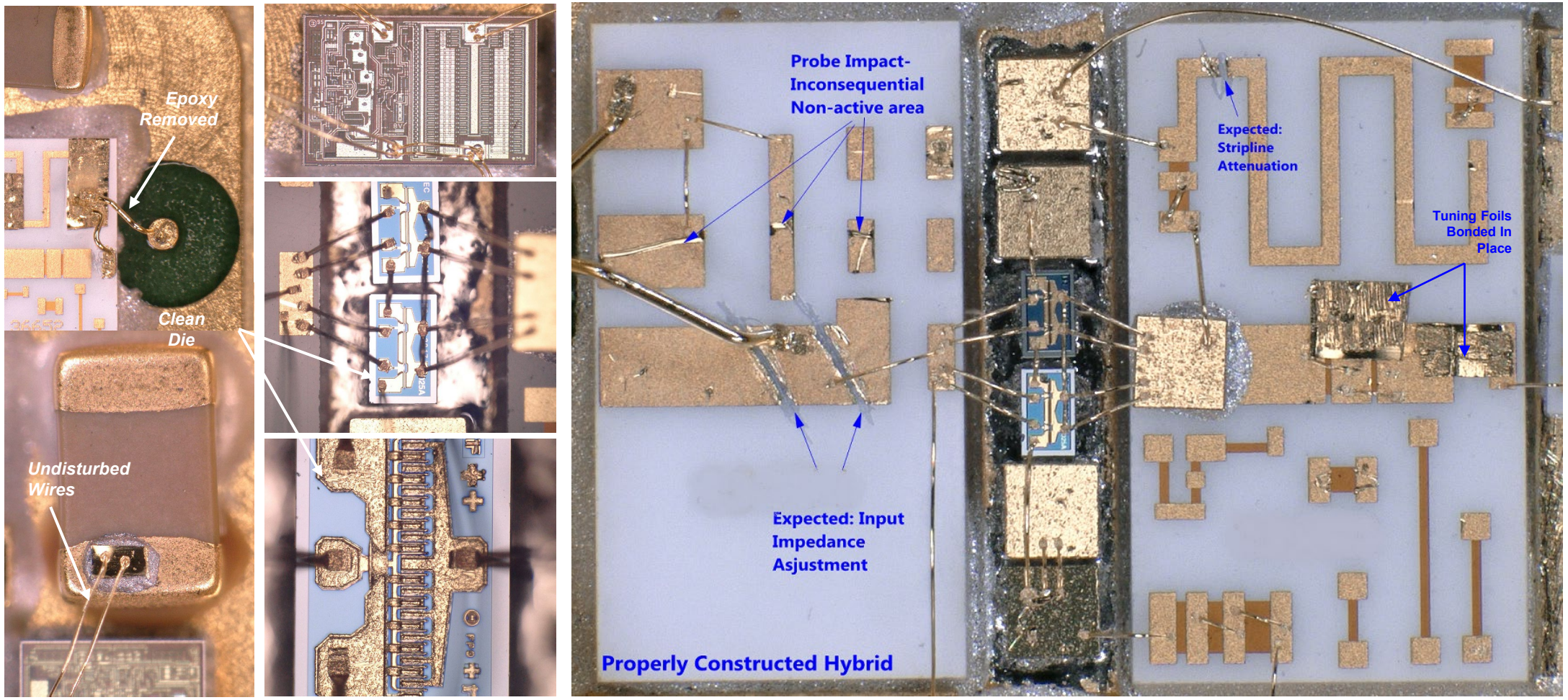
Example: COTS RF Amplifier, Conformance attributes

– Bond wires are un-disturbed, Substrate excess epoxy Removed.



No Contaminants, Tuning Induced or process Defects. Functions at frequency within operational extremes

Images Owned by RTX Corporation

Other Non-Conformances: *Impacting Functionality / Reliability*

- Hermetic Packages: *Moisture ingress immediate effects on RF circuitry*
  - *Defective feedthrough solder seal or fractured glass.*
  - *Defective Laser or Solder Seal.*
- Wire bond Issues: *Weak compromised attachment*
  - *Substrate trace contaminants (Exposure, Handling control).*
  - *Surface Oxidation (Exposure, Handling Control).*
  - *Trace Nickel layer oxidation (Pad lift, plating issues with substrate supplier).*
- Supply Chain Die Issues: *Availability & EOL results in a die change*
  - *Shift in electrical characteristics, timing or driving current.*
  - *Component topology does not allow for input protection diodes or circuitry rendering logic and control elements vulnerable to ESD.*
  - *Discrete die fabrication doping Issues: Can result in Resistors, Capacitors Diodes, Transistor performance shifts leading to failure.*
- *Substrate Issues: Driven by supplier quality*
  - *Circuit trace plating issues, substrate adhesion or Necking leading to opens (acts as a fuse)*

Conclusions

While the Military standards provide us with guidance on the performance and inspection criteria for the Class K, H & G category of devices, there are some issues with interpretation when evaluating (pre-cap inspection) or analyzing failures of the E & D class devices. Both the supplier and customer may have to negotiate the terms of what may be acceptable construction and quality in some instances.

Recommendations

- If the E or D Class device is essential to NHA functionality, a first article pre-cap inspection is recommended. Rework and replacement is costly!
- Extended testing, construction analysis & DPA is an alternative method to determine whether or not the acquired device has potential quality / reliability Issues
- Define requirements and request objective evidence of product functionality / conformance in product acquisition documents.
- Review the COTS supplier's product specifications in detail! Requires engineering review of the Test flow, Assembly, Quality and Inspection protocol and what stated exceptions there are to the standards.

Thank you for your Time!

Abstract:

When it comes to inspection and failure analysis, we often refer to Performance specifications in MIL-PRF-38534 and visual inspection criteria defined in MIL-STD-883 TM2017. Conformance and failure criteria depends upon which level the hybrid assembly was built to and oftentimes with custom and commercial grade hybrids this can be a challenge. Understanding how the sub-assembly is utilized at the system level and what the deployed environmental requirements are, aids in interpreting how well the hybrid will perform in the intended environment. We will review several examples design assembly and process non-conformances which resulted in hybrid and next higher assembly failures and how these issues were addressed.