Benefits and Challenges of High Temperature Probe

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Outline

- Benefits of Higher Temperature
- Testing Temperature Trend
- Defect Acceleration
- Changing Test Conditions
- Challenges
- Additional Considerations
- Conclusion

Why Higher Temperature?

35th ANNIVERSARY

1. Path to Automotive Grade 0
2. Additional reliability margin

AEC - Q100 - REV-J1
March 24, 2026

Automotive Electronics Council
Component Technical Committee

1.3.4 Definition of Part Operating Temperature Grade

The part operating temperature grades are defined in Table 1 below:

Table 1: Part Operating Temperature Grades

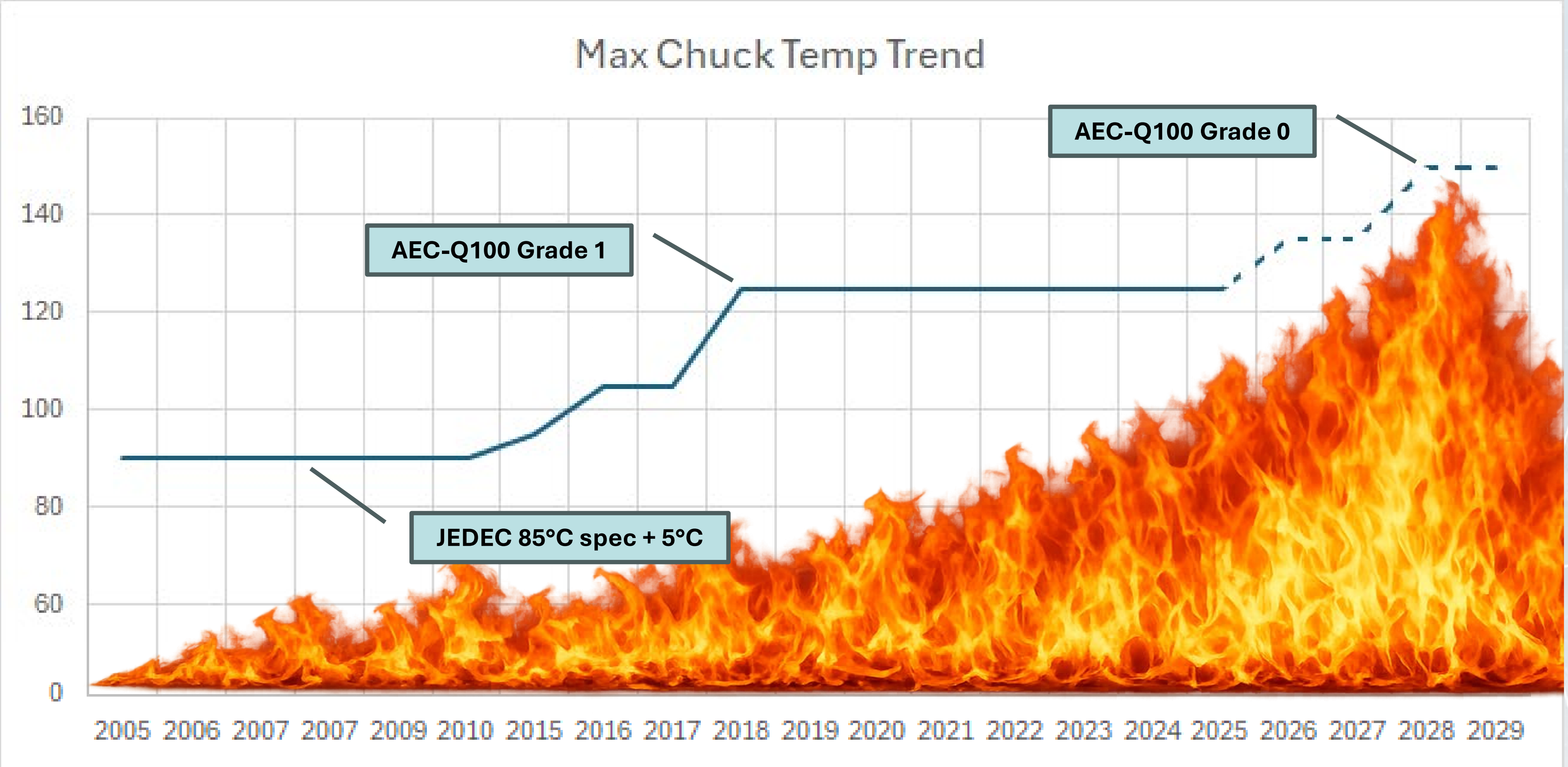
Grade	Ambient Operating Temperature Range
0	-40°C to +150°C
1	-40°C to +125°C
2	-40°C to +105°C
3	-40°C to +85°C

Grade	Role in automotive standards
1	• Validated upper operating limit for most in-vehicle electronics (See AEC-Q100*) • Primary required automotive qualification temperature • Provides strong acceleration of relevant failure mechanisms • Preserves correlation to real automotive environments
0	• Reserved for harsher under-hood applications • Used selectively as an accelerated stress to demonstrate additional thermal margin • Imposes substantially more severe qualification than Grade 1 • Very little demand (currently)

*http://www.aecouncil.com/files/Documents/AEC%20Q100-Rev%20J1.pdf

Max Probing Temperature Trend

Key Drivers:
- JEDEC 85°C spec +5°C
- AEC-Q100 Grade 1 → 0 (125C → 135C → 150C)



Defect Acceleration

- **Most reliability failures:**
  - Thermally activated
  - Occur over the course of years

- **Testing at use temperatures:**
  - Impractical (too slow)
  - Cost-prohibitive

- **Many solid-state degradation processes act like chemical reactions**

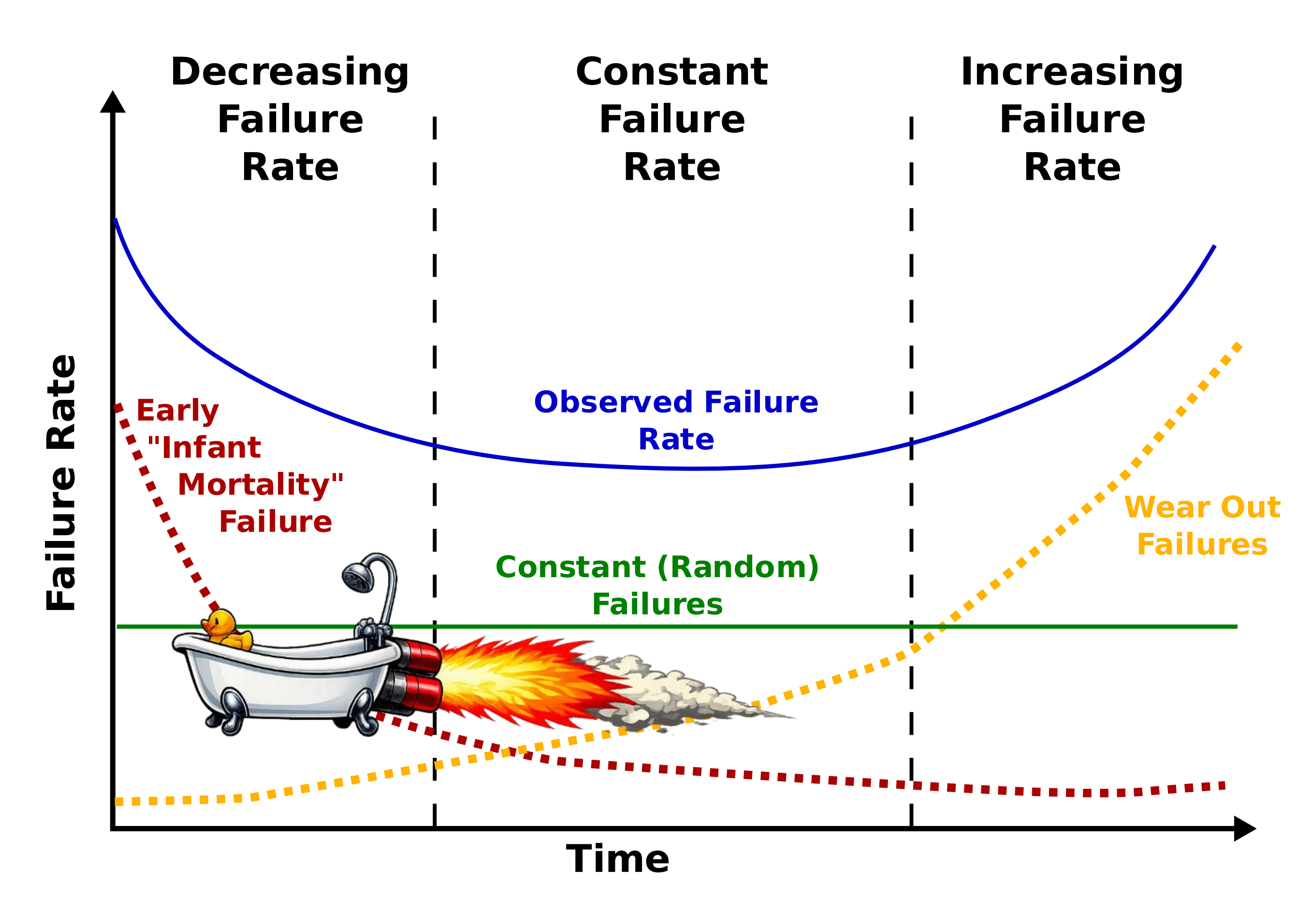
- **Fail rate can be accelerated using the Arrhenius model**

- **Compresses years of aging time**

$$AF = \frac{\mathrm{Rate}(T_2)}{\mathrm{Rate}(T_1)} = \exp\left(\frac{E_a}{k}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right)$$

Accelerating The Bathtub

- Across industry, burn-in routinely performed at high temperatures*.
- Shifts **bathtub curve** to the **left** by accelerating failure mechanisms.
- Results in higher quality test flow.



*See https://www.jedec.org/sites/default/files/docs/22A108G.pdf

Arrhenius Temperature Acceleration

- **Example:**
  - 10 defects per 10,000 devices after 30 minutes @125 °C
  - Relative acceleration 135 °C vs. 125 °C:

- $T_{use} = 55°C = 328\ K$
- $AF_X = e^{E_a/_k\left(1/T_{use} - 1/T_{test}\right)}$
- $E_a = 0.7\ eV$
- $k = 8.617 \times 10^{-5}\ eV/_K$

$$AF_{135/125} = \frac{AF_{135}}{AF_{125}} = \frac{128.02}{77.66} = 1.65$$

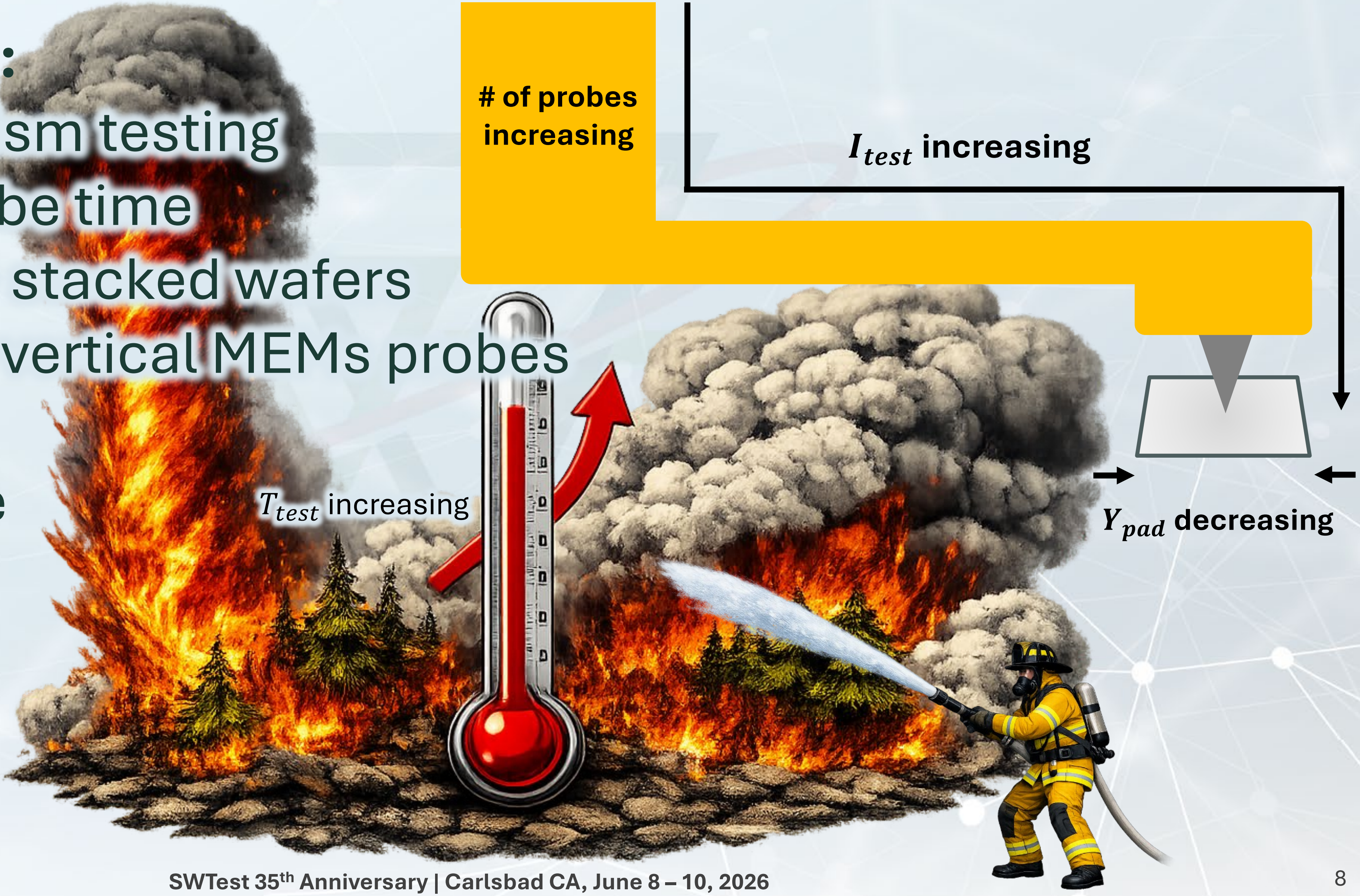
$$r = 1.65 \times 10 = \mathbf{16.5}$$

6-7 more defects found in the same testing time*!

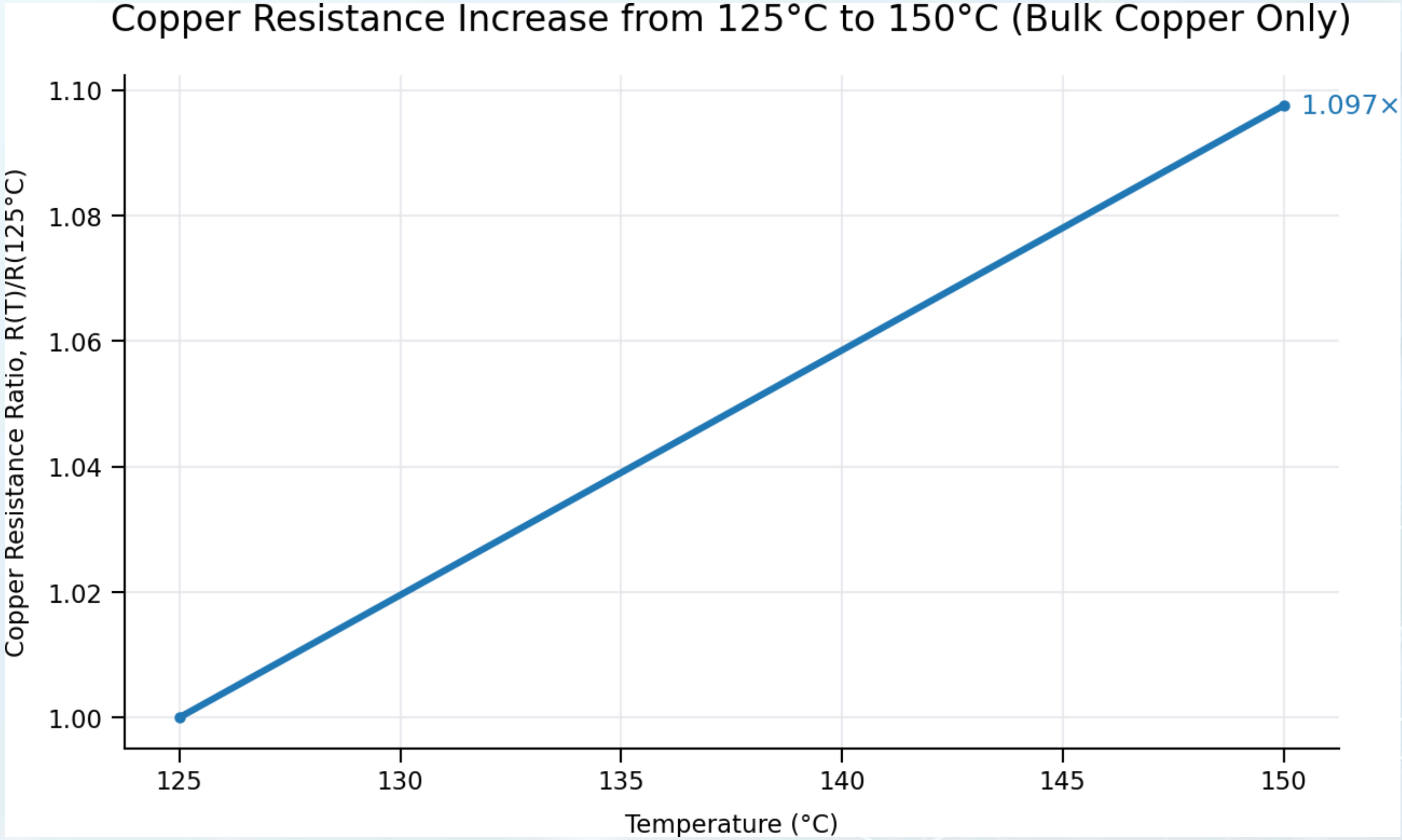
**Assumes same dominant thermally-activated mechanism.*

The Perfect “Fire”-Storm

- **Requirements:**
  - Max parallelism testing
  - Lo~~~ng probe time
  - Monolithic → stacked wafers
  - Cantilever → vertical MEMs probes
- **Increasing:**
  - Temperature
  - Probe count
  - Current
- **Decreasing:**
  - Pad size

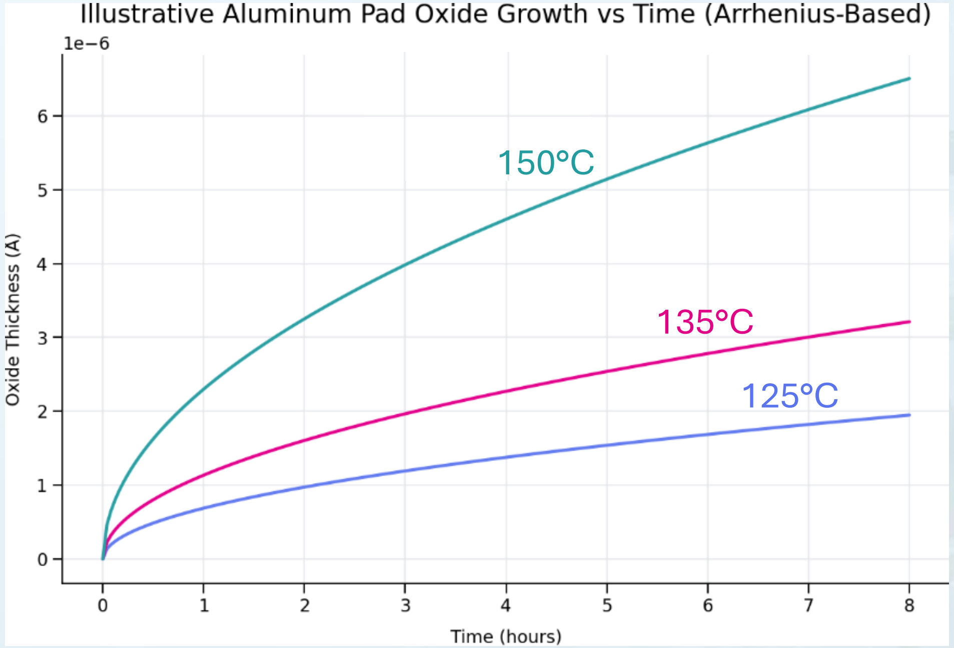


Probe Card IR Drop vs. Temperature



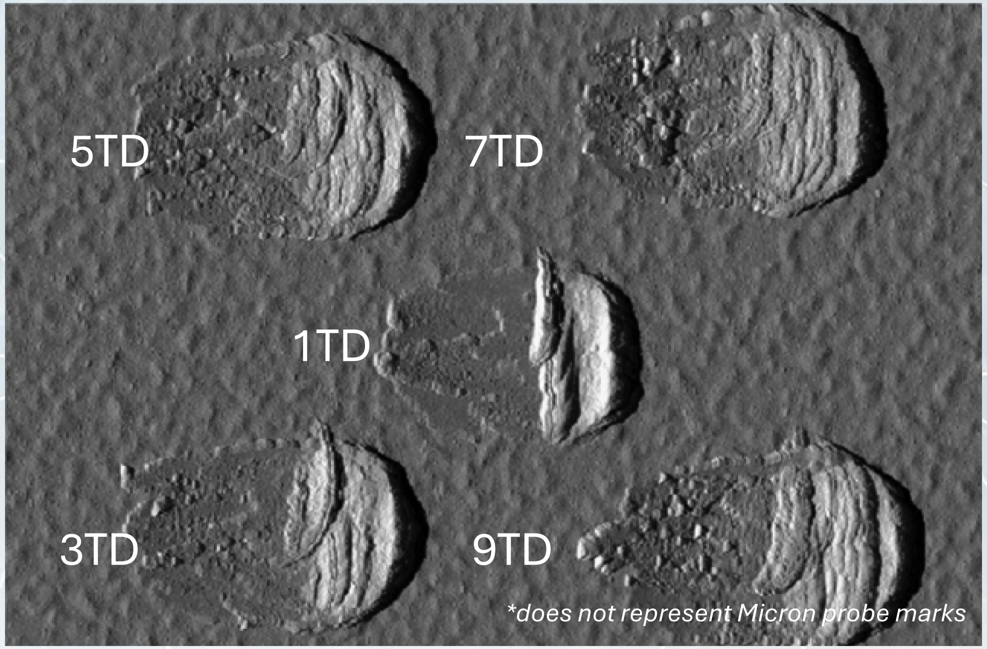
- **25°C increase raises copper resistance ~10%.**
- **~10% thicker copper required to hold IR drop constant.**
- **Impact:**
  - **Trace routing**
  - **Cost**

Key Challenge - Pad Oxidization



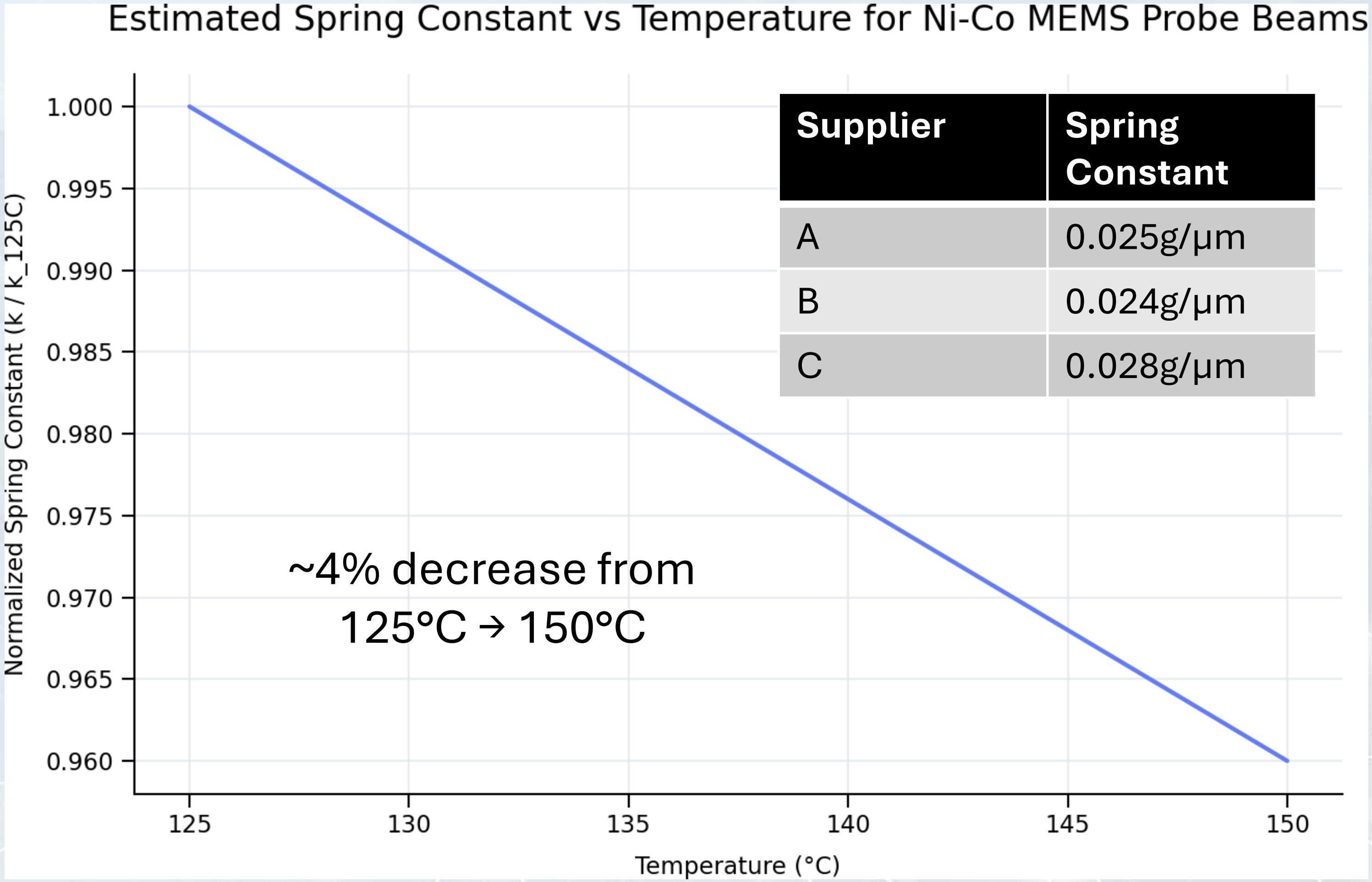
- Al_2O_3 thickness increases exponentially with temperature
- Highest growth rate just after contact

- Each contact exposes fresh Al
- Rapidly re-oxidizes
- CRES distribution may increase



Key Challenge - Spring Constant

- **Reaction to Heat:**
  - Young's modulus ↓
  - Spring Constant ↓
  - Probe Force ↓
  - CRES ↑
- **Mitigation:**
  - Prober Overdrive ↑
- **Impact:**
  - Scrub Length ↑
  - Pad Size Capability ↓



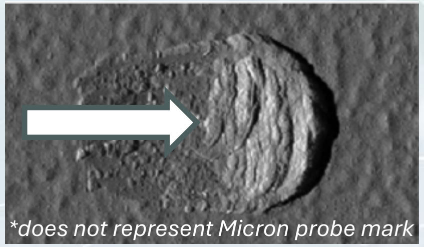
Supplier	Spring Constant
A	0.025g/μm
B	0.024g/μm
C	0.028g/μm

Example: $OD_{150} \approx \frac{k_{150}}{k_{125}} \times OD_{125} \approx \frac{1}{0.96} \times 100\mu m \approx \mathbf{104\mu m}$

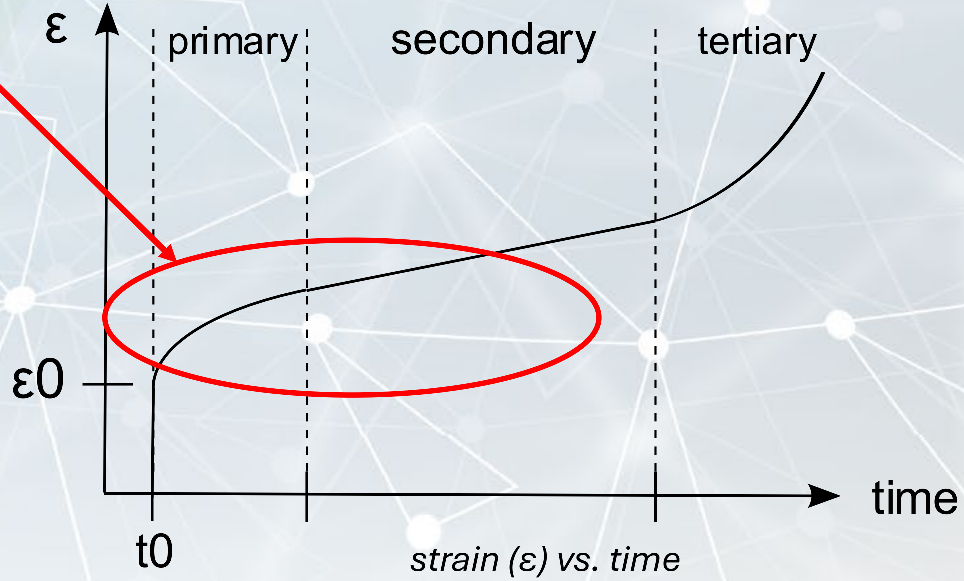
Key Challenge - Pad Creep

- Creep starts **~35%** of melting point (K)
- Melting point of Al = 660°C (933°K)
  - $0.35 * 933°K = 326.6°K$
  - $125°C = 398°K$
- @125°C, already in the region for creep
- $\frac{d_\varepsilon}{d_t}$ ↑ with temperature

	$\frac{T_{test}(K)}{T_m(K)}$
At 125°C:	$\frac{398°K}{933°K} \approx 0.43$
At 150°C:	$\frac{423°K}{933°K} \approx 0.45$



- Probe marks deeper and longer vs. time

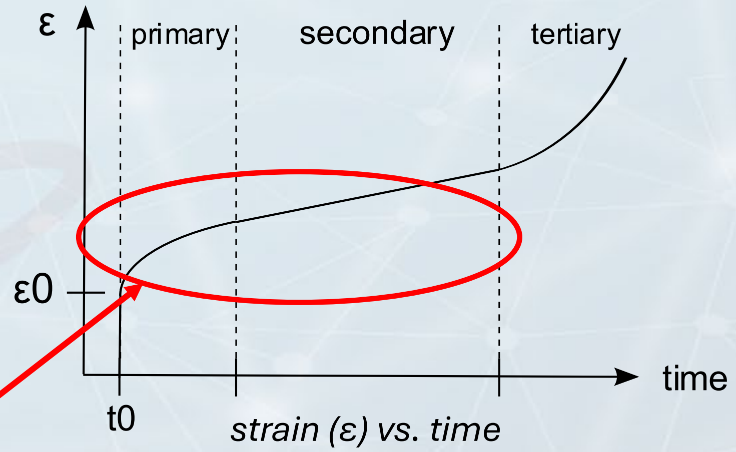


strain (ε) vs. time

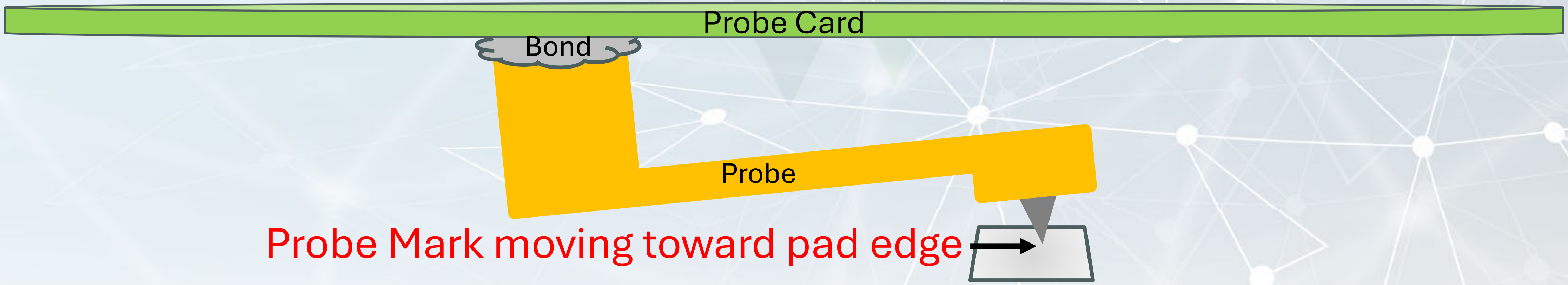
Key Challenge - Solder Creep

Alloy	Melting Point (°K)	Creep Onset (~$0.35 \times T_m$)
AuSn (eutectic)	553°K	~194°K
Sn-5Sb	508°K	~178°K
SAC305	490°K	~172°K

- 125°C = 398°K
- @125°C, already in the region for creep
- >125°C creep will be worse*

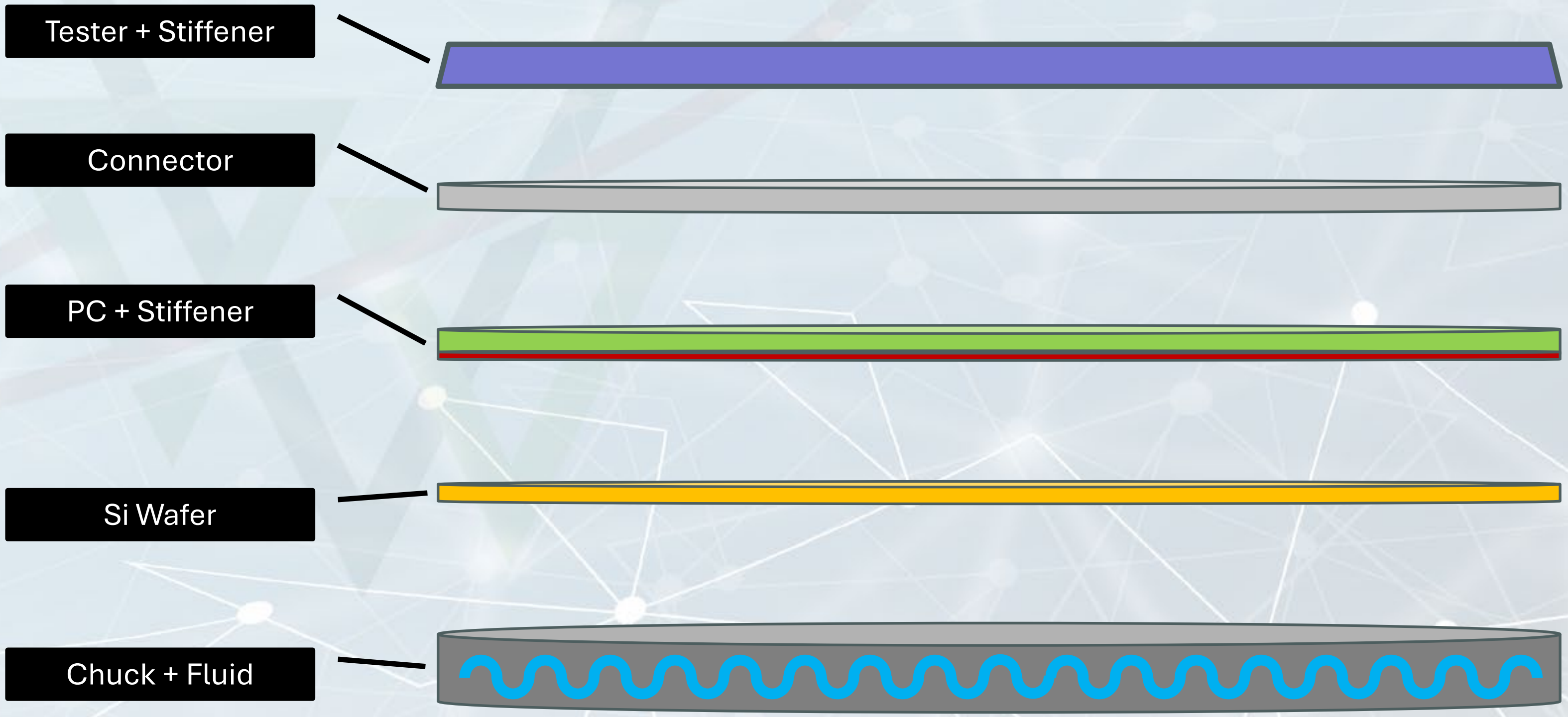


*Recall: $\frac{d_\varepsilon}{d_t}$ ↑ with temperature



Key Challenge - Deformation

- **All materials must operate up to 150°C + margin**
- **Least → Most Stable:**
  - Epoxy, mold, adhesive compounds
  - PCB materials
  - Solder alloys
  - Metals (Al, Ni, Cu)
  - Ceramic/Silicon



Additional Considerations

- Test program changes
- Re-characterization of FIT rates
- Customer qualification requirements
- Component limitations (derating)
- CTE matching issues

Conclusion

- **Key takeaways**
  - 135°C needed to increase margin vs. Grade 1
  - 150°C needed to achieve Grade 0
- **What makes it hard (top risks)**
  - Pad oxidation & creep
  - Probe spring constant + solder creep
  - IR drop increase
- **Path forward**
  - Micron execute phased qualification roadmap
  - Industry help needed

Thank You!