Comparison of Silicon Carbide Packages with Different Solder Attach Materials under High Temperature, Fast Power Cycling Conditions

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Reliability & Product Design Lifecycle

FMEA

- Identify risks, uncertainties, and fundamental assumptions for likely failure causes, based on historical data and engineering expertise.

Quantitative Evaluation of Alternatives

- Empirically validate occurrence and impact of failure modes and failure mechanisms.

Design for Reliability

- Use empirical evidence and specifications to design new product for reliability within expected application.

Reliability Modeling

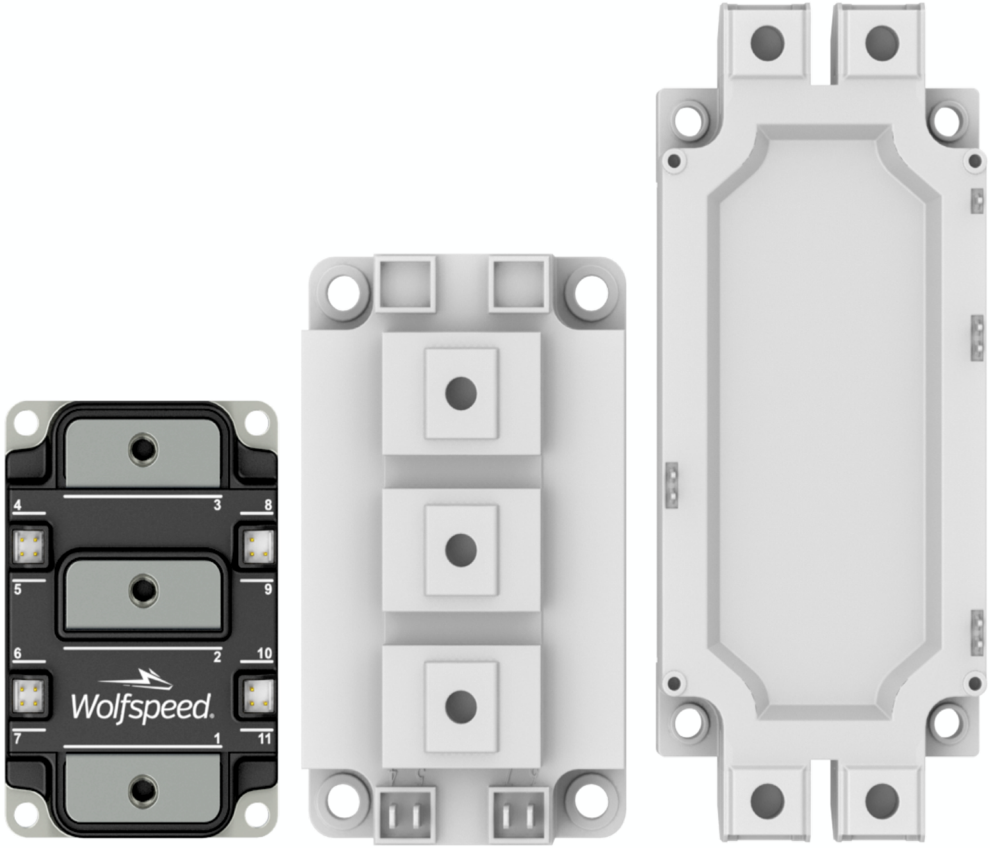
- Apply statistical analysis techniques to analyze reliability metrics of released products.

Design of Experiment

Why do we use Power Cycling?

- Industry-Standard Tool for Packages
- Capable of Replicating End-Use Environment
- Established Failure Modes / Mechanisms
  - Device Solder Fatigue → Thermal Resistance Change
  - Wirebond Failure → Voltage Change

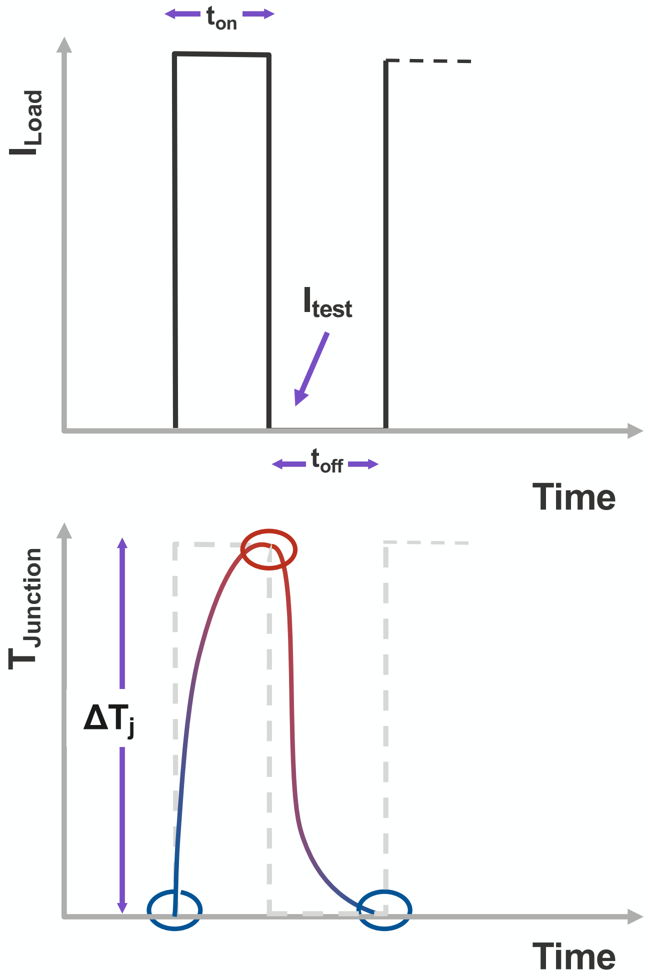
Motivation



Higher Package Power Density = Higher Thermo-Mechanical Burden

Overview of Power Cycling

1. I_{load} applied for t_{on}
2. I_{load} removed for t_{off}
3. I_{test} measures TSEP
4. Virtual Junction Temperature & Thermal Resistance Calculated



Power Cycling Parameters

Fixed Parameters throughout Test

t_{on}	2	s
t_{off}	4	s

Starting Parameters, Fluctuate throughout Test

T_{jmax}	175	°C
ΔT_j	80	°C

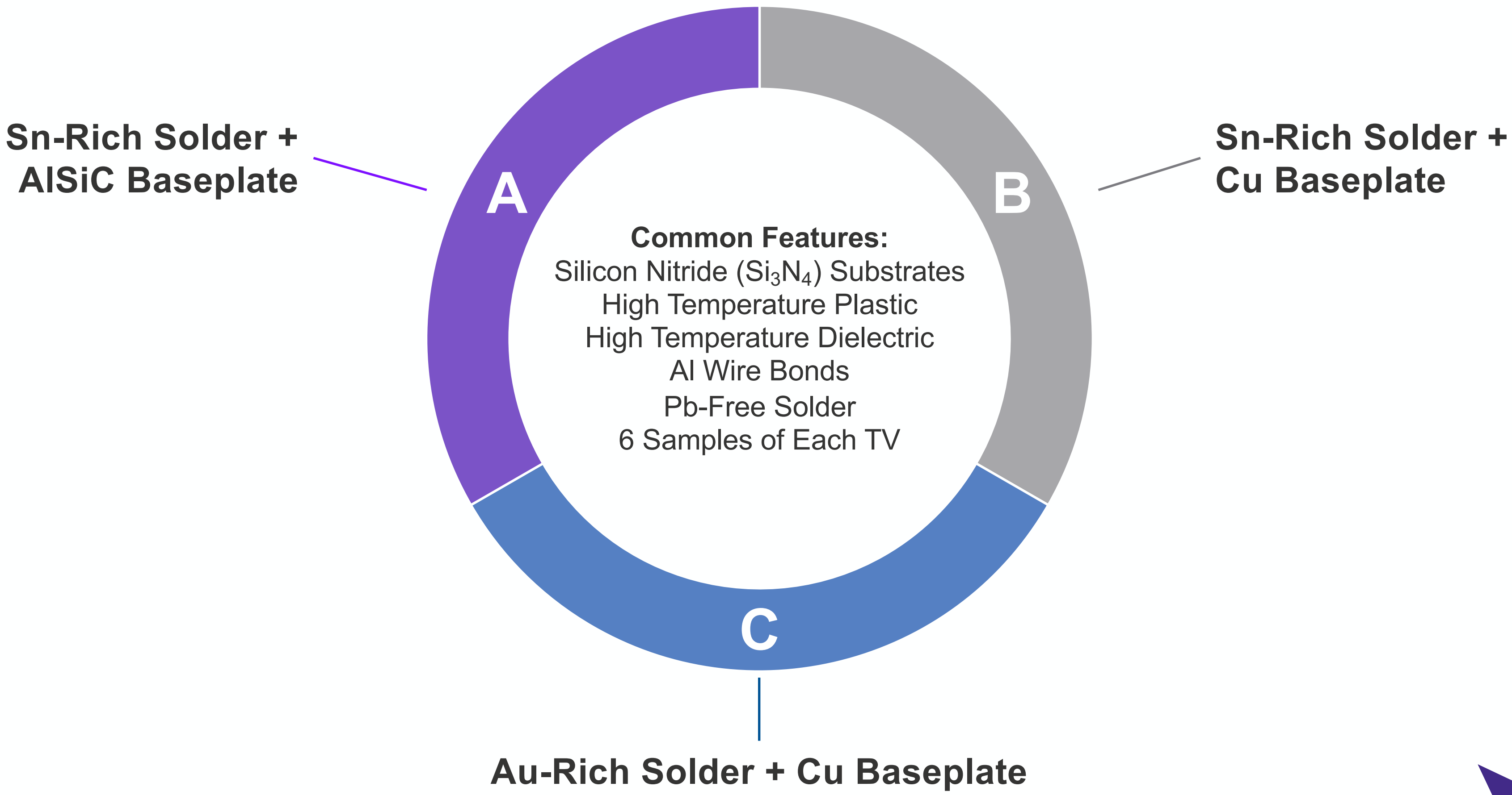
Set from DUT Characterization Over-Temperature

I_{load}	Set to Achieve Starting T_{jmax}
T_{liquid}	Set to Achieve Starting ΔT_j

End-of-Life Failure Criteria

ΔR_{th}	20	%
ΔV_f	5	%

Test Vehicle Material Selection

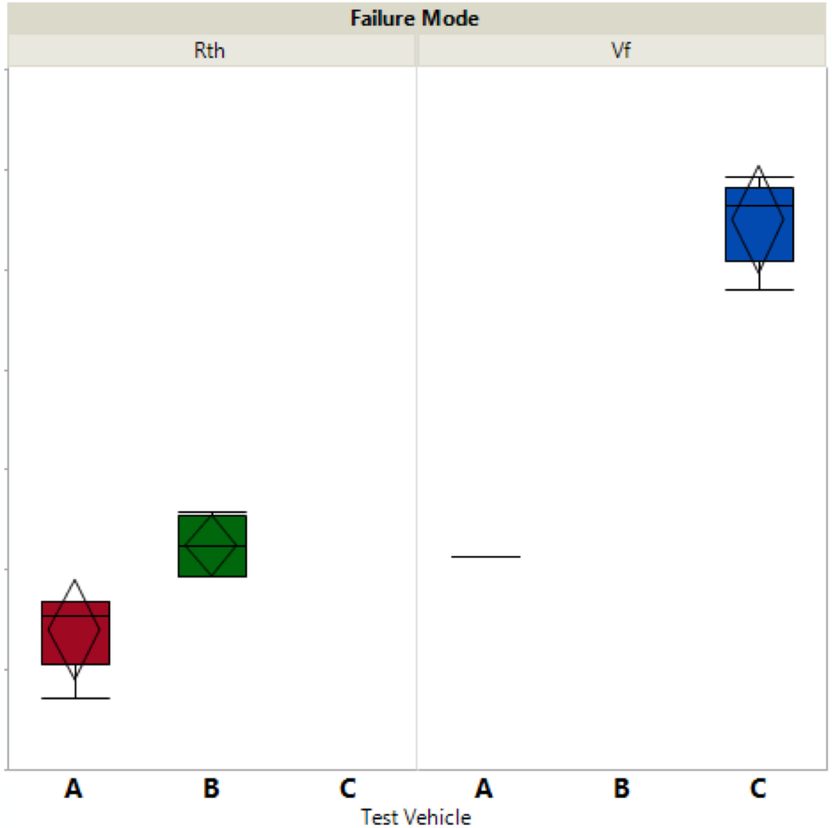


Statistical Analysis

Reliability Modeling Procedure

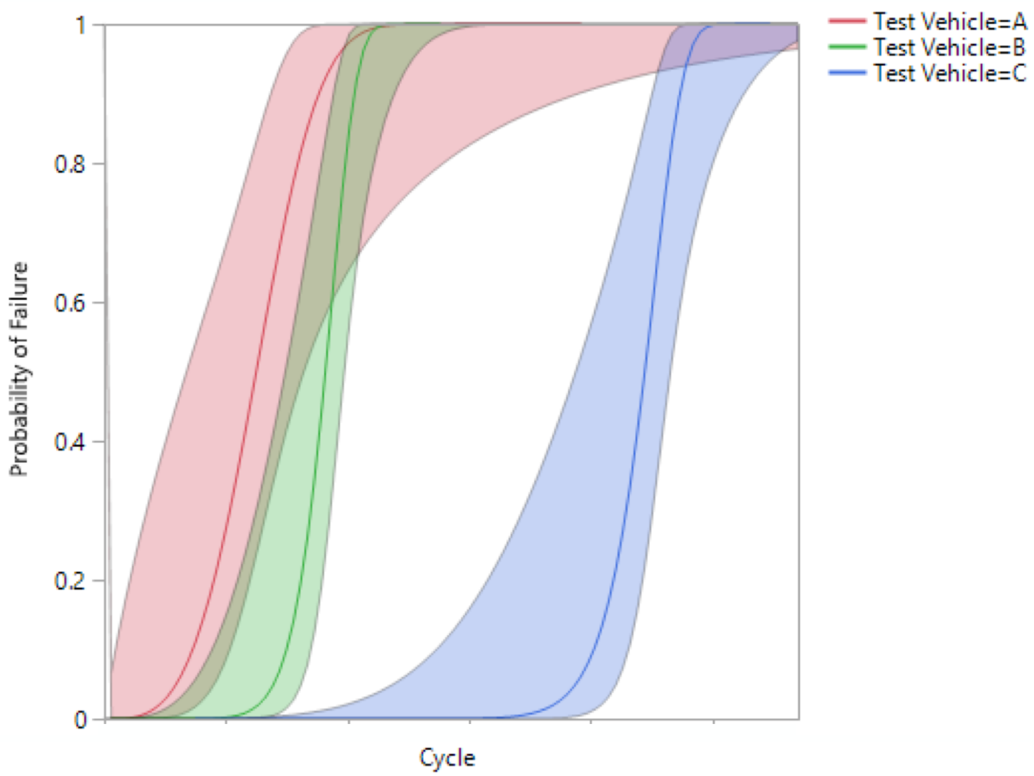
1. Gather lifetime (failure) data for the units.
2. Select an appropriate lifetime statistical distribution to fit the data and model the expected life behavior of the product.
3. Estimate the parameters that will fit the distribution.
4. Generate plots and results to estimate life characteristics of the design.

Lifetime Estimation



	Mean Lifetime Improvement	
A vs. B	1.5 ×	Impact of Cu Thermal Conductivity
A vs. C	3.7 ×	Impact of Solder Alloy Temperature Rating
B vs. C	2.4 ×	

Probabilistic Lifetime Prediction



2-Parameter Weibull

Cumulative Distribution

$$F(t) = 1 - e^{-\left(\frac{t}{\eta}\right)^{\beta}}$$

	$\hat{\beta}$ (Shape Estimate)	$\hat{s}$ (Standard Error)
Test Vehicle 1	3.48	3,144
Test Vehicle 2	9.77	2,385
Test Vehicle 3	19.08	3,891

Experimental Verification

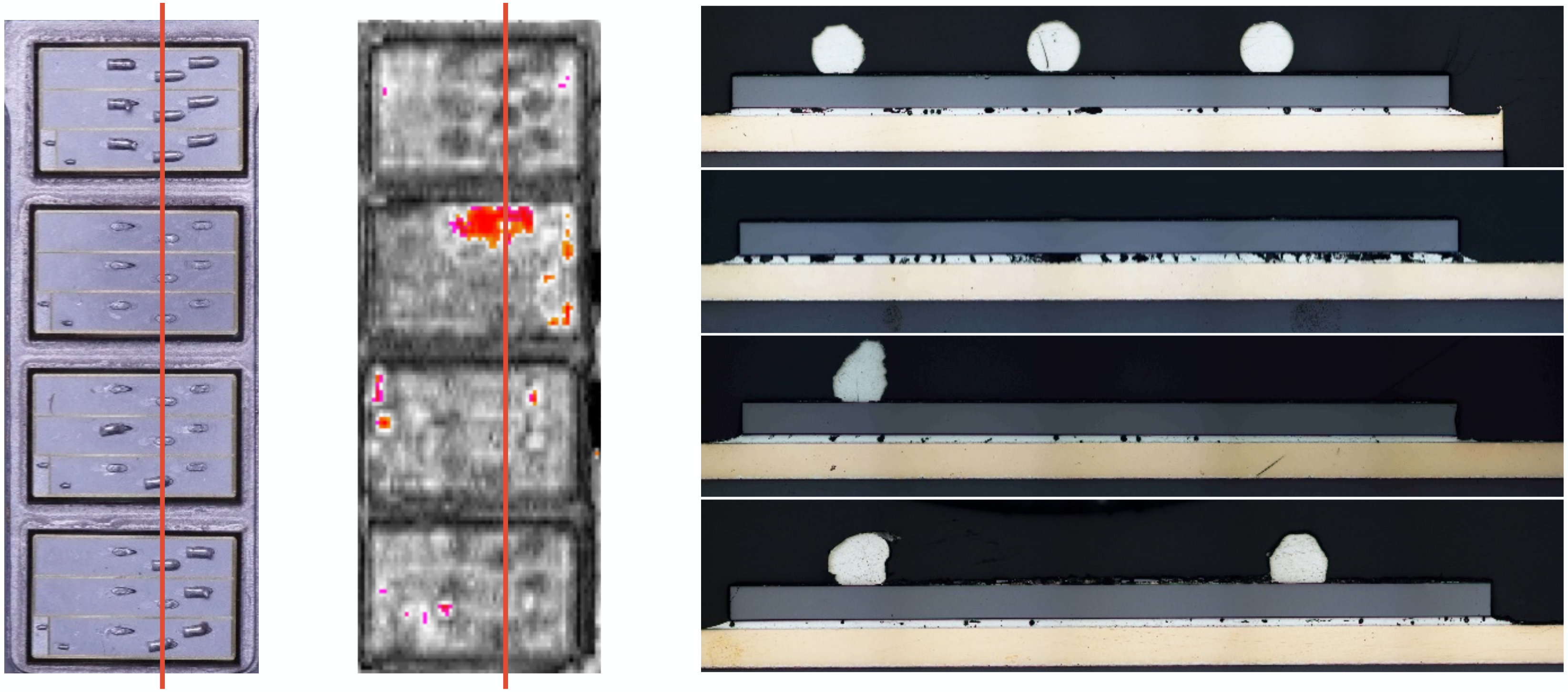
Test Vehicle A (Sn-Rich Solder, AlSiC Baseplate)

MOSFET 4

MOSFET 3

MOSFET 2

MOSFET 1



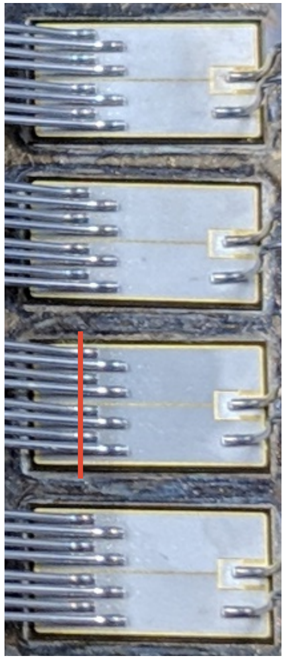
Test Vehicle B (Sn-Rich Solder, Cu Baseplate)

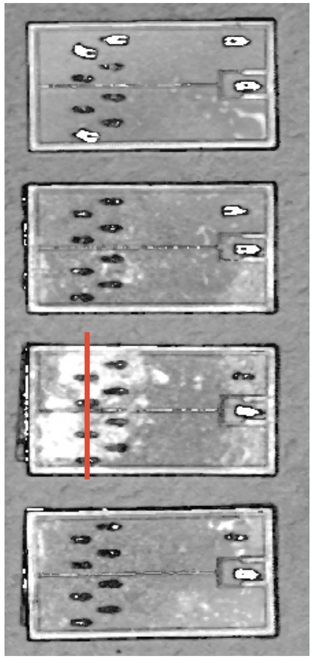
MOSFET 4

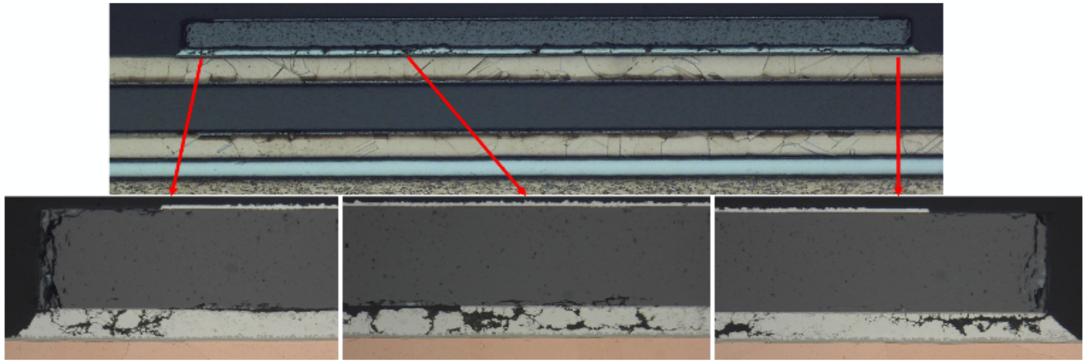
MOSFET 3

MOSFET 2

MOSFET 1







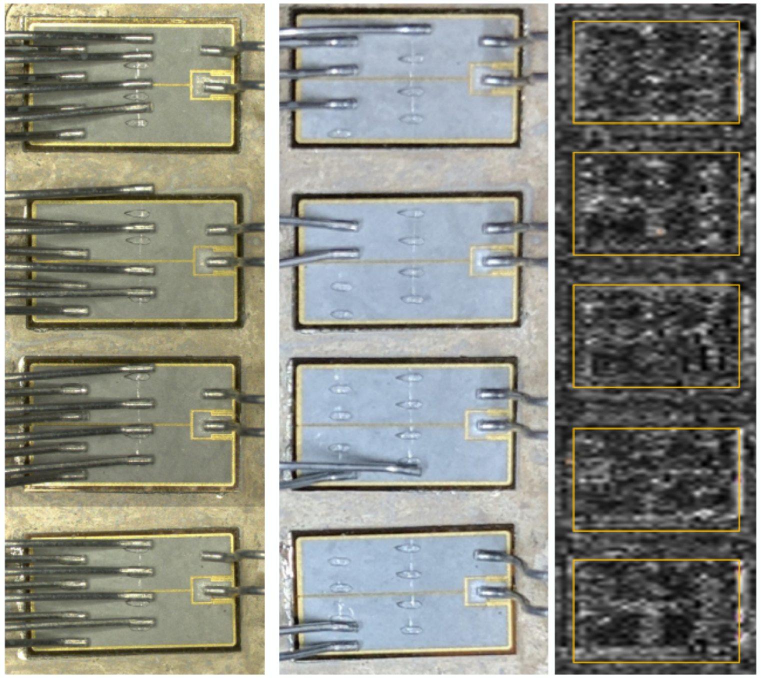
Test Vehicle C (Au-Rich Solder, Cu Baseplate)

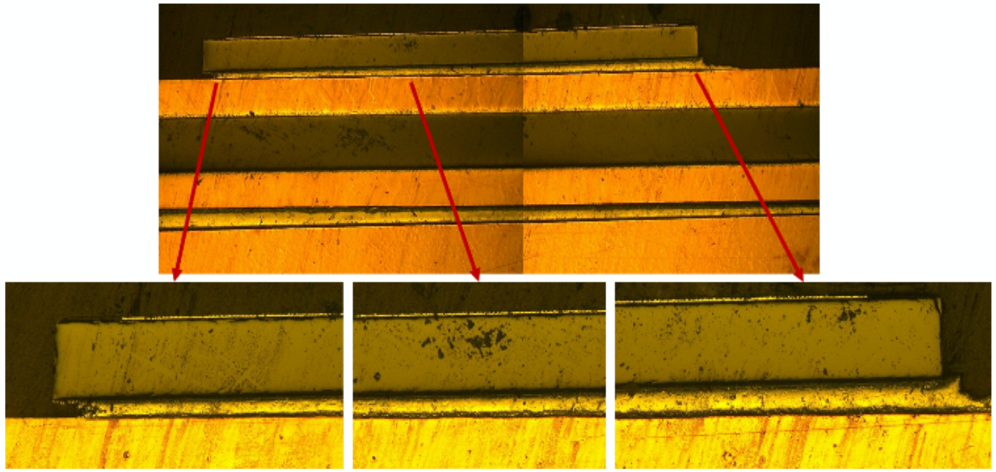
MOSFET 4

MOSFET 3

MOSFET 2

MOSFET 1





Conclusions

– Standard PC failure modes still hold true for SiC-based packages.

– Rate of degradation is highly subject to applied Stress Conditions & Material Selection.

– Package design decisions must be made to support the end-application features.