DPA 2025

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What is DPA (Destructive Physical Analysis)?

- A sequential deconstruction of an electronic component with the intent to identify defects which are known to affect long term reliability in the intended (Hi-Rel or high reliability) applications. Think Space, Missiles, Nuclear Weapon Fuses, Military Equipment, Teelecommunication

- Previous failures inform the criteria applied to prevent failures in the future.

- What Failures? Early missile failures, infamous fuses in World War II American torpedoes, Botched Rocket Launches or Satellite failures (like Corona spy satellites). In all these cases, Failure Analysis was performed where possible to identify the causes.

What is DPA (Destructive Physical Analysis) cont'd.?

- Some people call Failure Analysis DPA! And they aren't really wrong....
- You actually destructively disassemble the non-functional device to determine its root cause of the Failure.
- The difference between our first definition and the one above is that we are using the results of a Failure Analysis to inform the correct test plan and specification for a DPA that will actually prevent failures from happening at all! (Think about JD Powers' new car surveys that identify the best Car to buy based on the numbers of defects found at warranty repair). The thought being that fewer defects built into a system results in fewer failures in the long run. The thinking is the same.

What is DPA (Destructive Physical Analysis) cont'd.?

- DPA is applied to specific pedigreed lots of components with unique Part Numbers (P/N) built in a short time window known as a Lot Date Code (LDC). Each DPA represent a single P/N and LDC

- Sample sizes typically range from 1-5 samples but can range up to 30.

- If you've studied statistics much, you will know that looking at 1-5 samples will not give you a very strong Confidence Interval (CI) ! It takes 22 pcs. of a (homogenous) population to achieve a 90% CI.

- What does that mean (pun intended)?? It means that you are only 90% confident in finding an outlier (defect) in the population you're sampling. Sampling 1 device shouldn't even find anything..... But that's another story.

What is DPA (Destructive Physical Analysis) cont'd.?

- When did lot level testing and the concept of DPA Testing come about?
- The lot level inspection concept came from the Minute Man program built by North American Aviation Autonetics Div. (became Rockwell and then Boeing) which had incredible reliability for its time in the early 60s.
- The Apollo program also built by North American Aviation borrowed the concept and took it further being the first program to use Integrated Circuits (Microcircuits) in a Hi-Rel application (manned space flight)! Jayne Partridge of MIT developed the reliability program for Apollo.

What is DPA (Destructive Physical Analysis) cont'd.?

- The concept of a "Microcircuit" came about in the late 50's on the Atlas ICBM program. Dr. Wen Tsing Chow of American Bosch Arma Corporation needed to build a navigation guidance system (a computer) that would fit on the tip of a missile (weighing <500 lbs.) Dr. Chow was the first to conceive of the concept of “photo-chemical circuits” or the micro-miniaturization of electronic devices to achieve this end. He built the first “ integrated circuits” on ceramic substrates to accomplish this goal. His pioneering efforts led to the creation of the modern semiconductor industry. The reliability of his integrated circuits and thus the Guidance and Control Computers relied heavily upon highly controlled manufacturing practices and testing to ensure their reliability

- This reduced the size of a computer from a room to a few feet.

What is DPA (Destructive Physical Analysis) cont'd.?

- ARMA lost the competition to build the G&N Computer for the Minuteman I to Autonetics. His fundamental research in “integrated circuits,” which the Air Force owned, was utilized heavily by Texas Instruments to create the first integrated circuits on germanium. This was the first program to use integrated circuits in space.

- The Apollo Guidance & Navigation Computer program led by the Instrumentation Laboratory of MIT also concluded integrated circuits would be required to provide the necessary computing power and reliability for the Apollo missions.

What is DPA (Destructive Physical Analysis) cont'd.?

- In November of 1965, Jayne Partridge, Eldon C. Hall, and L. David Handley, all of the MIT Instrumentation Laboratory, presented a paper to the 3rd annual Symposium on the Physics of Failure in Electronics titled " The Application of Failure Analysis In Procuring and Screening of Integrated Circuits".

- Within this paper, the fundamental concepts of DPA were laid out from which a specification was generated titled Apollo G & N Specification ND1002248. This specification was applied with tremendous success by the Raytheon Co. on the Apollo G & N Computer program.

What is DPA (Destructive Physical Analysis) cont'd.?

- This paper presented the dilemma that Non-Destructive electrical screening and Accelerated Aging schemes alone could not ferret out devices with built-in construction defects that had long times (years not hours) to failure associated with them.

- It further proffered the concept of statistically significant sampling for the employment of a Pre-Cap Visual Inspection program for all integrated circuits being utilized. This was something new! The Apollo G&N Specification ND 1002257 was drafted and utilized during the program. The current military standard test methods for this inspection still mirror this document to this day!

What is DPA (Destructive Physical Analysis) cont'd.?

- Following the successful approach used on Apollo, the first programs to employ DPA as we know it today were Fleet Satcom at TRW and Trident at Hughes Aircraft in the 1972 time-frame. “Black” satellite programs were also looking to improve their reliability and began employing DPA.

- We were there! Hi-Rel Laboratories,Inc. was the first non-OEM/Government lab to perform DPA for these 2 programs in the 1973 timeframe.

- **DPA Specifications Proliferated**
  LMSC D329716, TRW M273876, Boeing D-290-10020-10, GSFC S-311-70, NSA 77-30, Rockwell MF-0001-004, GD 4-00A0001, RCA RE-100 and a host of others.

  Mil-Std-1580, the Air Force DPA document, was released in 1980 and drew heavily on the LMSC D329716 document

What is DPA (Destructive Physical Analysis) cont'd.?

- Military, Civil, and Commercial Space Programs relied heavily on DPA as a means of culling out built in defects. These programs included: Space Shuttle, GPS, UHF, DMSP, DSCS, Atlas, Delta, Goes, Mil-Star, Titan, to name just a few.

- Reliability soared, but the $600 hammer of the late 1980s fostered the “faster better cheaper” mind set championed by Perry and Goldin. The costly results of this misguided approach still linger like a bad hangover.

- Further refinements and consolidations of the DPA specifications occurred during and most notably following the “faster better cheaper” period. In 2003, Mil-Std-1580 Rev. B was released. Many other specifications in fact defer to this document including NASA DPA specifications. Additionally, a mechanism now exists to bring out revisions to this specification faster than the previous 13 year period at Rev. A. which came out in late 1989.

What is DPA (Destructive Physical Analysis) cont'd.?

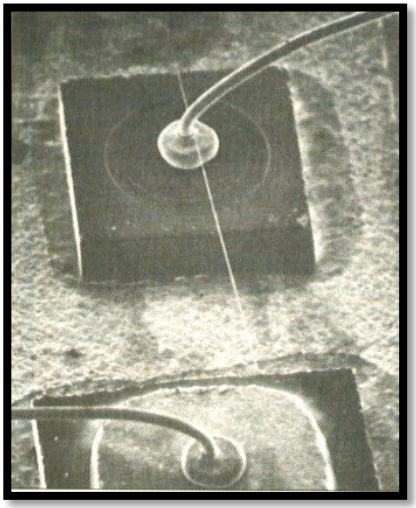
- It's humorous to note that the next full revision (C) to Mil-Std-1580 did not come out until late 2019! However, 3 changes up to w/CHANGE 3, were made on shorter intervals to the B revision. The biggest change was the addition of Prohibited Materials Analysis (PMA) Testing for the presence of pure Sn, Cd, or Zn in 2011 to w/CHANGE 2.

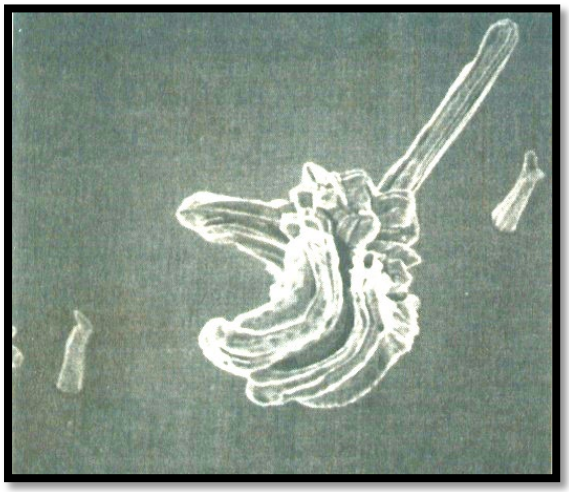
- Most of the preliminary work for Rev. D has been completed and is awaiting authorization from Aerospace Corp. to proceed.

History of PMA

In the mid 80's F-15 Radar Systems were intermittently failing

- localized to the controller hybrids, Hi-Rel discovered a large number of fine wire-like Sn whiskers (~0.1 mils in diameter) bridging different die
- Upon formation of the short, the whiskers would vaporize leaving no evidence behind and explaining the intermittency.
- The source was the pure Sn plated interior lid
- Air Force and others put out a mandate prohibiting the use of Pure Sn platings





History of PMA

In 1996, several HS-601 Spacecraft failed on orbit due to their controller microprocessors being shorted out.

- Problem was isolated to the relays that controlled power to the processors
- Re-examination of the ground spares showed the hook lead terminals and bodies were pure Sn plated

- Previous research by the same manufacturer revealed Sn whiskers formed on these hooks when placed in a vacuum, creating a self sustaining arc permanently latching the relay
- On orbit the result was catastrophic!

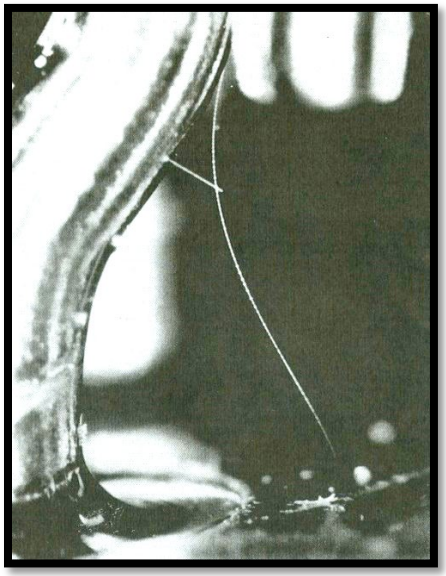


Photo From ISTFA 1992 Proceedings.
"Tin Whisker Induced Failure in a Vacuum"
Authors: D.H. Van Westerhuyzen, P.G. Backes, S.C .Merrel, and R.L.Poeschel - All with Hughes Aircraft.

History of PMA

Research prior to and after these events led to the conclusion that an alloying content of >2% was necessary to retard whisker formation in Sn.

This led to the introduction of Prohibited Materials Analysis (PMA) testing by the manufacturer of the HS-601 and eventually the rest of the industry

Cd and Zn were also known to form whiskers so these were also to be analyzed for.

Problem fixed use Sn/Pb solder!

RoHS (2/2003) – Restriction of Hazardous Substances in electrical and electronic equipment - 6 hazardous materials: Pb, Hg, Cd, hexavalent Cr, PBB, and PBDE (polybrominated phenyls)

As the EU ROHS initiative neared implementation (7/2006), more and more manufacturers switched over to replacement solders.

Typical Pb-Free solders:

- 96Sn/4Ag and 96Sn3.5Ag0.5Cu
- 95Sn/5Sb
- Sn/Bi
- Pb/Bi (not recommended due to extremely low melting point)
- Ni/Au/Pd alloys
- Pure Sn!

RoHS Compliant

Purpose

(9.1.1 or 9.2.1)

This test method establishes the instrumentation, techniques, criteria, and standards to be utilized to measure the Pb content of Sn-Pb alloys and electroplated finishes containing at least 3 wt% of Pb, Cd and Zn surface finishes, and Zn and Cd bearing alloys without sufficient plating to provide a barrier to Zn sublimation using SEM-EDS or XRF equipment (9.1.1 or 9.2.1)

- Control the use of Sn, Cd, Zn – 3 elements
- Prevent Sn, Cd, and Zn whiskers
- Prevent Zn sublimation

Must have greater than 3% Pb – Why?

- To mitigate whiskers research shows you need ~2% alloying element to eliminate the stress in a tin plate

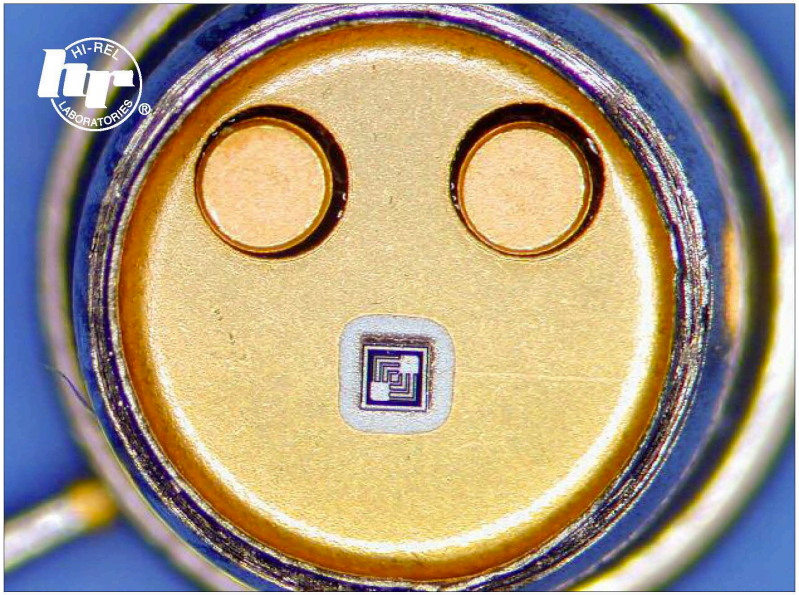
- 97% was chosen due to acknowledged inaccuracy in EDS and XRF

AUGUST 2012 - A Tin Whisker Extruded from the face of a X-sectioned solder joint.

ELAPSED TIME ? OVERNIGHT !.

Why We Do DPA

APRIL ✦ 2005



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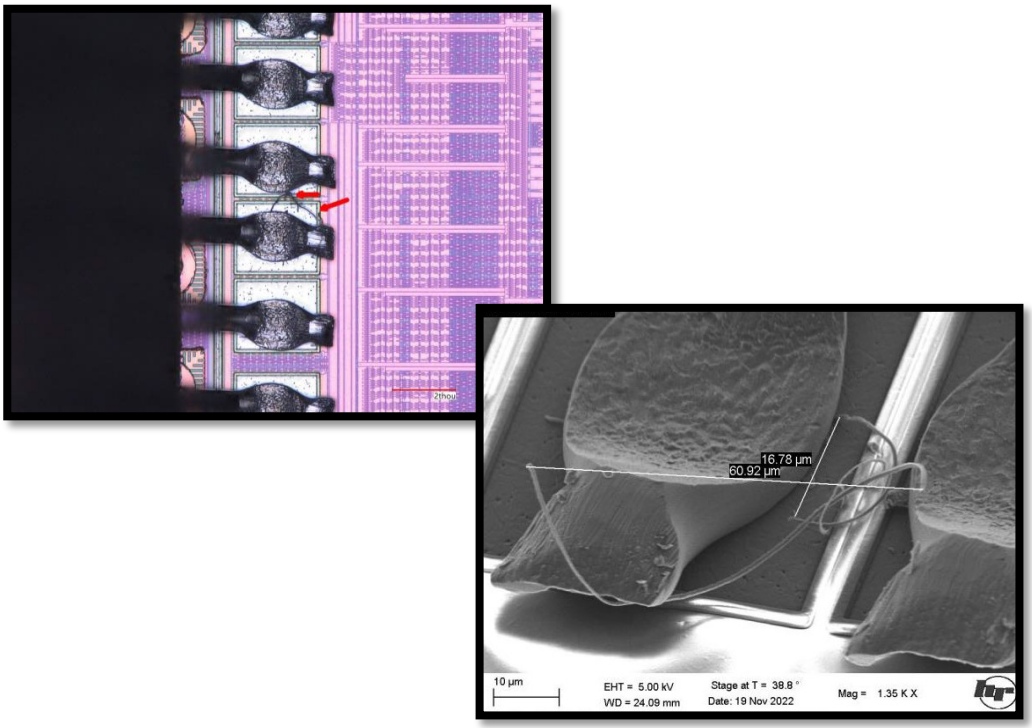
It's no April fool joke! Found this when we opened the device—a JANTXV part, of course—thought at first "Blue Tooth" technology had finally made its way down to the component level. The manufacturer has to say we knocked them off when we opened the part… but…there are no bond impressions on either the die or posts. Hope you EEE parts managers are taking notes. —*Bill Collins*

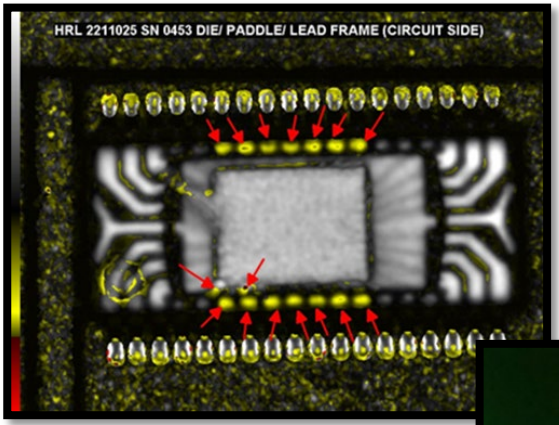
WHY WE DO DPA!

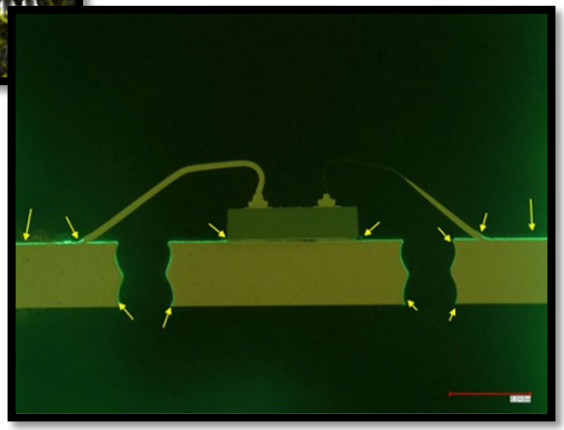
Loosely Attached Debris



WHY WE DO DPA!

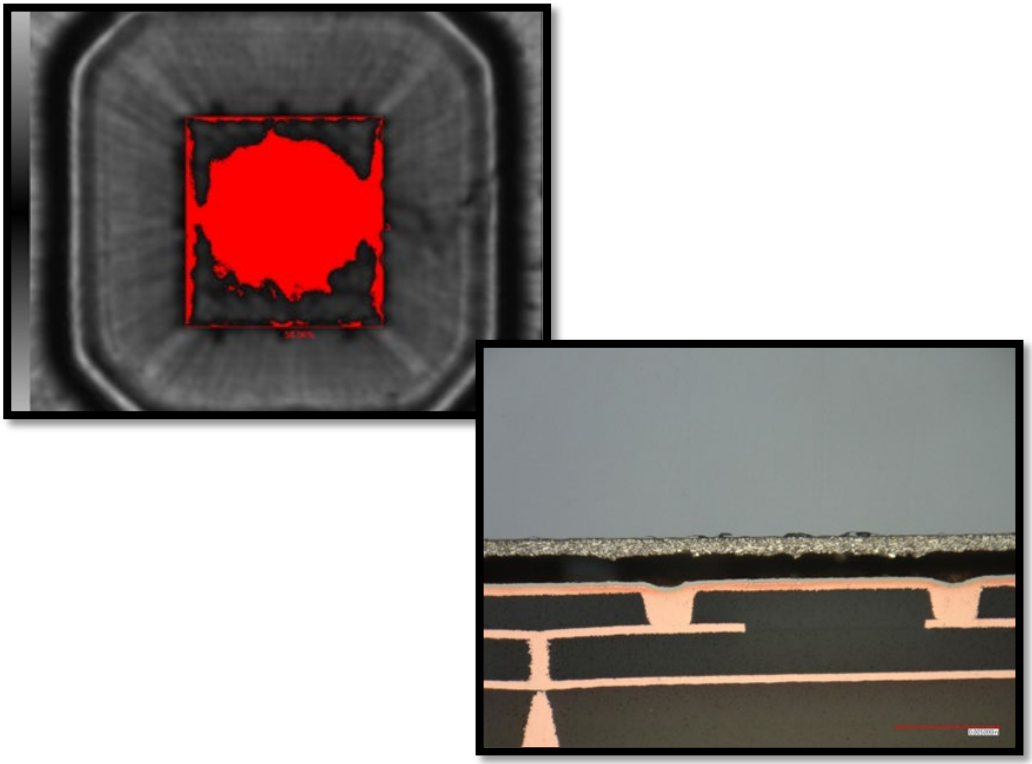
Delaminated Packages





WHY WE DO DPA!

Poor Die Attach



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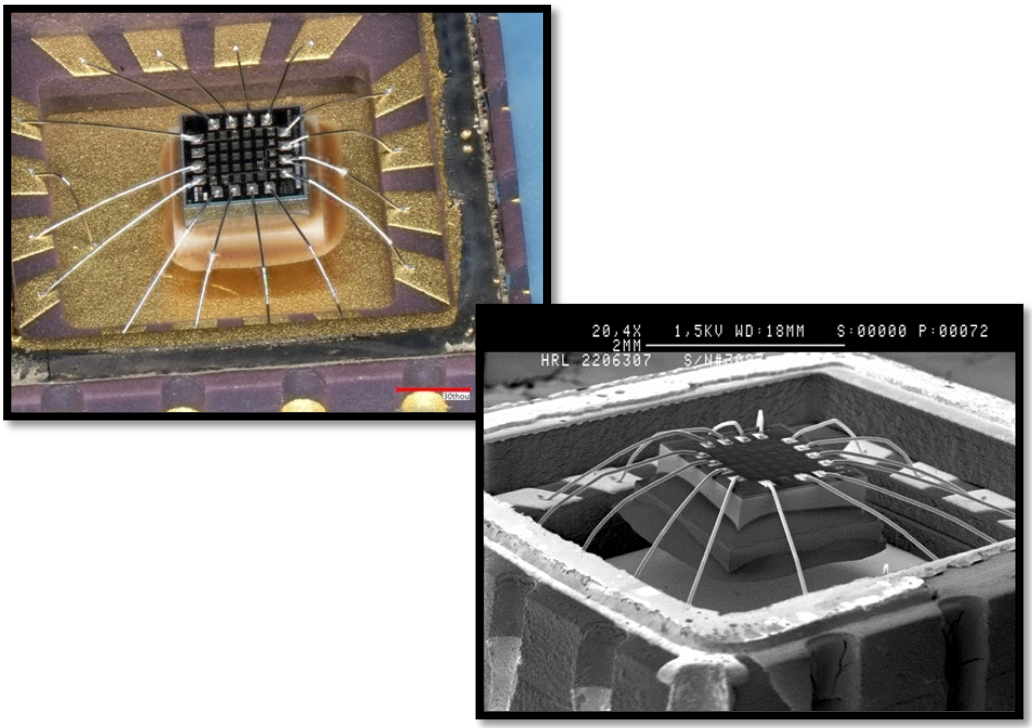
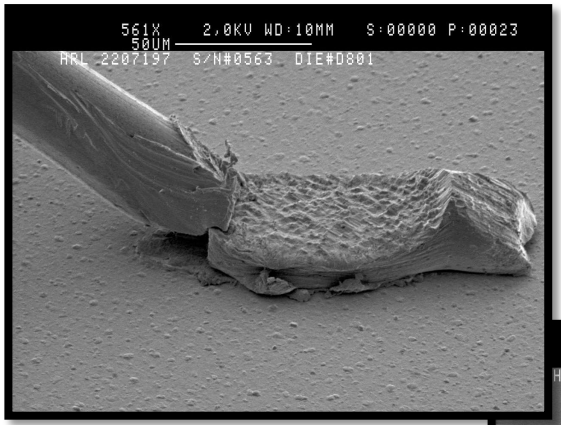
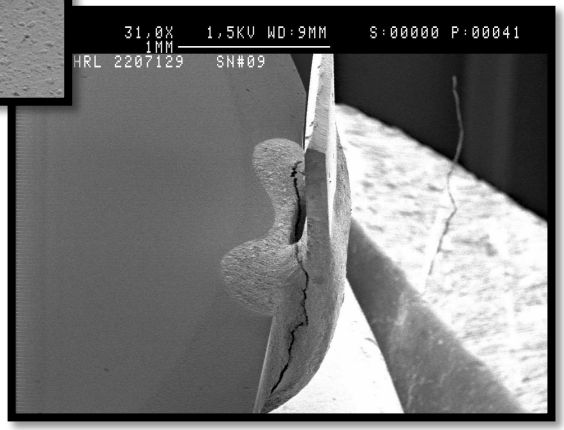
Poor Die Attach



WHY WE DO DPA!

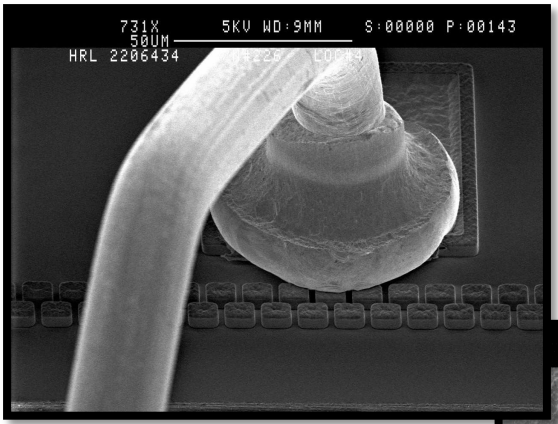
Fractured Connections

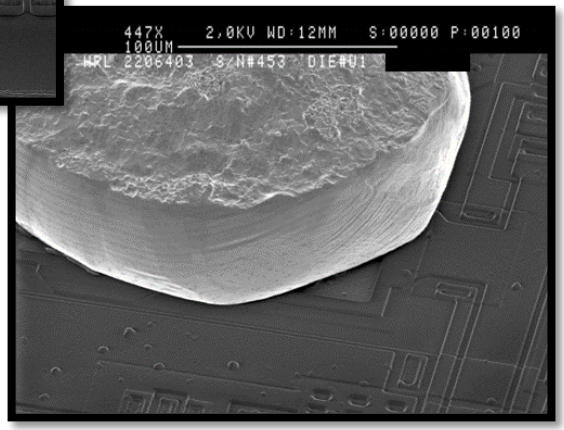




WHY WE DO DPA!

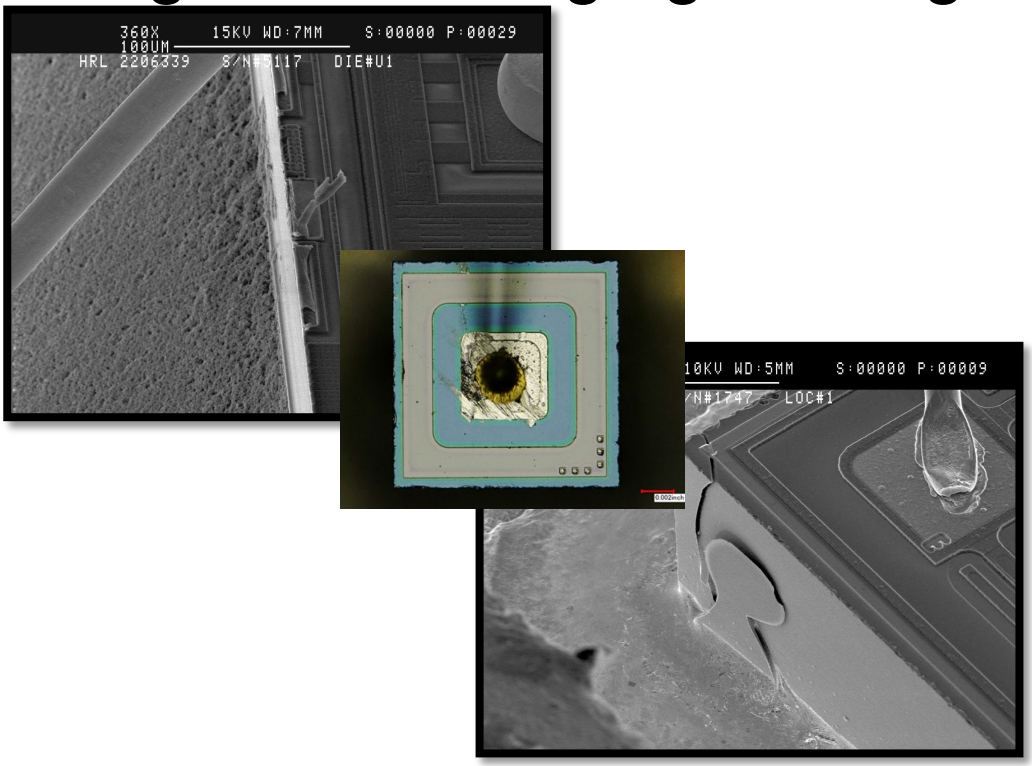
Bonds Over Non-common Metal





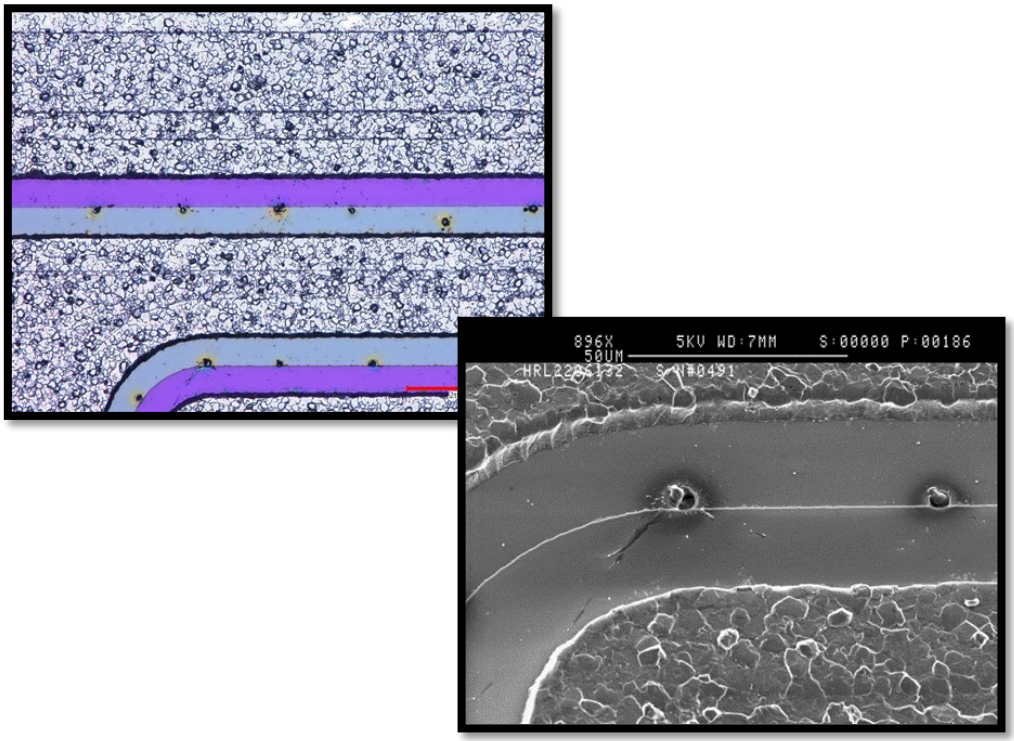
WHY WE DO DPA!

Dicing and Packaging Damage



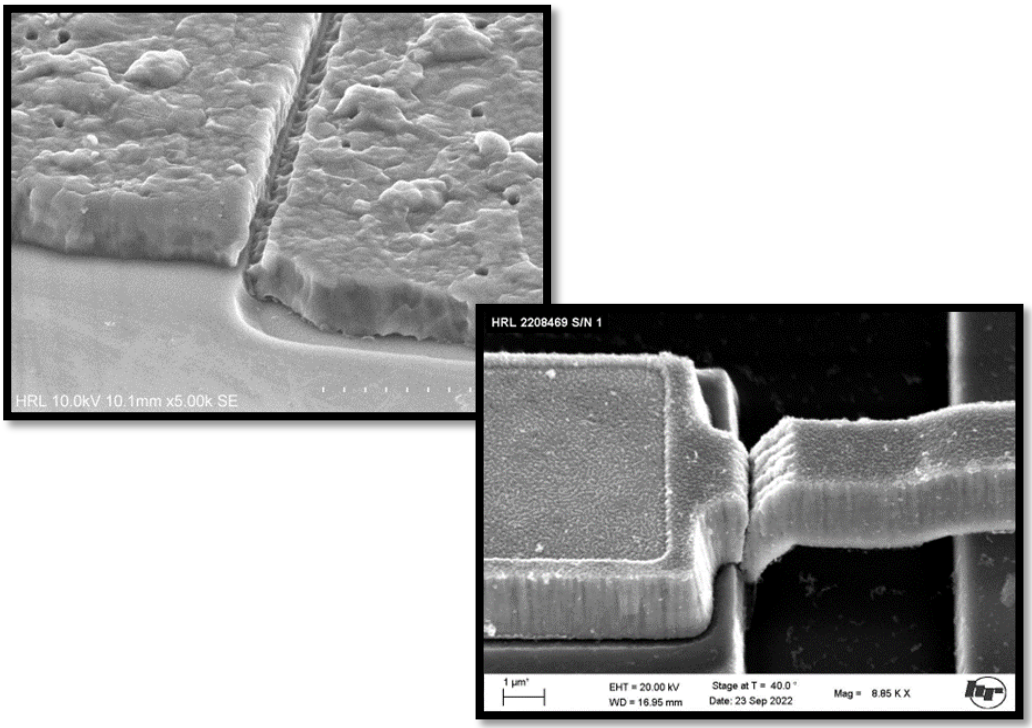
WHY WE DO DPA!

Electrical Test Damage

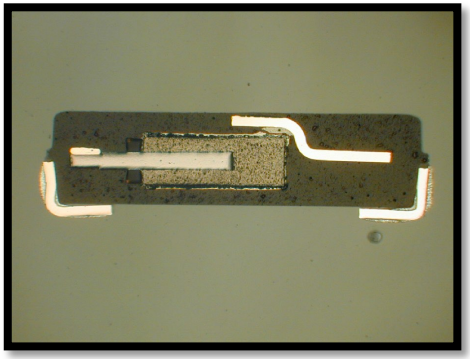


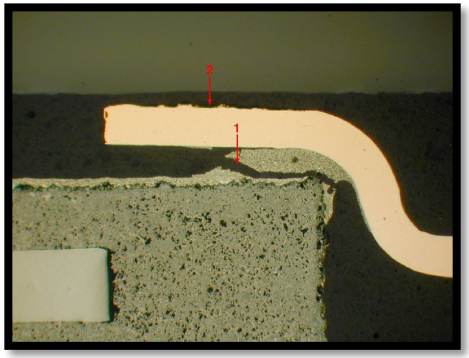
WHY WE DO DPA!

Poor Step Coverage

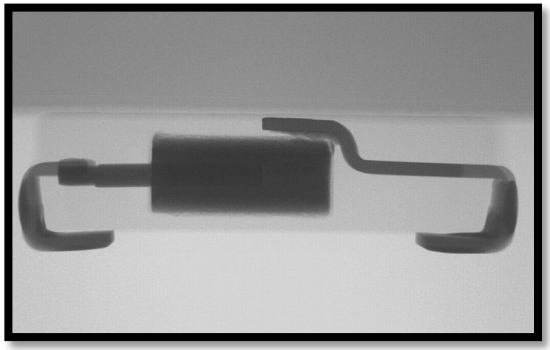


WHY WE DO DPA!

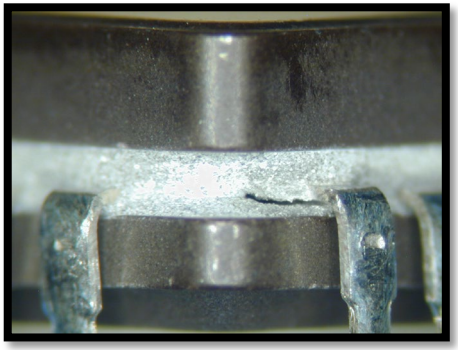


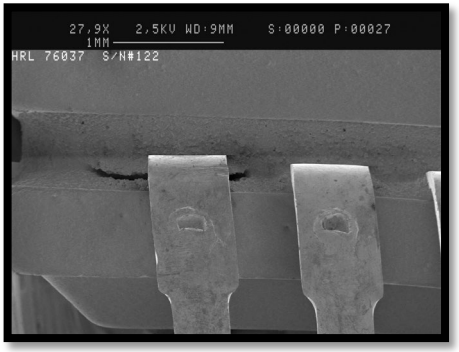


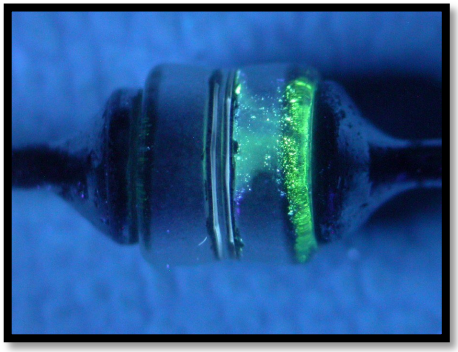
A ROUTINE DPA IDENTIFIED A DEFINITE PROBLEM WITH THE CATHODE SILVER EPOXY LEAD ATTACH IN THIS TANTALUM CHIP CAPACITOR.



WHY WE DO DPA!

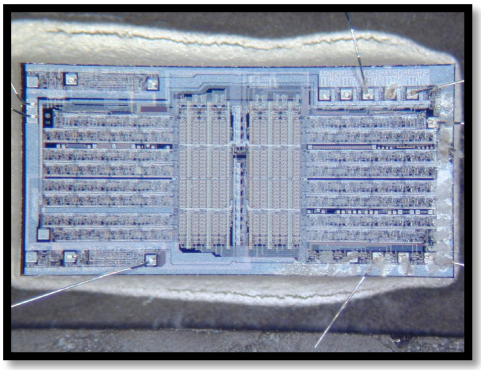


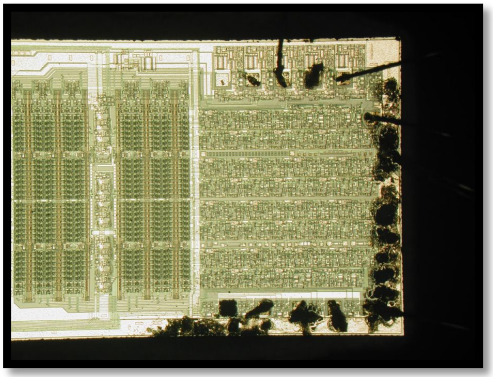




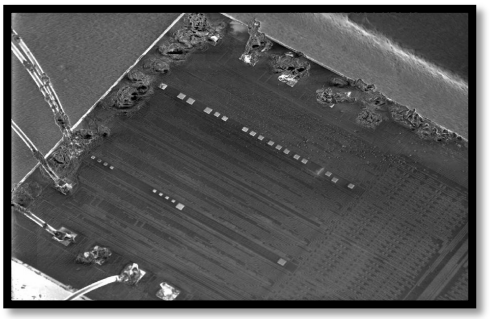
DEVICES WITH HERMETICITY ISSUES.

WHY WE DO DPA!



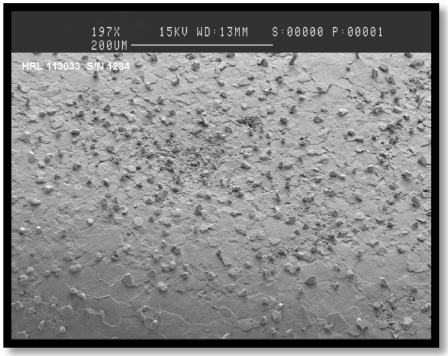


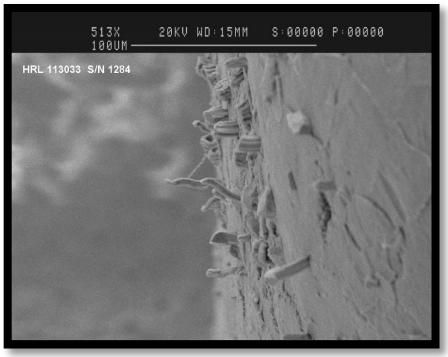
A DIE VERIFICATION OF A 13 YEAR OLD B LEVEL I.C. REVEALS THE IMPORTANCE OF HERMETICITY AND RGA TESTING AS EVIDENCED BY THE CORROSION IN THIS PART.



WHY WE DO DPA!

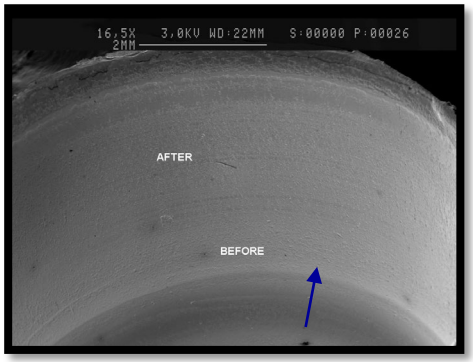
PURE TIN PLATED CAPACITOR END METALLIZATION. NOTHING TO WORRY ABOUT, RIGHT?

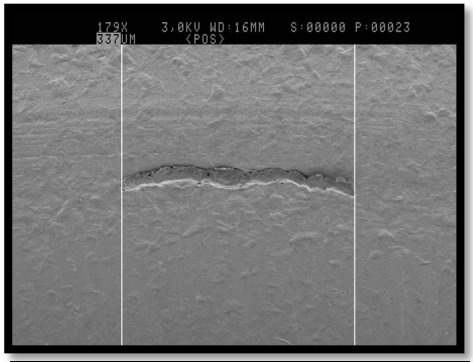




WHY WE DO DPA!

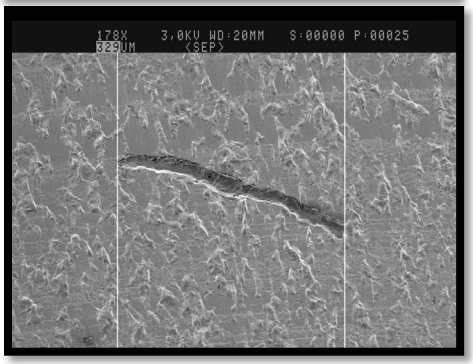
NICKEL FLAKES CAUSED FAILURES IN TO- STYLE CANS IN LATE 2004





13.3 MIL BURR BEFORE PIND

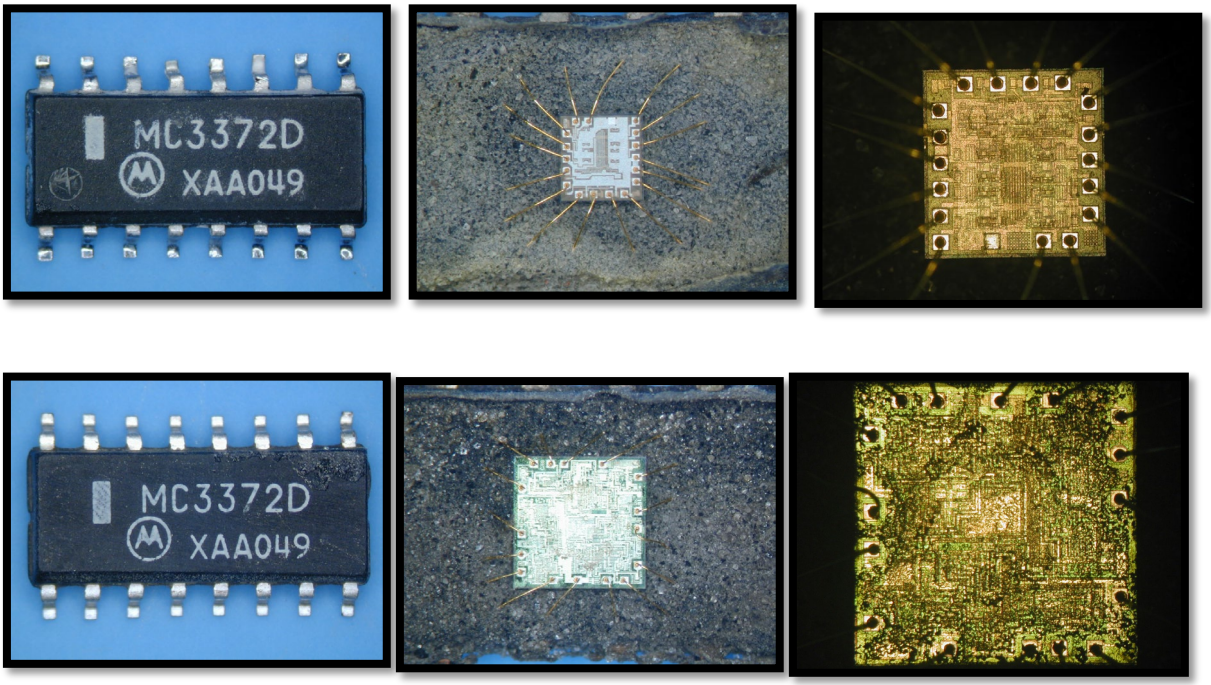
CAN NICKEL FLAKES MOVE?
YOU BET! THIS ONE WAS EVEN MAGNETICALLY ATTACHED AND SLID UP THE WALL AT PIND .



AFTER PIND

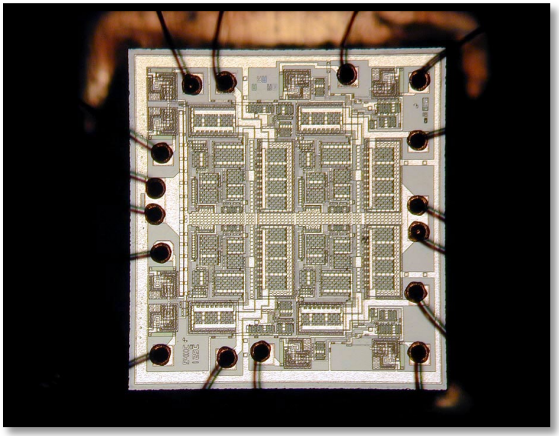
WHY WE DO DPA!

ARE THESE PARTS THE SAME?

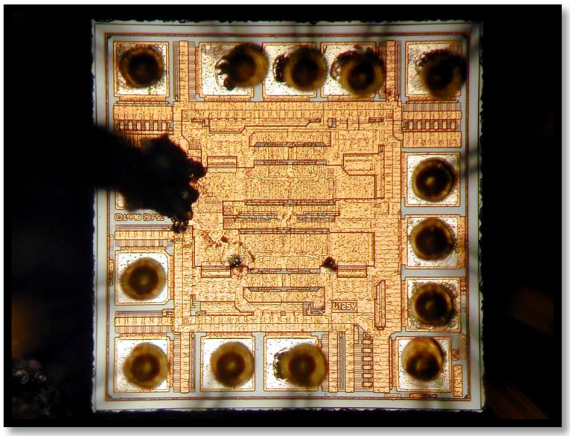


WHY WE DO DPA!

DIE SHRINK CAUSED COMMERCIAL SYSTEM FAILURE!



OLD DIE- 60X

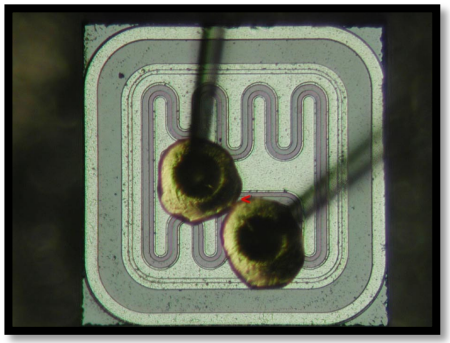


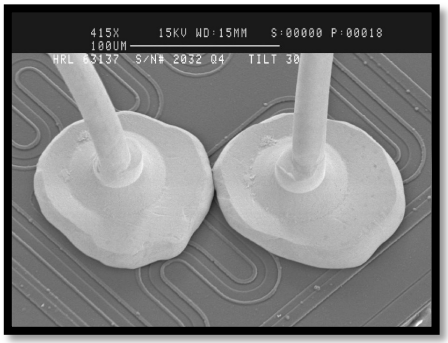
NEW DIE - 240X

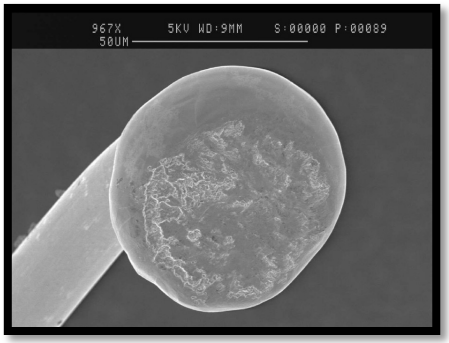
COMPARE BOND PAD SIZE - THEY ARE THE SAME DIMENSIONS ON BOTH DIE. THE NEW DIE IS BARELY 25% OF THE ORIGINAL DIE SIZE - USES DOUBLE LEVEL METAL AND POWER DISSIPATION IS CONSIDERABLY LESS.

WHY WE DO DPA!

Classic Internal Visual and Bond Lift Failures.

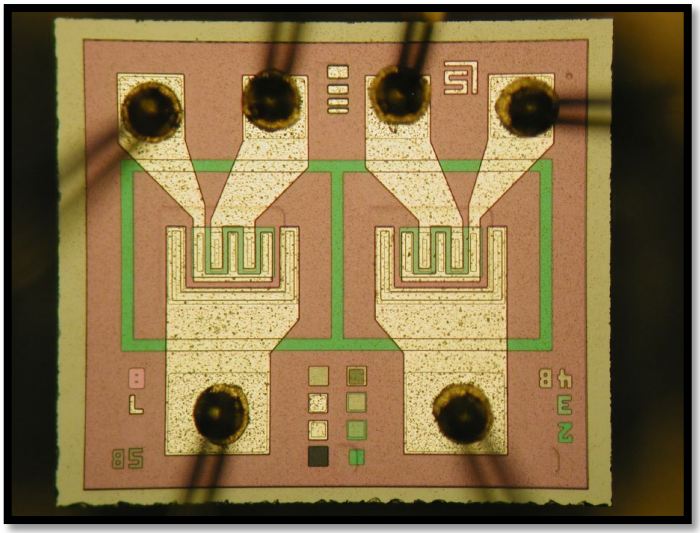


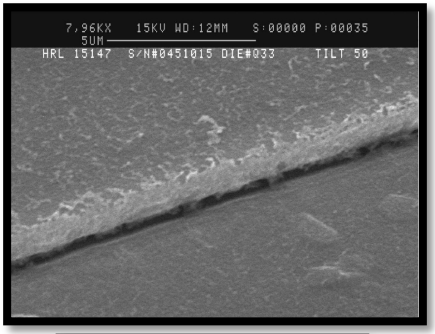


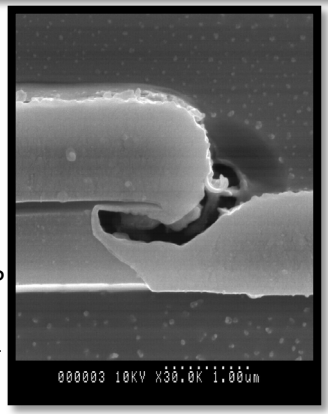


WHY WE DO DPA!

METALLIZATION STEP COVERAGE IN A TRANSISTOR WITHIN A DC-DC-CONVERTER HYBRID.





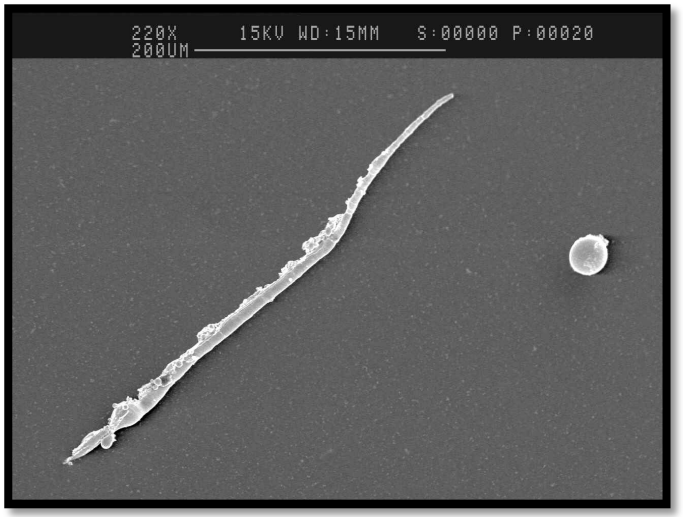


CAUGHT AT FINAL DPA OF A HYBRID. WHAT HAPPENED TO WLAT?

COLLECTOR STEP OF TRANSISTOR. NOTE 2% METAL COVERAGE.

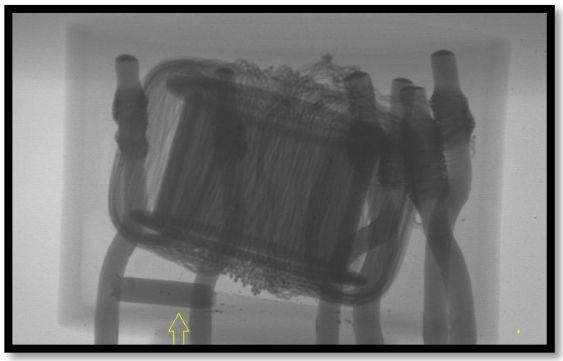
WHY WE DO DPA!

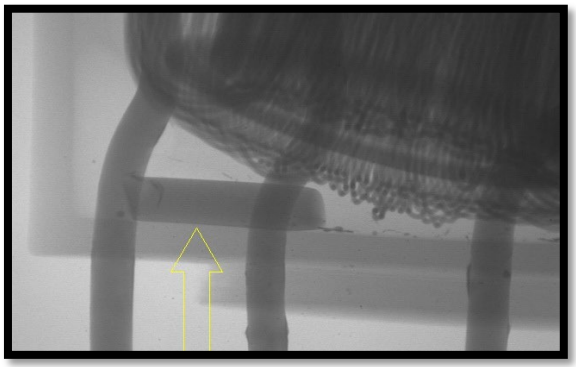
PIND TESTING DURING DPA OF AN I.C. HAD INDICATED PARTICLES. SUBSEQUENT PARTICLE TRAP AND SEM/EDS REVEALED GOLD-TIN PARTICLES FROM THE LID ATTACH WERE TO BLAME. NOTE THE LENGTH OF THE ELONGATED PARTICLE.



WHY WE DO DPA!

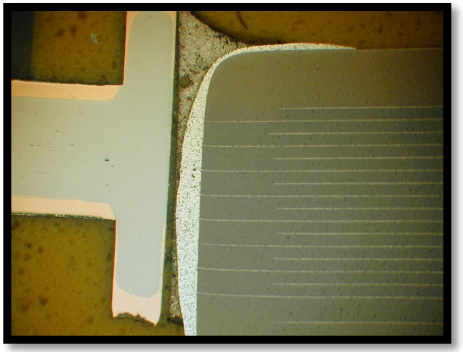
X-RAY DURING A RECENT DPA OF THIS MAGNETIC DEVICE REVEALED A LITTLE SOMETHING EXTRA IN THE ENCAPSULANT.

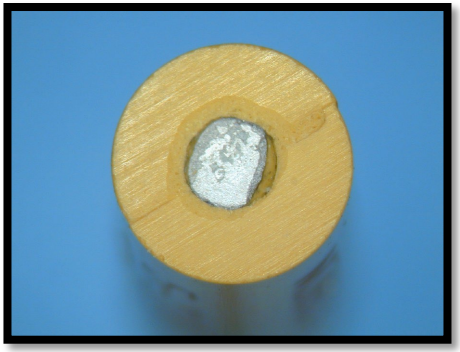


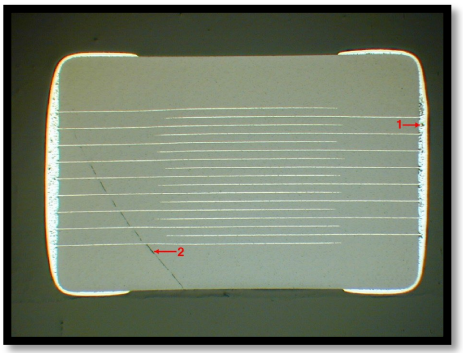


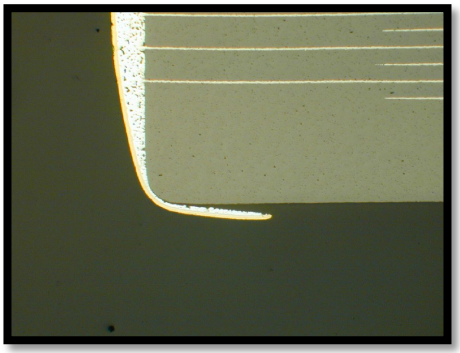
WHY WE DO DPA!

CAPACITORS HAVE TROUBLES TOO.



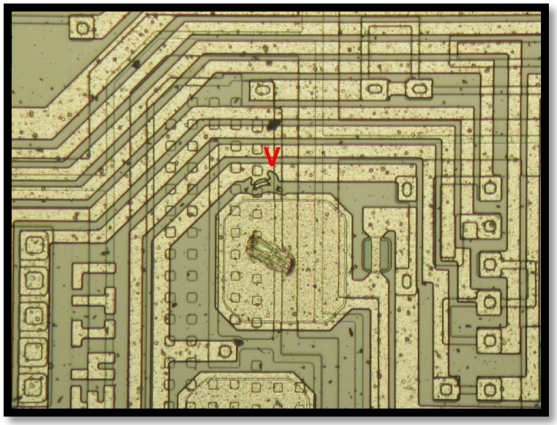


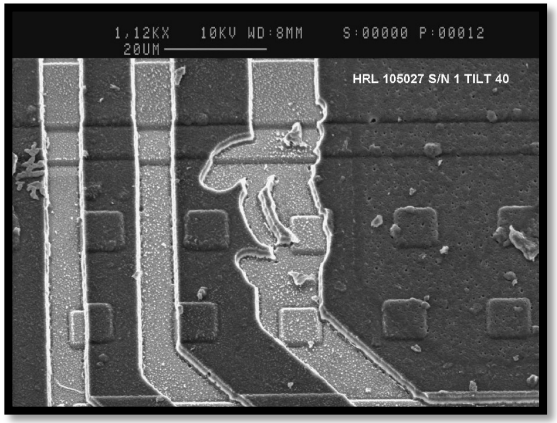


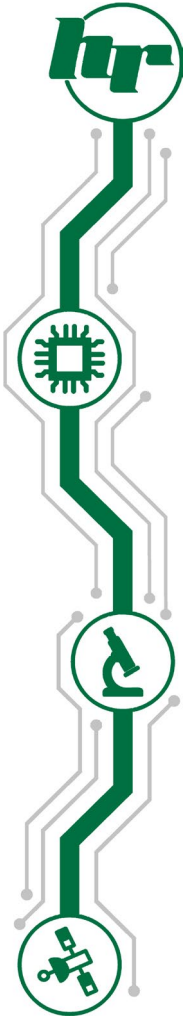


WHY WE DO DPA!

INTERNAL VISUAL INSPECTION OF THIS I.C. DURING DPA NOTED A METALLIZATION PATTERNING DEFECT. LOOK AT IT LONG ENOUGH AND YOU MIGHT SEE A BIRD IN A TOP HAT ON A PERCH.







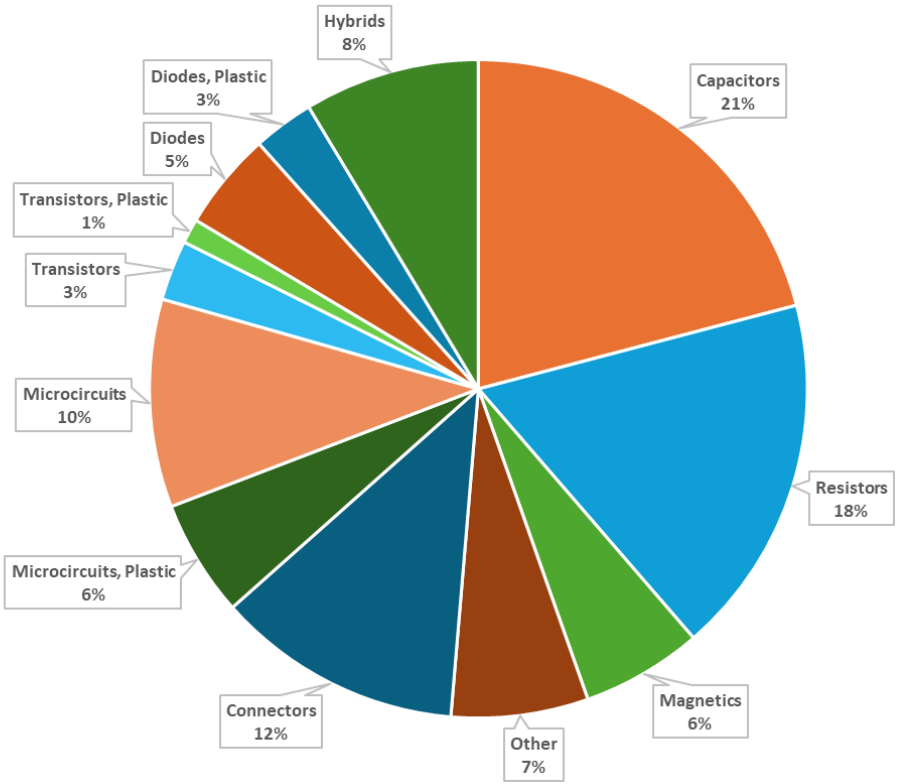
Hi-Rel Laboratories
2024 DPA Review

Trevor Devaney
President, Hi-Rel Laboratories

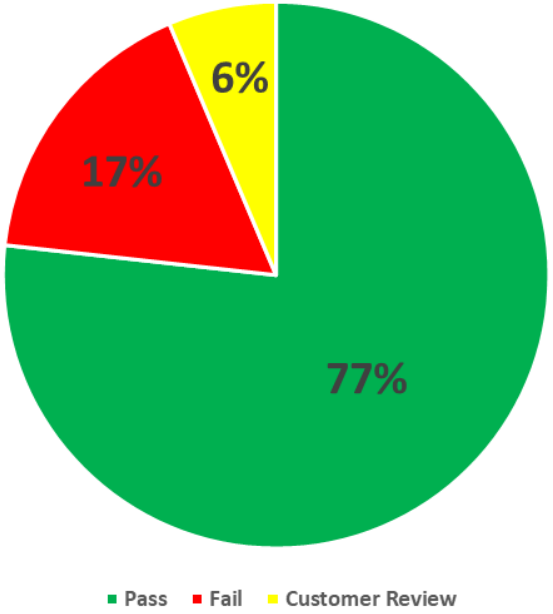
Discussion Topics

- DPA Results – 2024
- Why Do DPA?
- Q & A

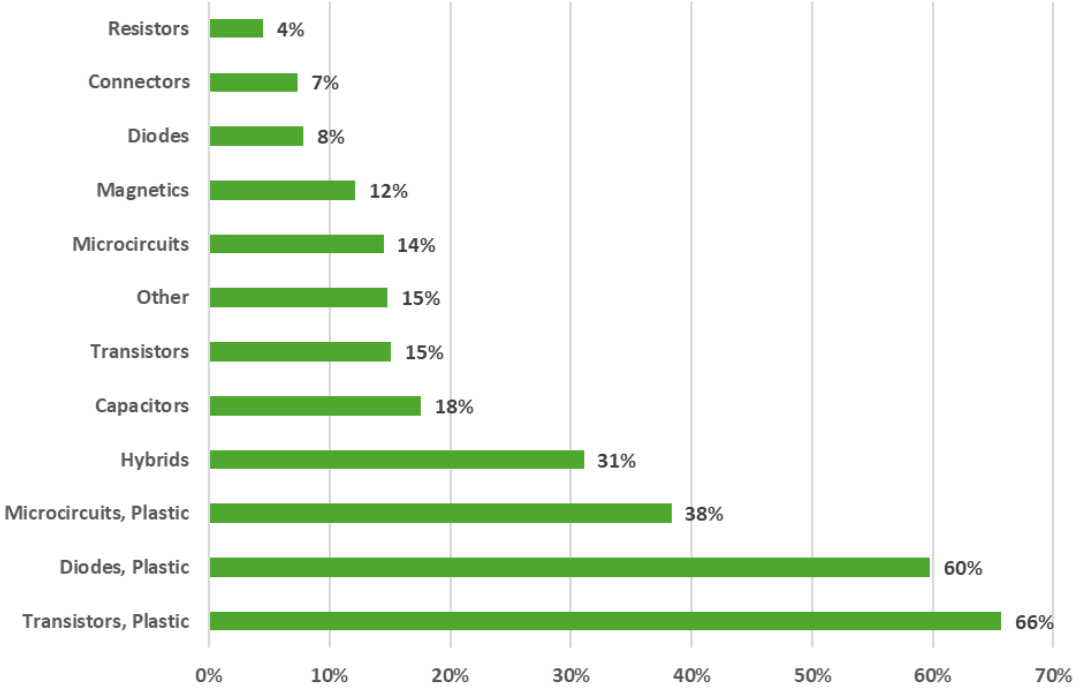
2024 Part Type Distribution

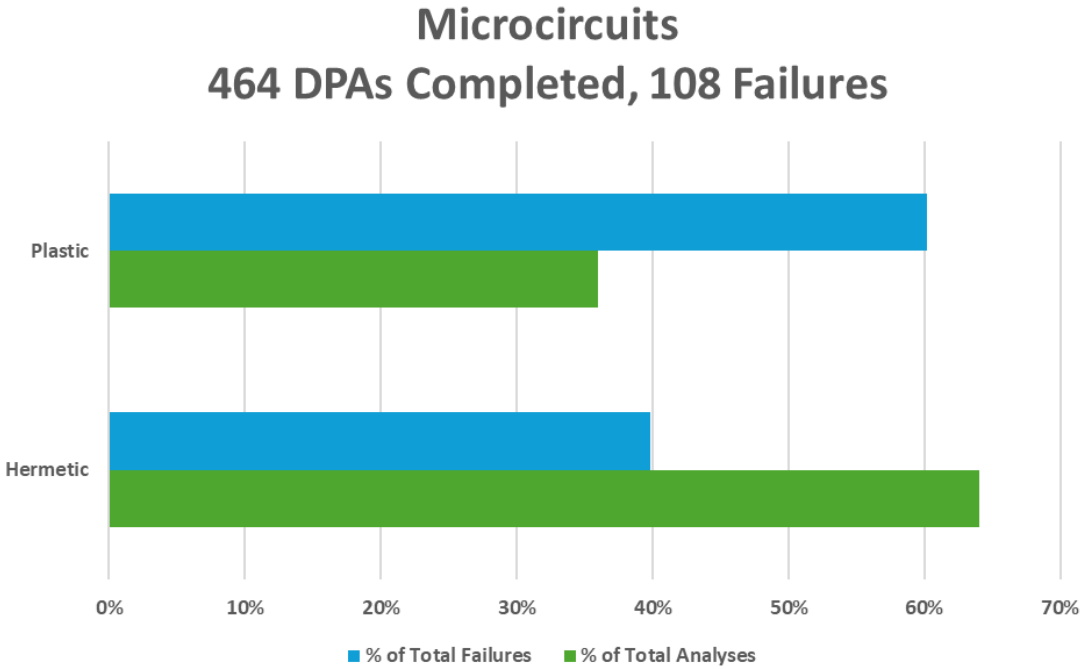


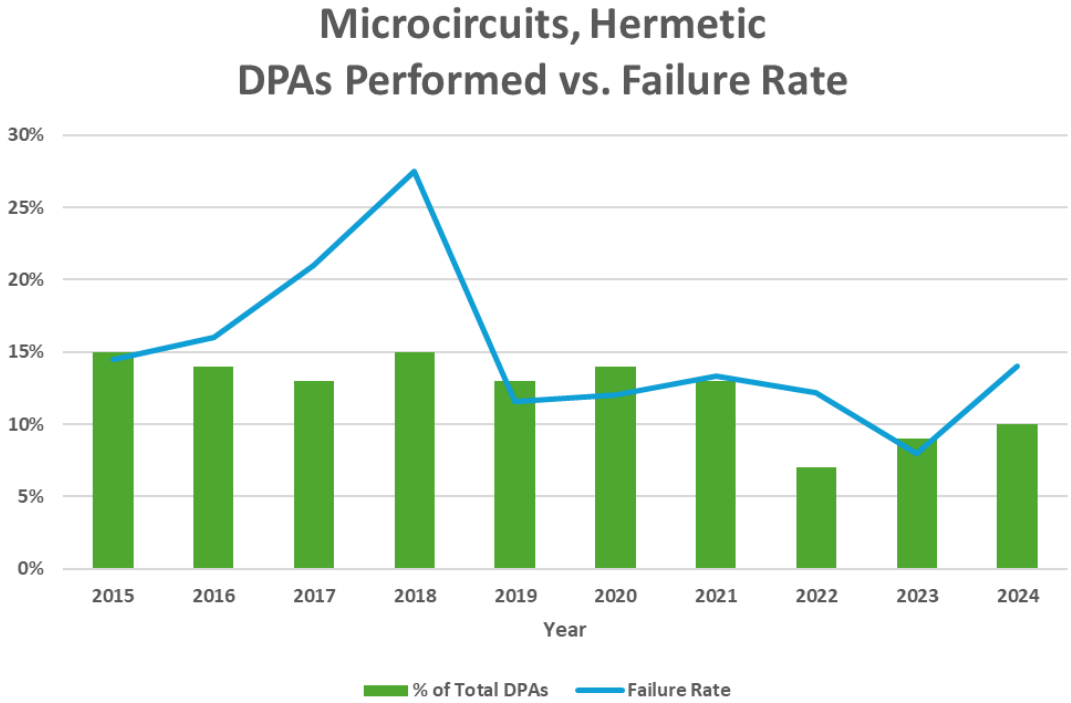
2024 DPA Disposition Breakdown
2908 Completed Analyses



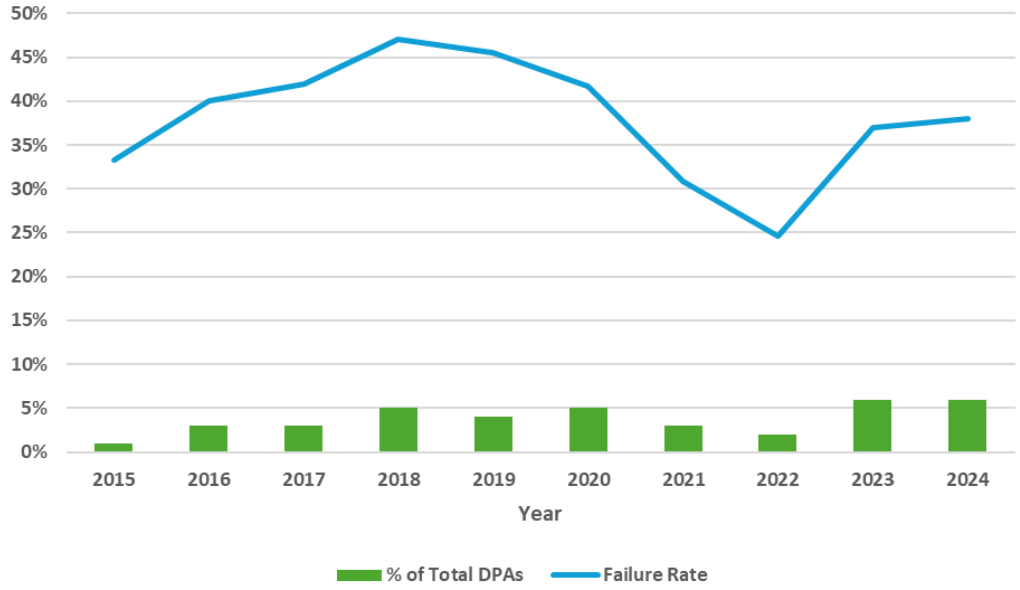
2024 Failure Rates Per Part Type

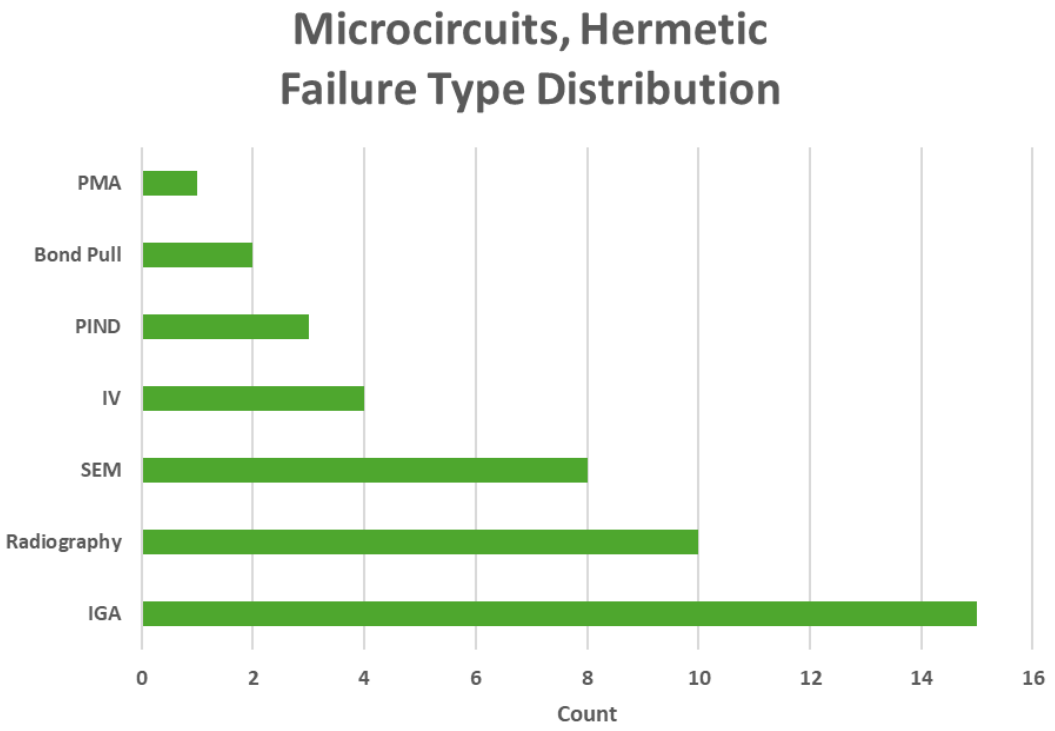



Microcircuits
464 DPAs Completed, 108 Failures
Plastic
Hermetic
0%
10%
20%
30%
40%
50%
60%
70%
% of Total Failures
% of Total Analyses

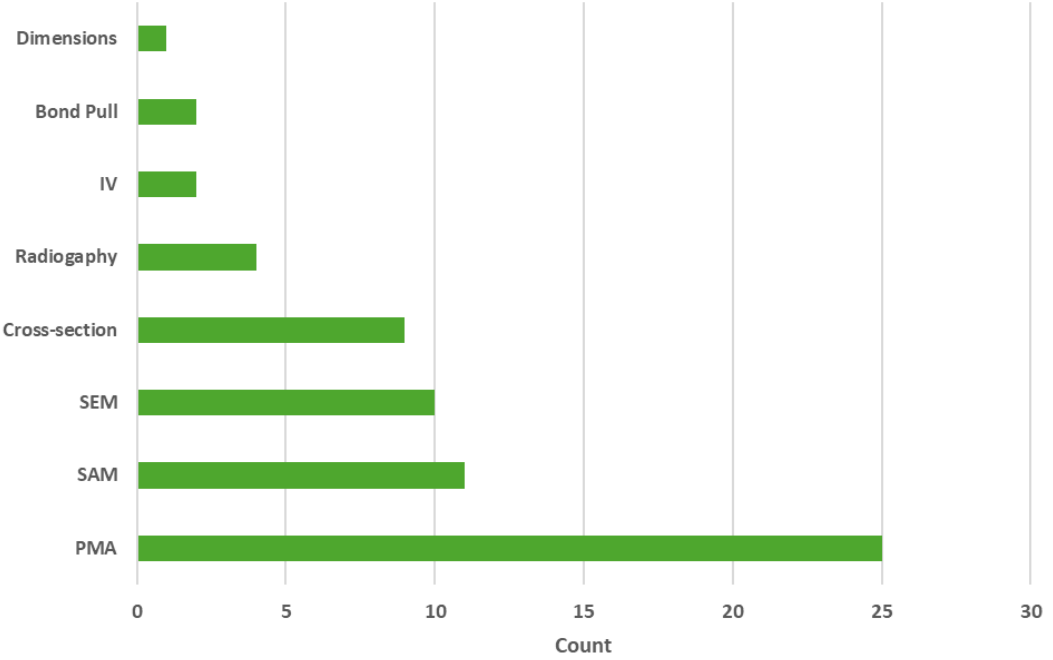

Microcircuits, Hermetic
DPAs Performed vs. Failure Rate
30%
25%
20%
15%
10%
5%
0%
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
% of Total DPAs
Failure Rate

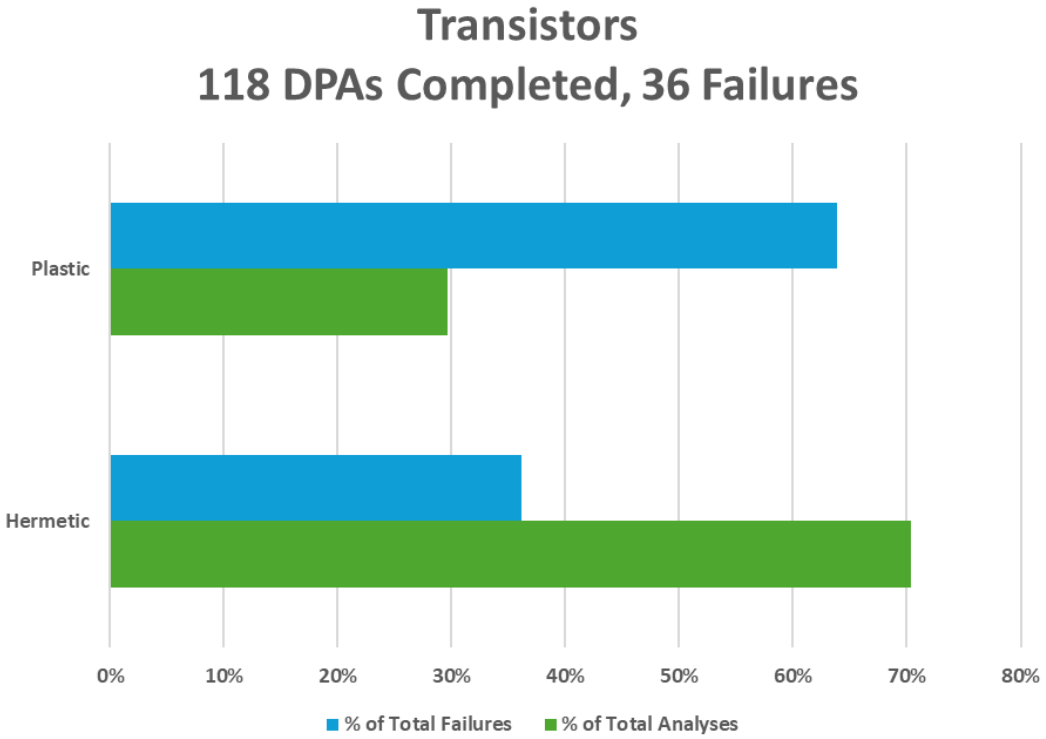
Microcircuits, Plastic
DPAs Performed vs. Failure Rate

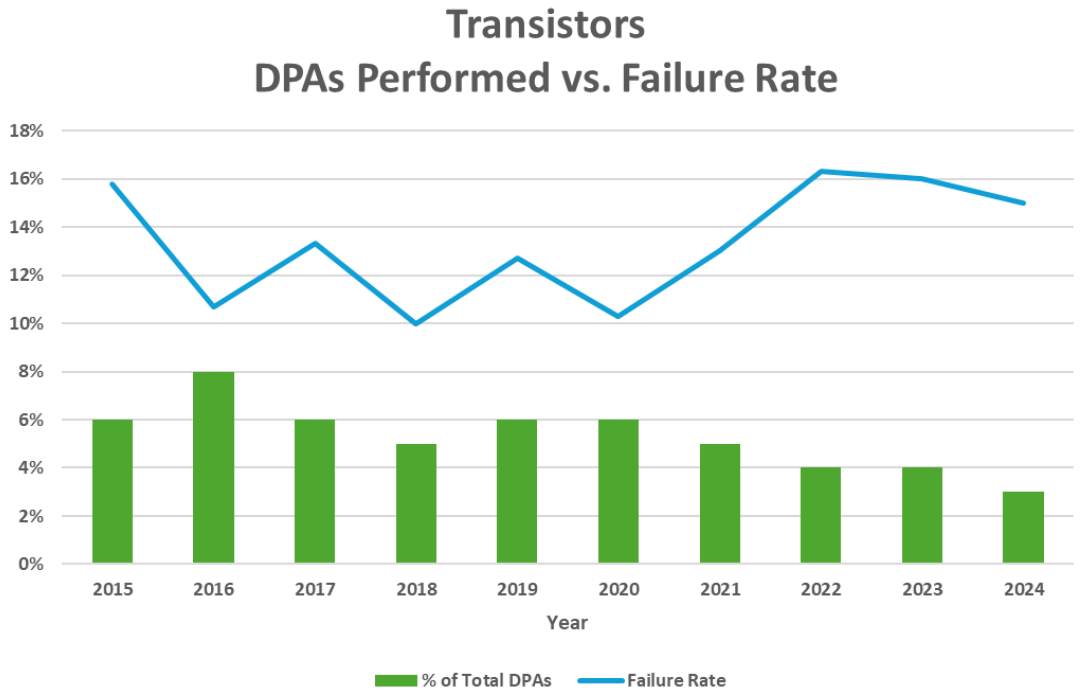


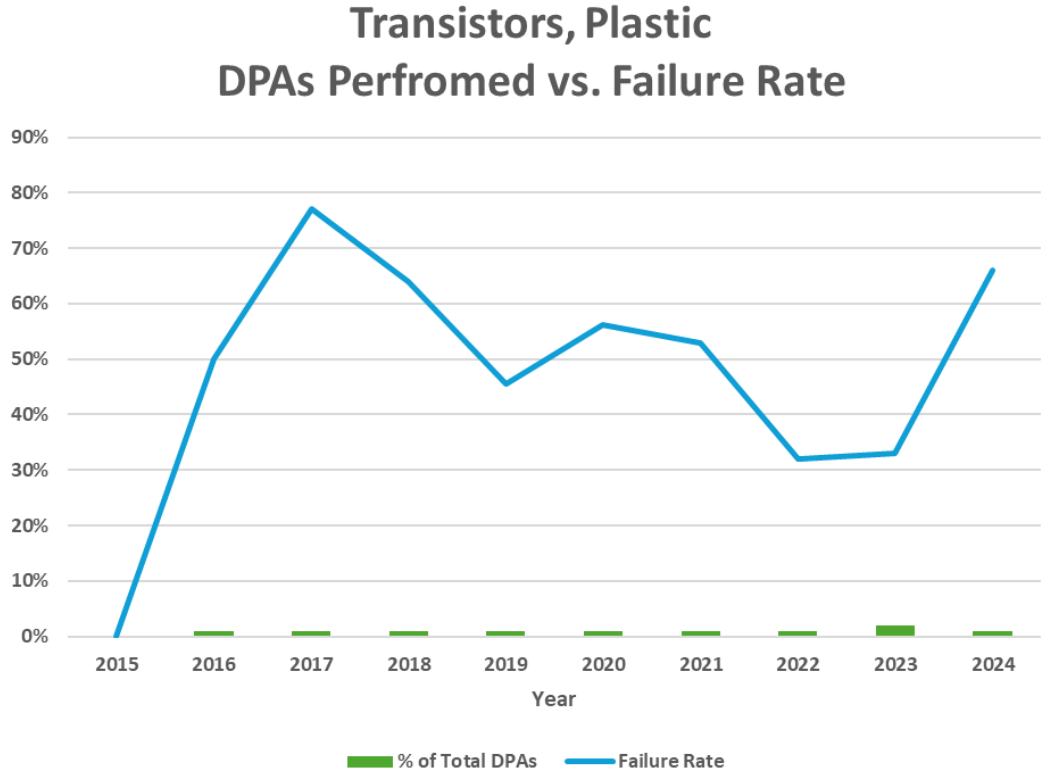

Microcircuits, Hermetic
Failure Type Distribution
PMA
Bond Pull
PIND
IV
SEM
Radiography
IGA
0
2
4
6
8
10
12
14
16
Count

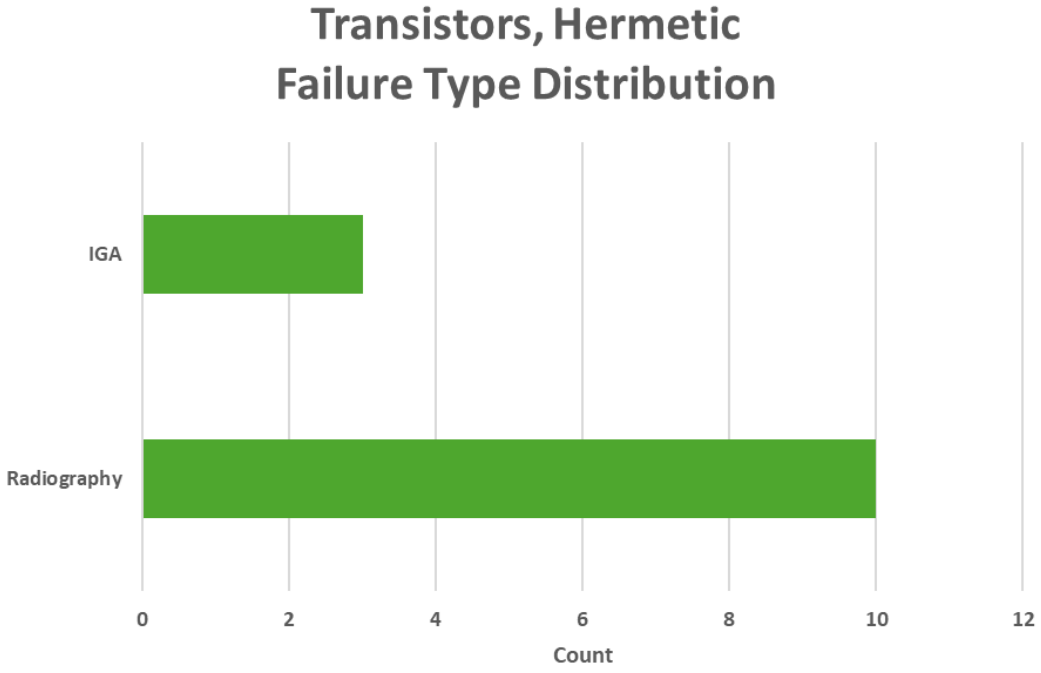
Microcircuits, Plastic
Failure Type Distribution

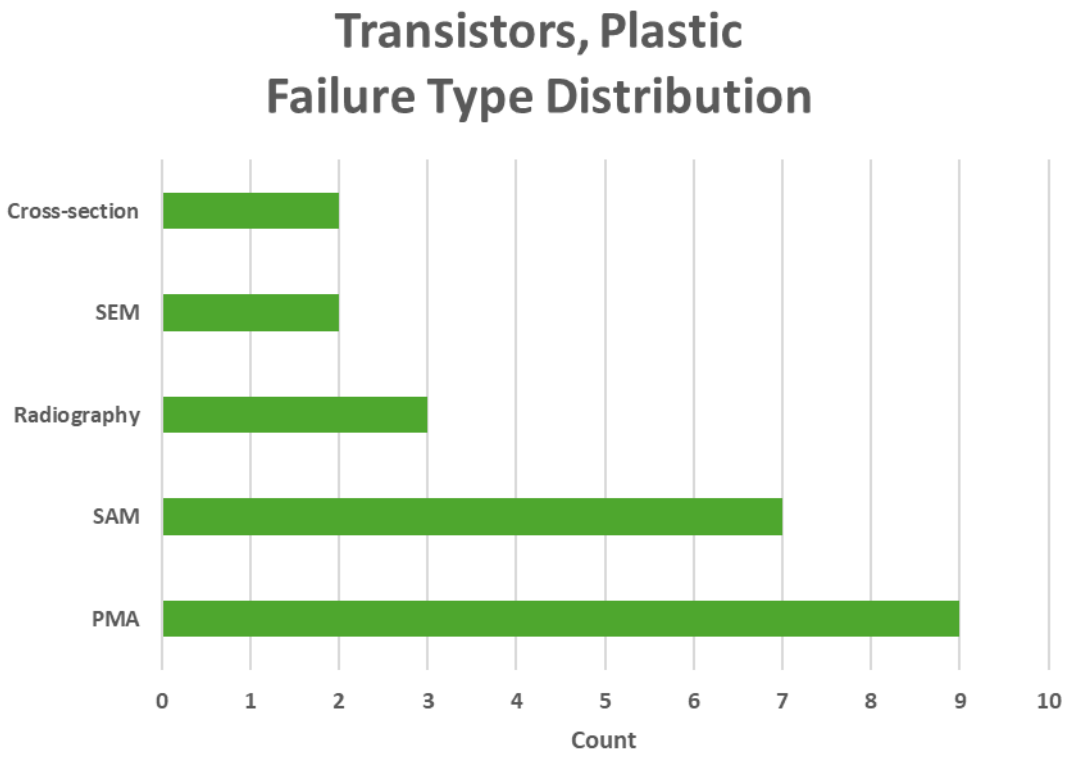


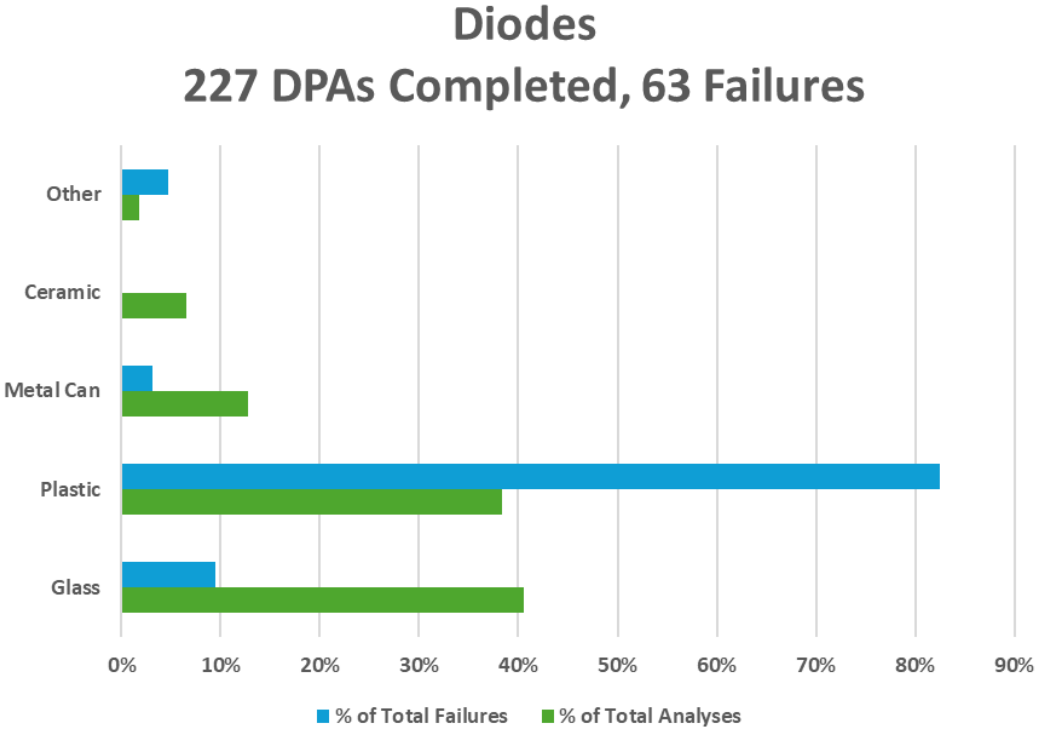

Transistors
118 DPAs Completed, 36 Failures
Plastic
Hermetic
0%
10%
20%
30%
40%
50%
60%
70%
80%
% of Total Failures
% of Total Analyses


Transistors
DPAs Performed vs. Failure Rate
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
% of Total DPAs
Failure Rate

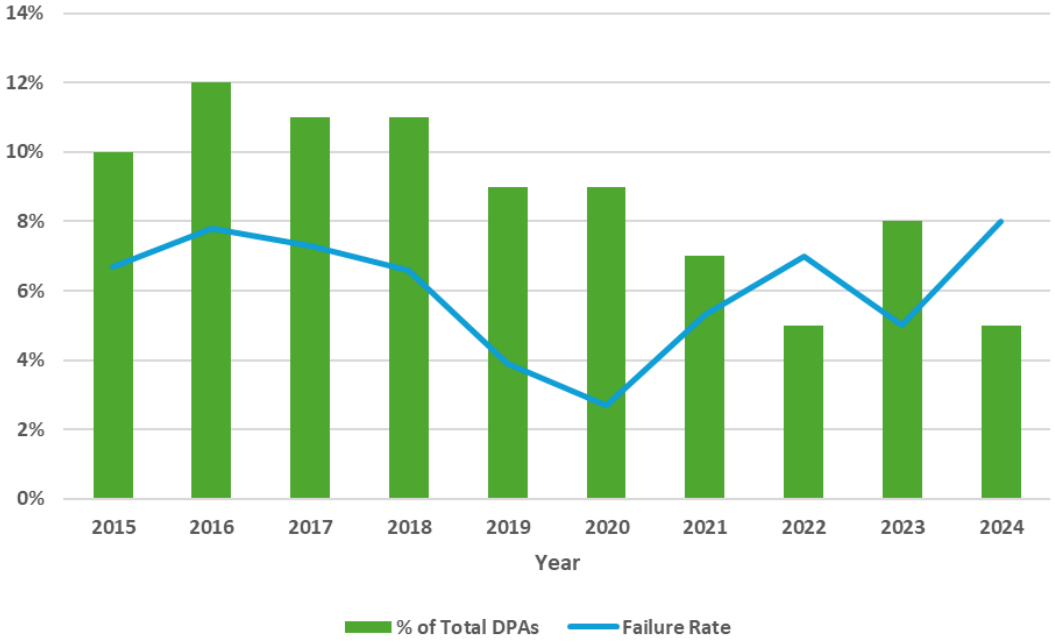

Transistors, Plastic
DPAs Perfromed vs. Failure Rate
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
% of Total DPAs
Failure Rate


Transistors, Hermetic
Failure Type Distribution
IGA
Radiography
0
2
4
6
8
10
12
Count

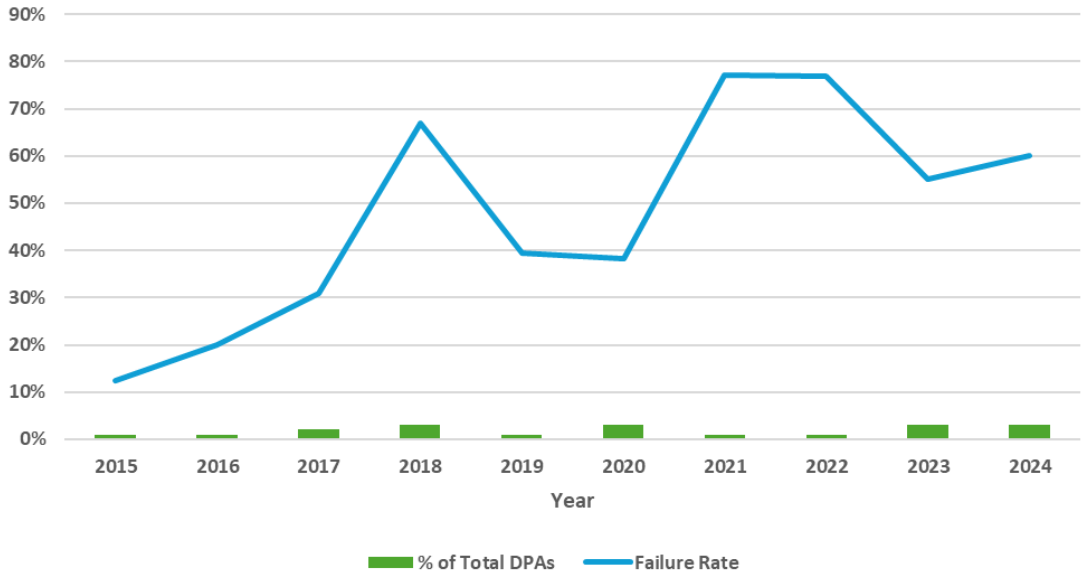

Transistors, Plastic
Failure Type Distribution
Cross-section
SEM
Radiography
SAM
PMA
0
1
2
3
4
5
6
7
8
9
10
Count


Diodes
227 DPAs Completed, 63 Failures
Other
Ceramic
Metal Can
Plastic
Glass
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
% of Total Failures
% of Total Analyses

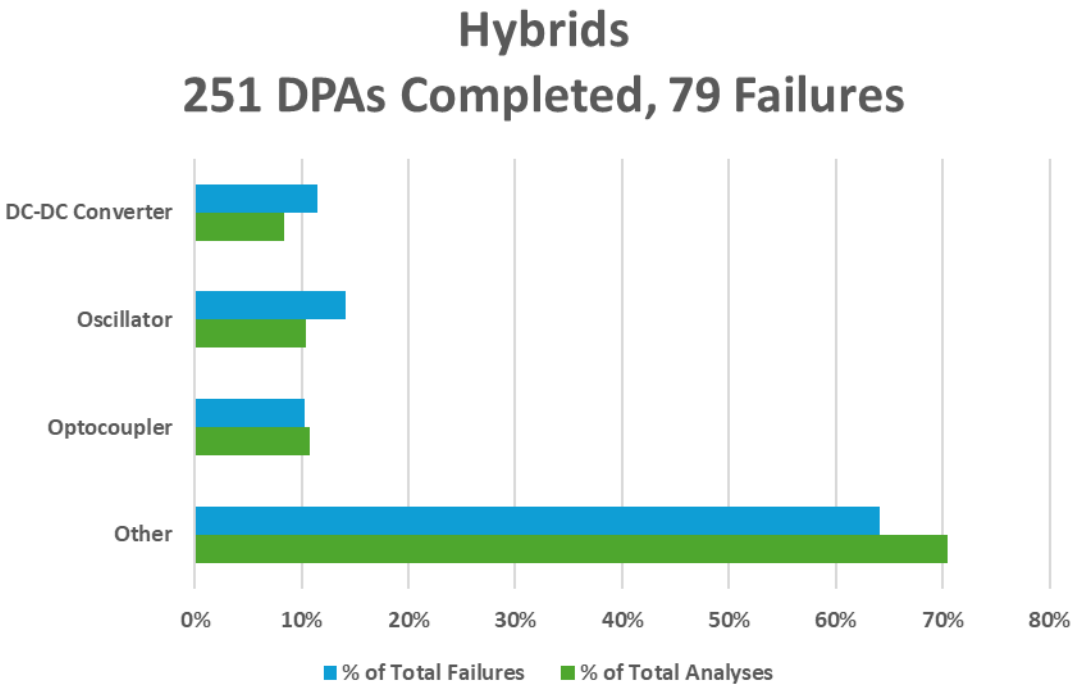
Diodes
DPAs Performed vs. Failure Rate

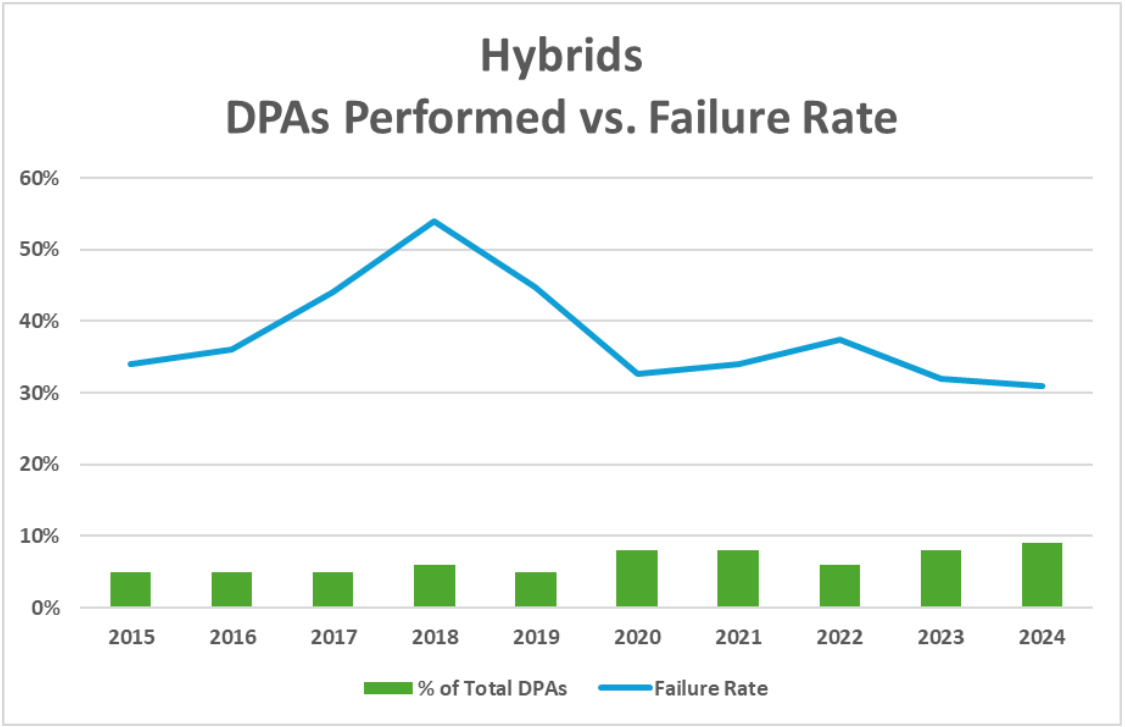


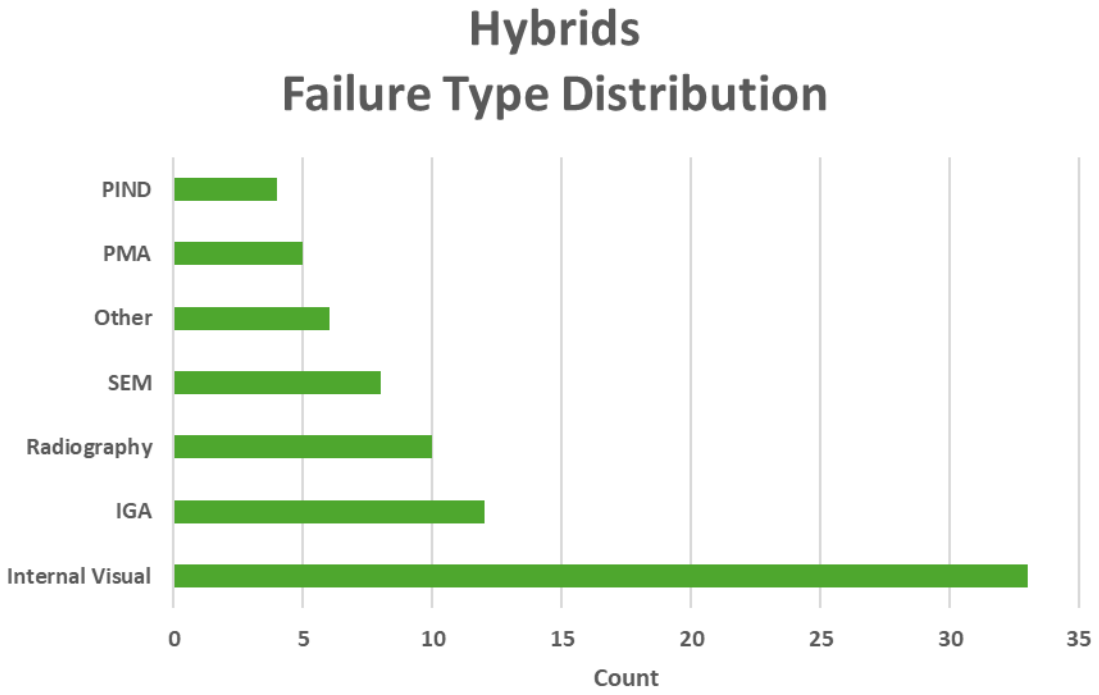
Diodes, Plastic
DPAs Performed vs. Failure Rate

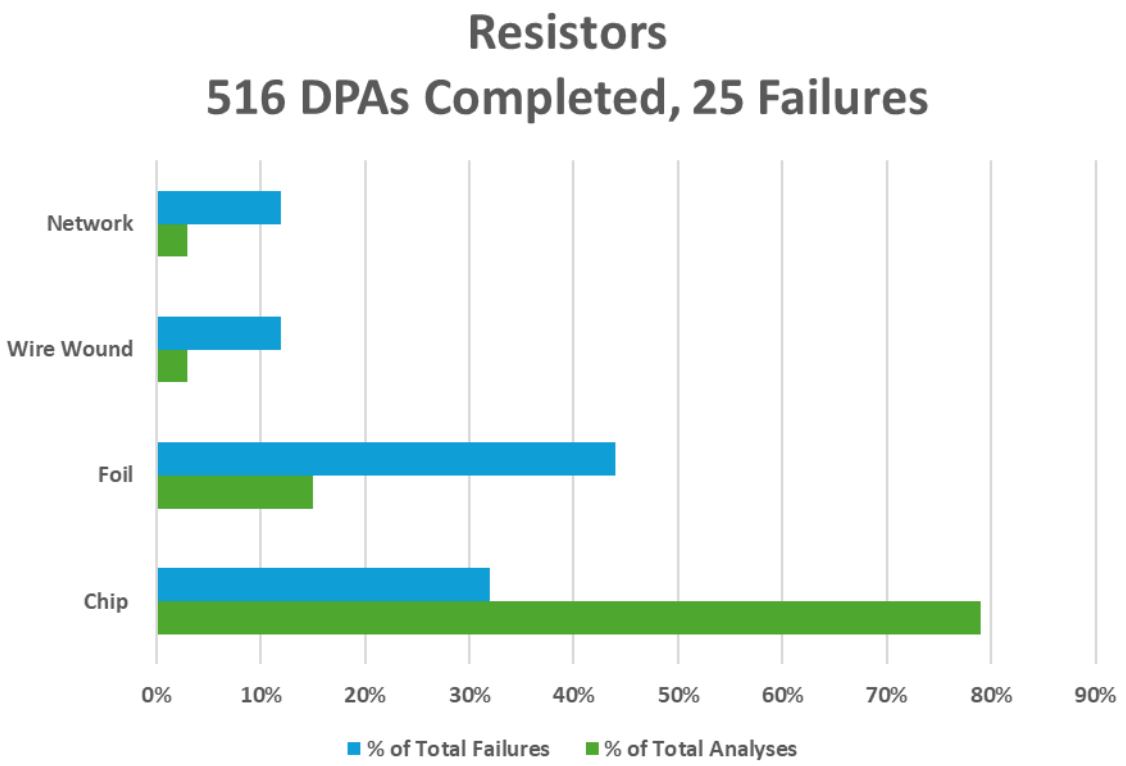


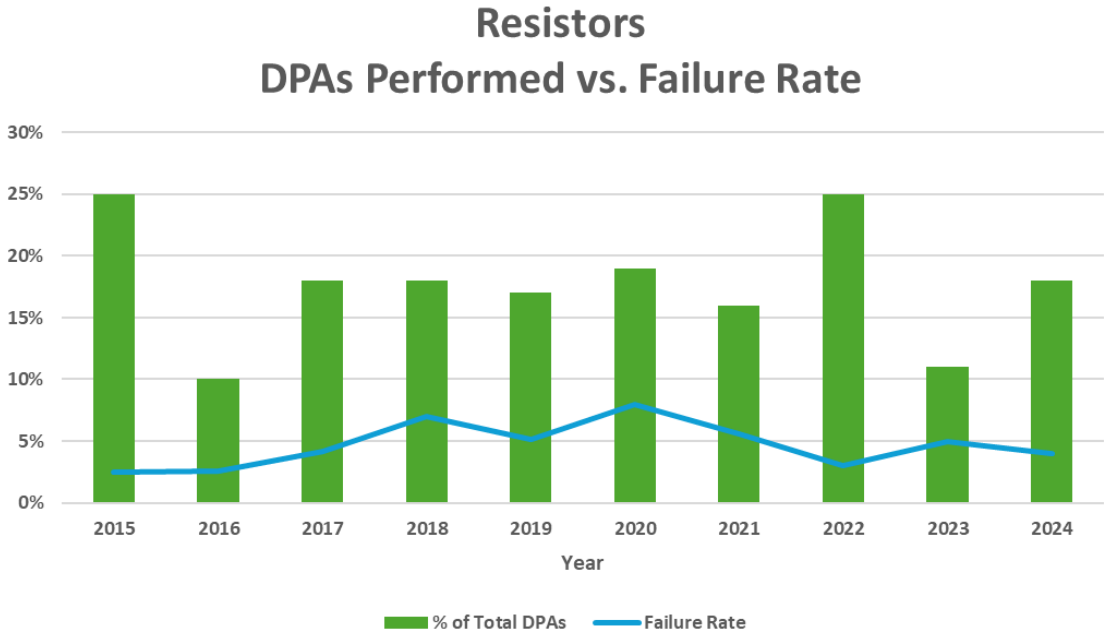

Diodes
Failure Type Distribution
External Visual
Cross-section
Radiography
Marking Permanency
Scribe and Break
Hermeticity
IGA
0
1
2
3
4
Count

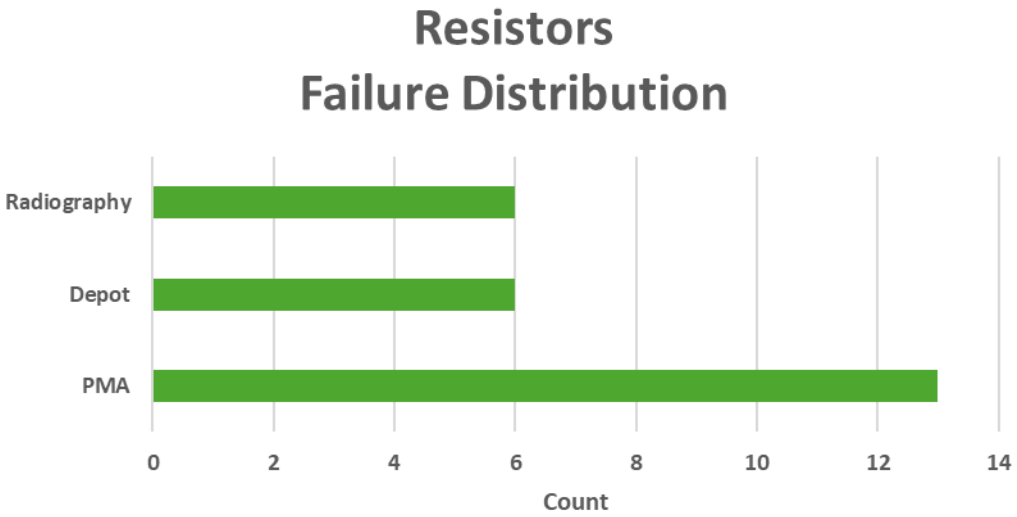

Hybrids
251 DPAs Completed, 79 Failures
DC-DC Converter
Oscillator
Optocoupler
Other
0%
10%
20%
30%
40%
50%
60%
70%
80%
% of Total Failures
% of Total Analyses


Hybrids
DPAs Performed vs. Failure Rate
60%
50%
40%
30%
20%
10%
0%
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
% of Total DPAs
Failure Rate

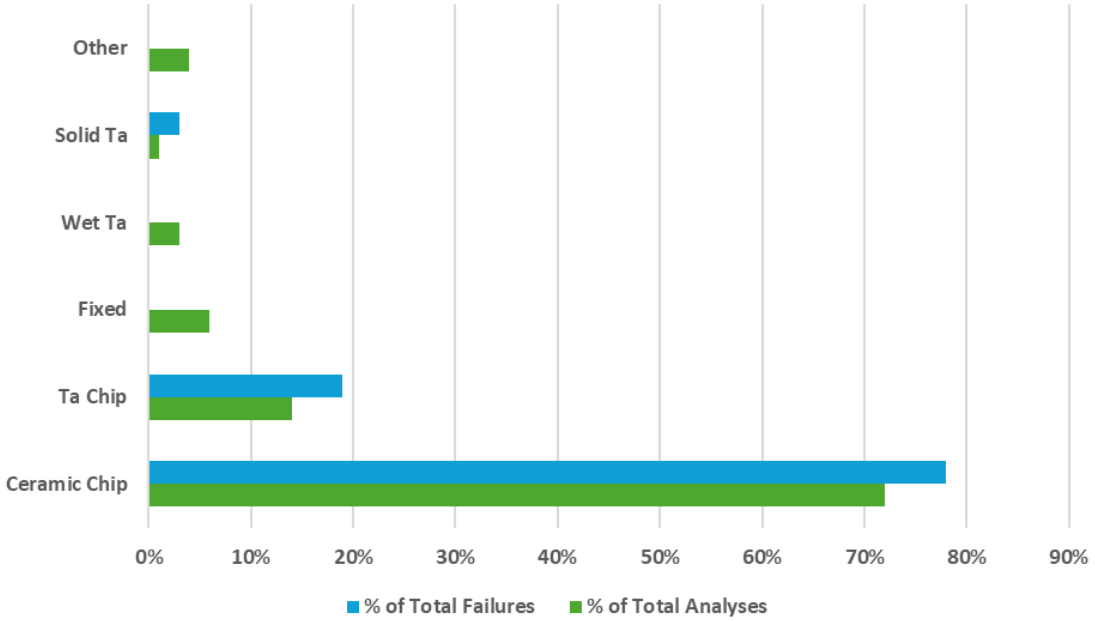

Hybrids
Failure Type Distribution
PIND
PMA
Other
SEM
Radiography
IGA
Internal Visual
0
5
10
15
20
25
30
35
Count

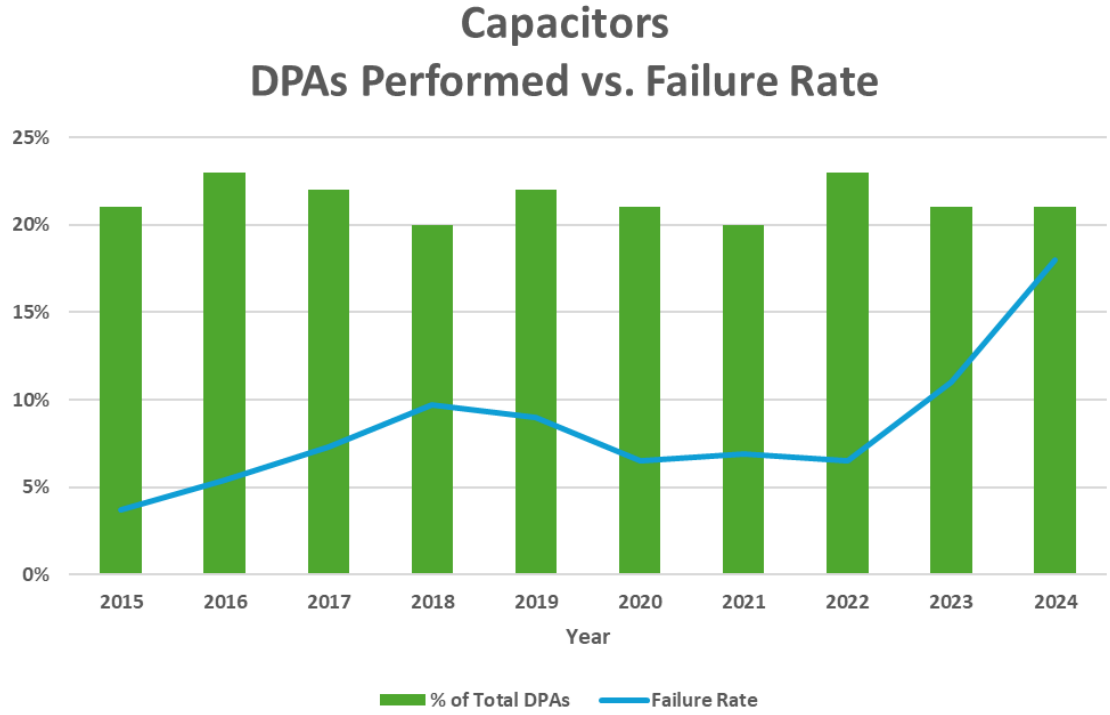

Resistors
516 DPAs Completed, 25 Failures
Network
Wire Wound
Foil
Chip
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
% of Total Failures
% of Total Analyses

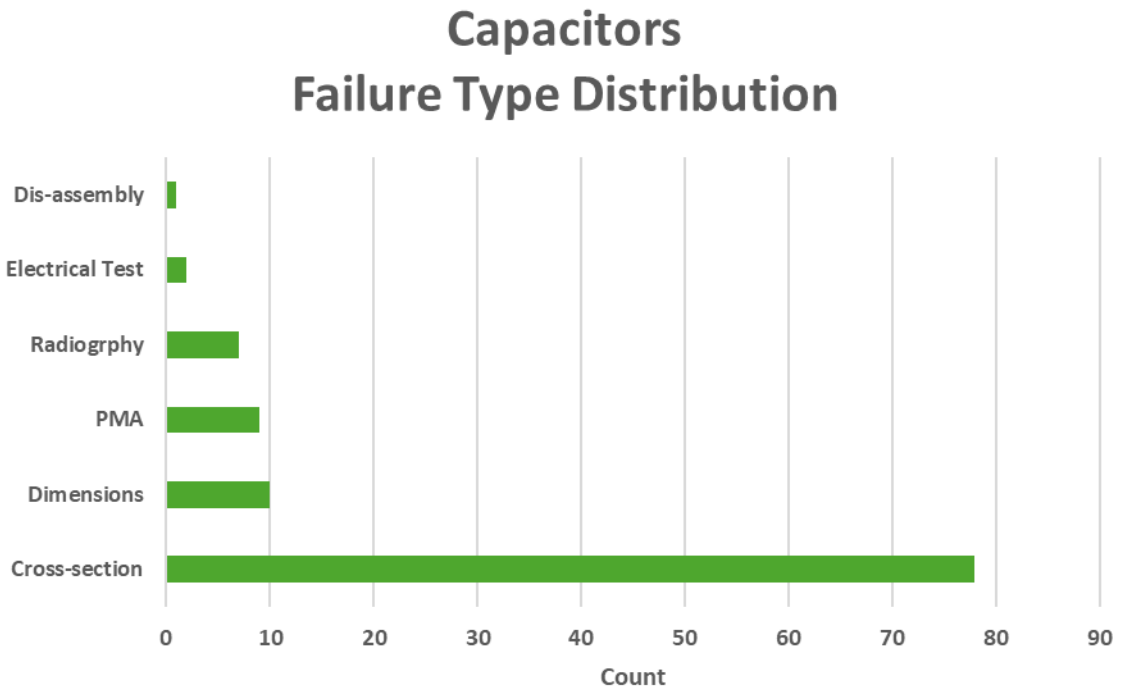

Resistors
DPAs Performed vs. Failure Rate
30%
25%
20%
15%
10%
5%
0%
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
% of Total DPAs
Failure Rate

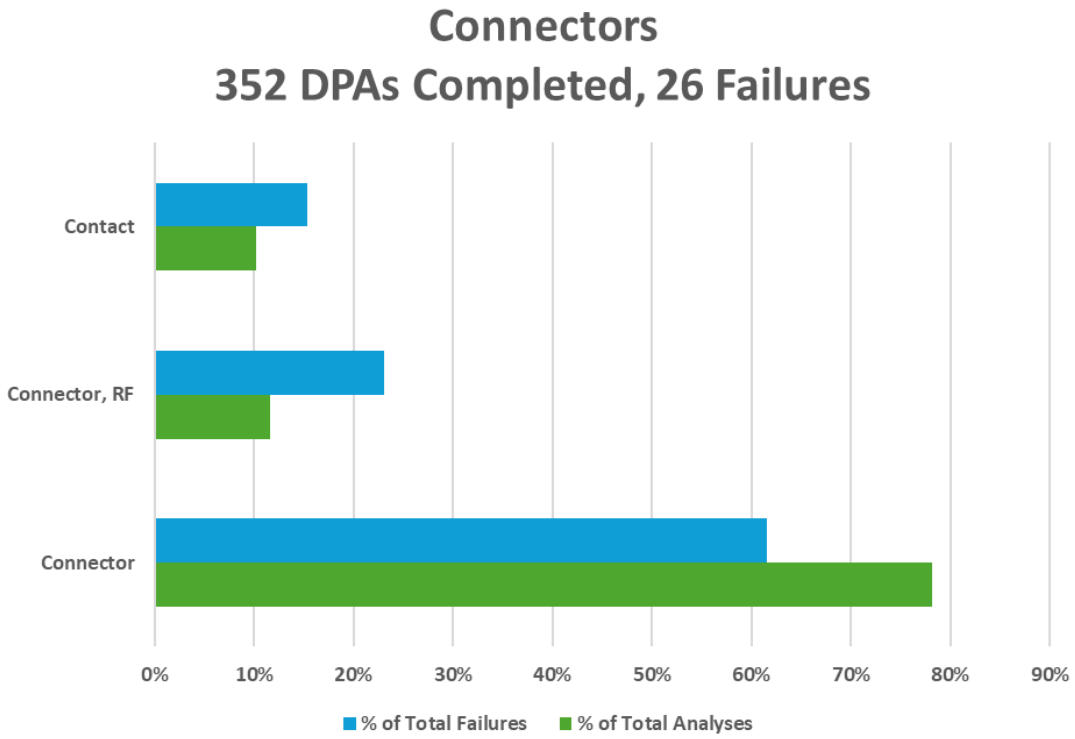

Resistors
Failure Distribution
Radiography
Depot
PMA
0
2
4
6
8
10
12
14
Count

Capacitors
607 DPAs Completed, 107 Failures

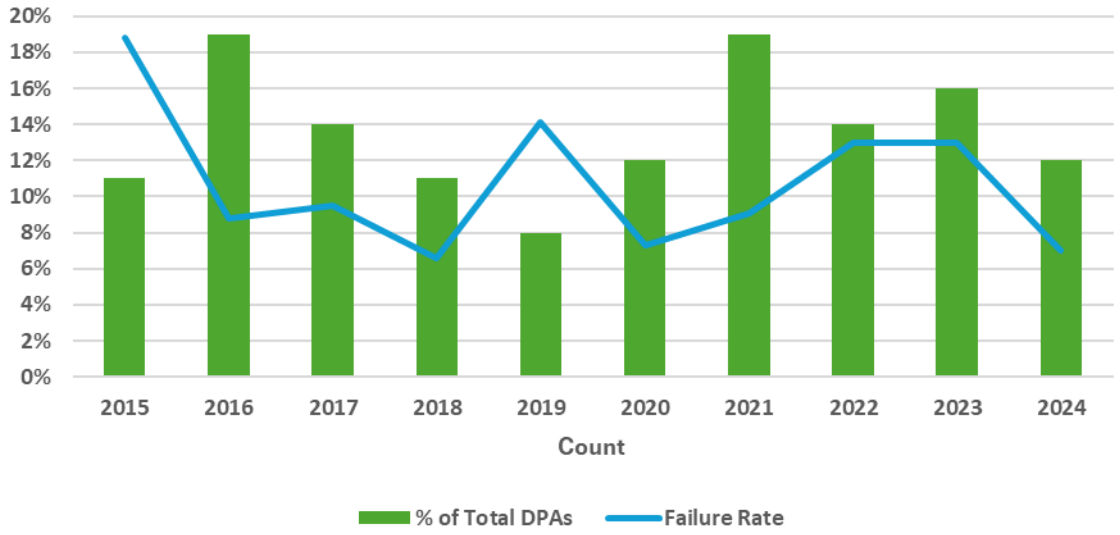


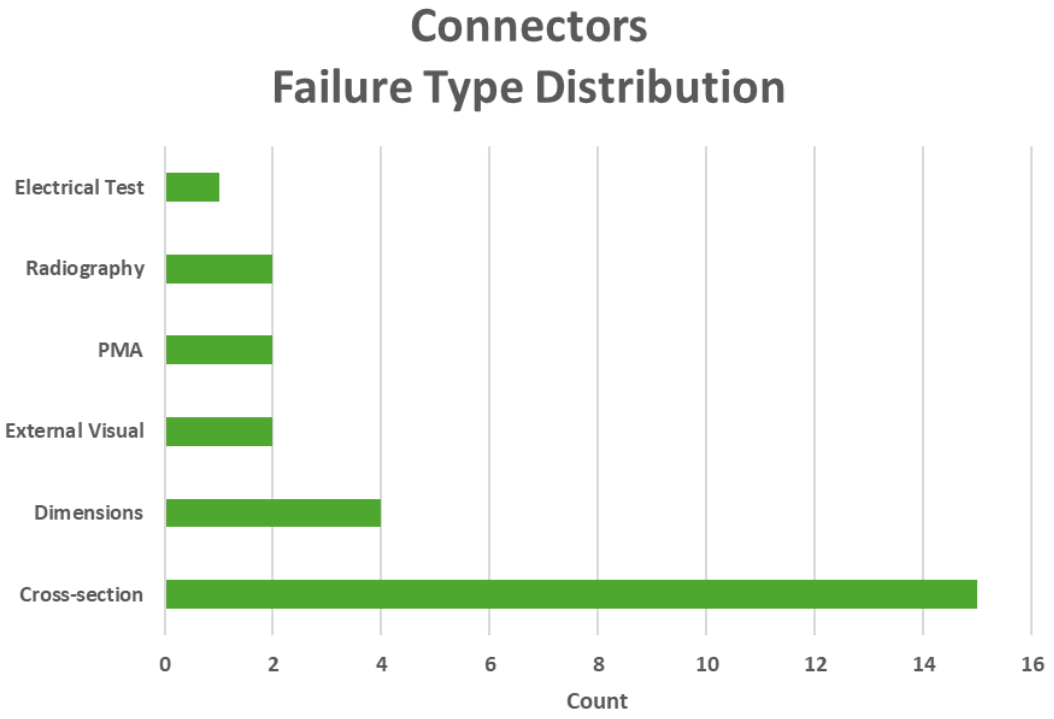

Capacitors
DPAs Performed vs. Failure Rate
25%
20%
15%
10%
5%
0%
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Year
% of Total DPAs
Failure Rate

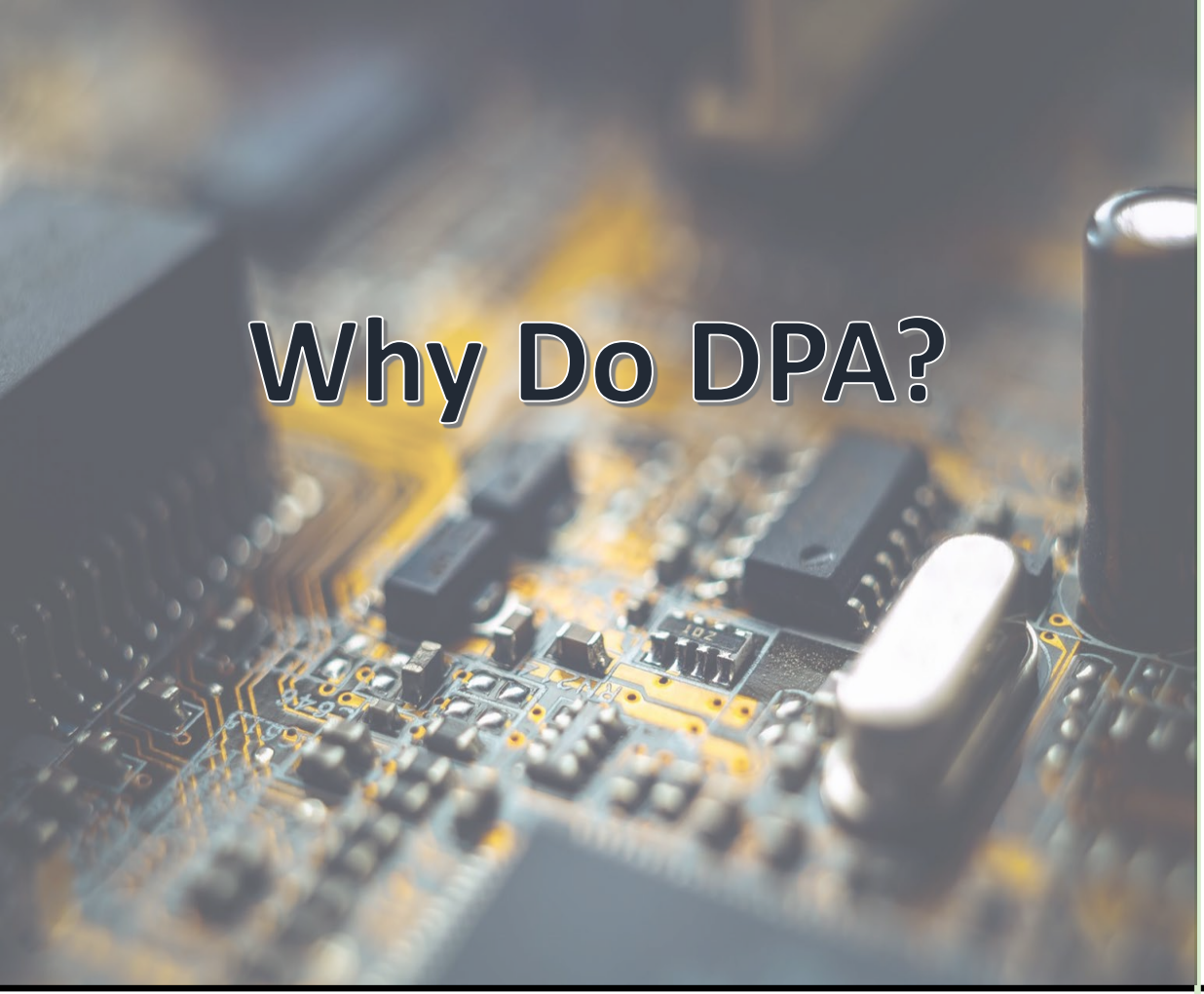

Capacitors
Failure Type Distribution
Dis-assembly
Electrical Test
Radiogrphy
PMA
Dimensions
Cross-section
0
10
20
30
40
50
60
70
80
90
Count


Connectors
352 DPAs Completed, 26 Failures
Contact
Connector, RF
Connector
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
% of Total Failures
% of Total Analyses

Connectors
DPAs Performed vs. Failure Rate

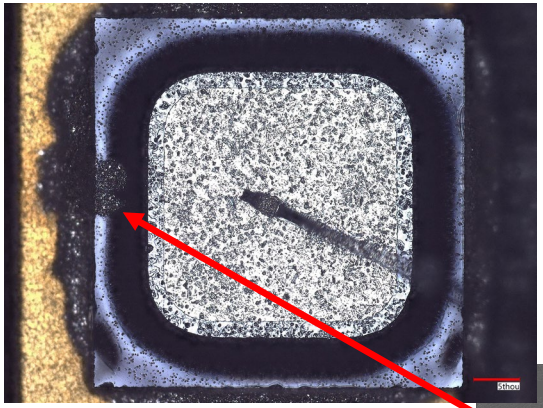



Connectors
Failure Type Distribution
Electrical Test
Radiography
PMA
External Visual
Dimensions
Cross-section
0
2
4
6
8
10
12
14
16
Count

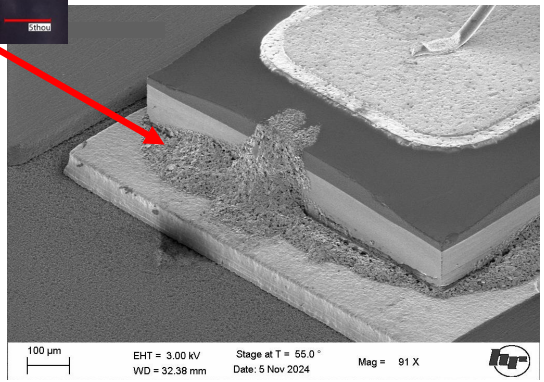


Why Do DPA?

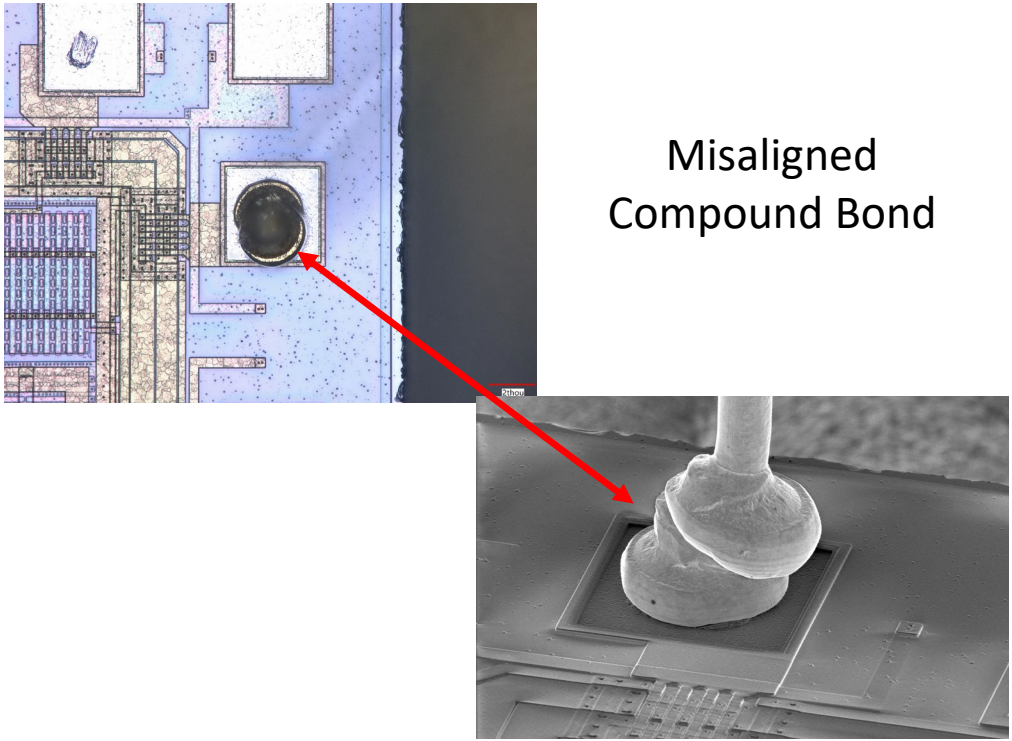
Visual Inspection



Attach Extending to the Die Surface

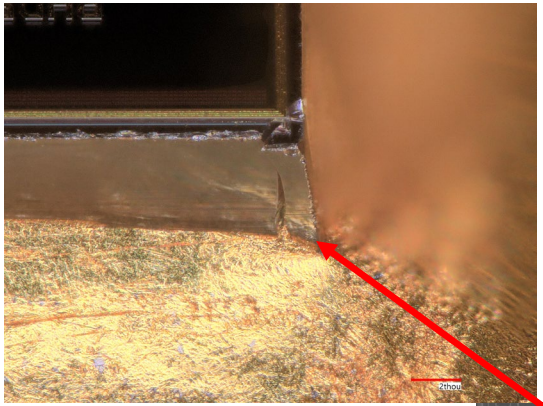


Visual Inspection

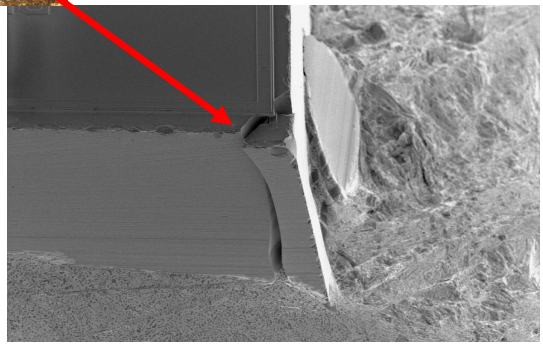


Misaligned
Compound Bond

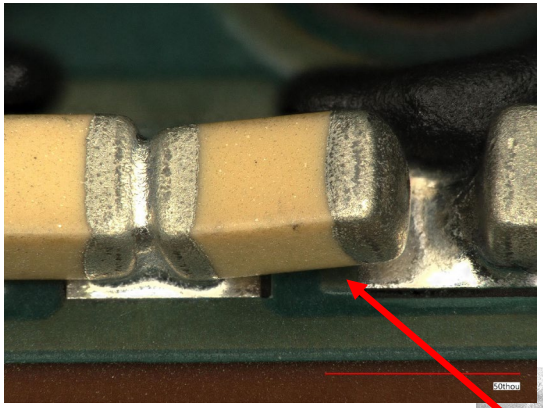
Visual Inspection



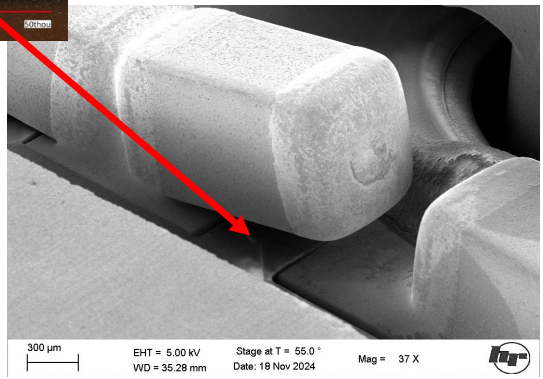
Silicon Shard



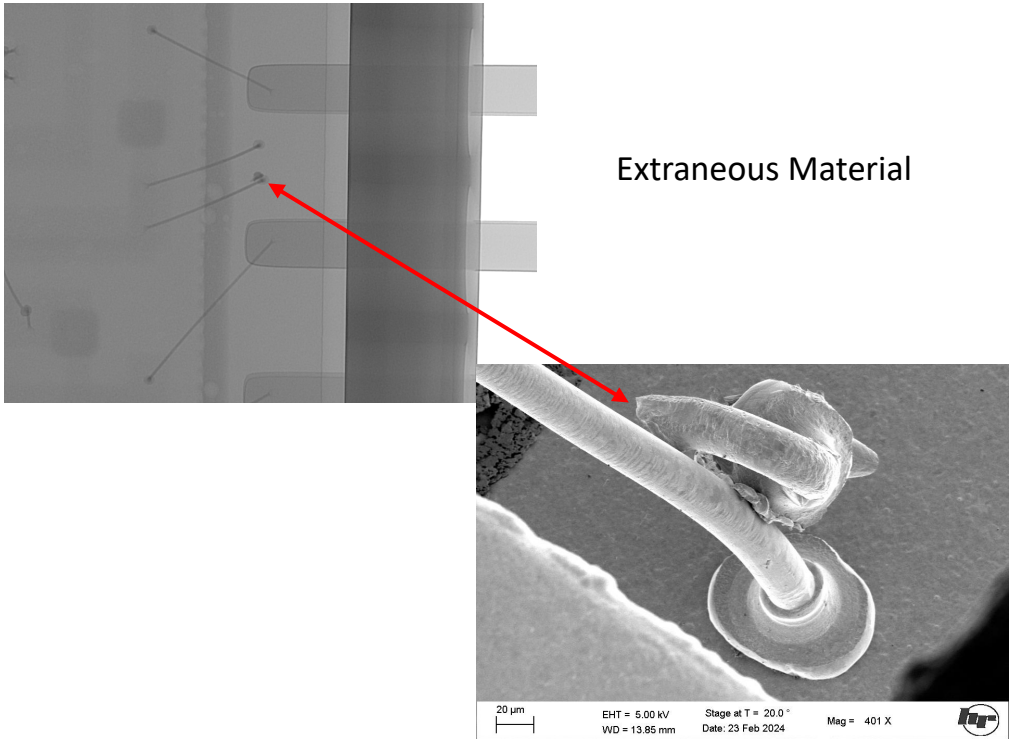
Visual Inspection



Unsoldered Component Termination



Radiography



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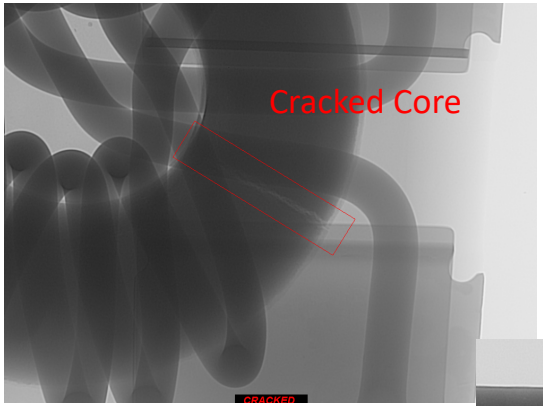
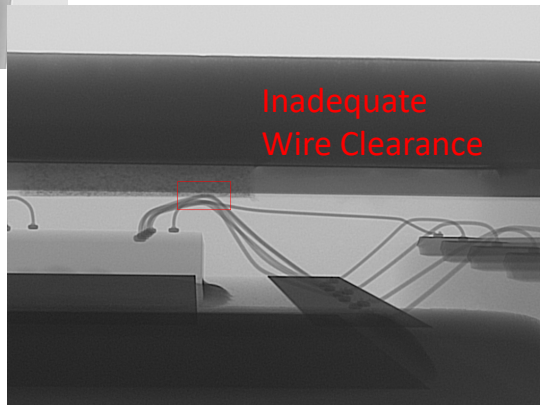
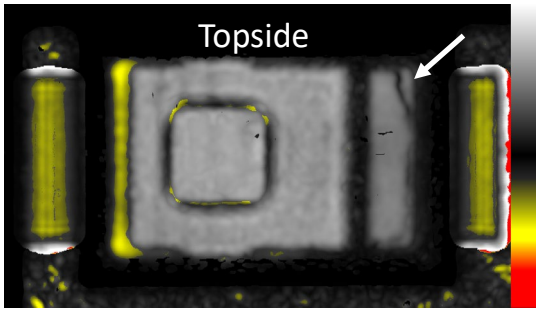
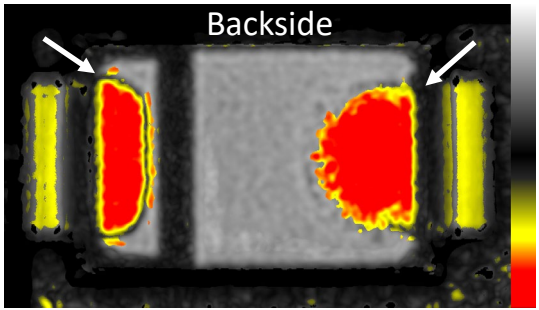


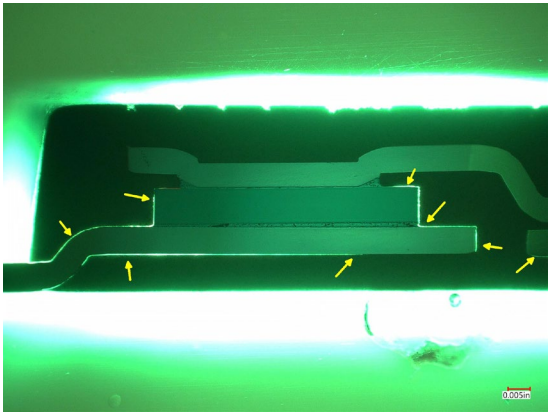


SAM and Cross-section



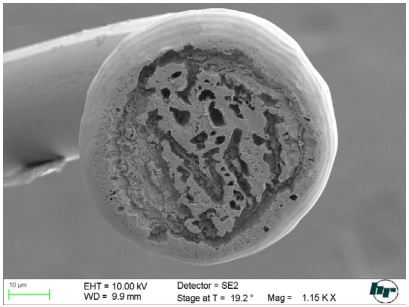


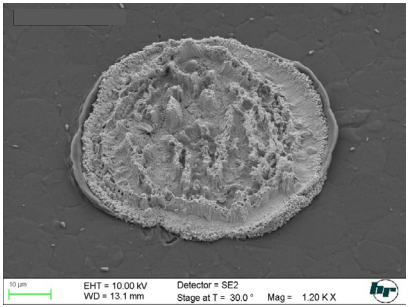
Delaminated Package

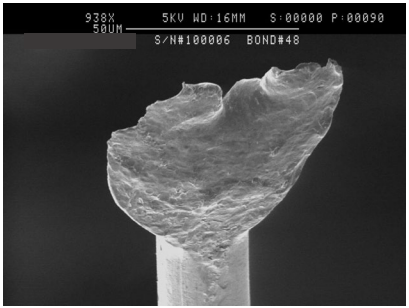


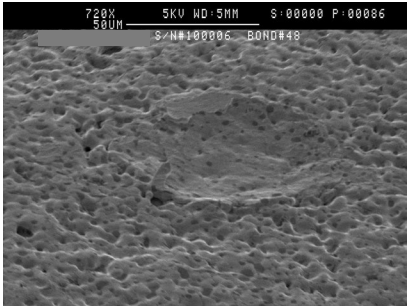
Bond Pull

Low Force Bond Lifts

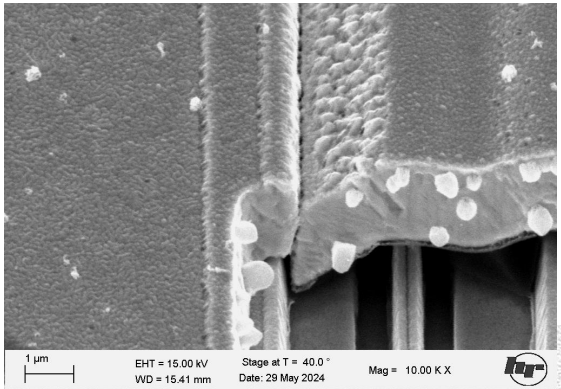




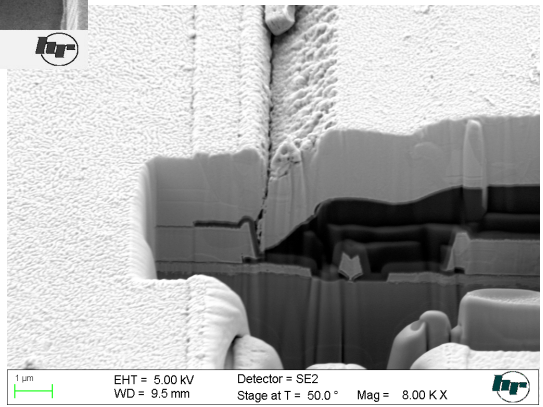




Step Coverage



Poor Step Coverage



Cross-section