Extending the power cycling lifetime of SiC diodes (by increased cooling temperatures)

ISiCPEAW 2013

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Fraunhofer IISB

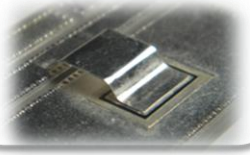
Outline

1. Introduction
2. Experimental Part
3. Test Results & Explanation
4. Outlook for SiC devices

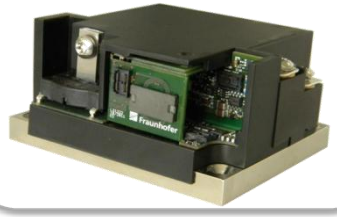
Power Electronics at Fraunhofer IISB

Device Technologies

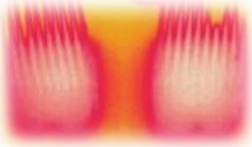
Joining Technologies



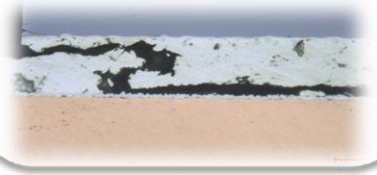
Power Modules



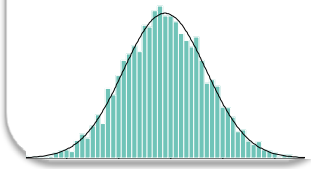
Accelerated Aging



Analysis of Failure Mechanisms



Lifetime Modeling



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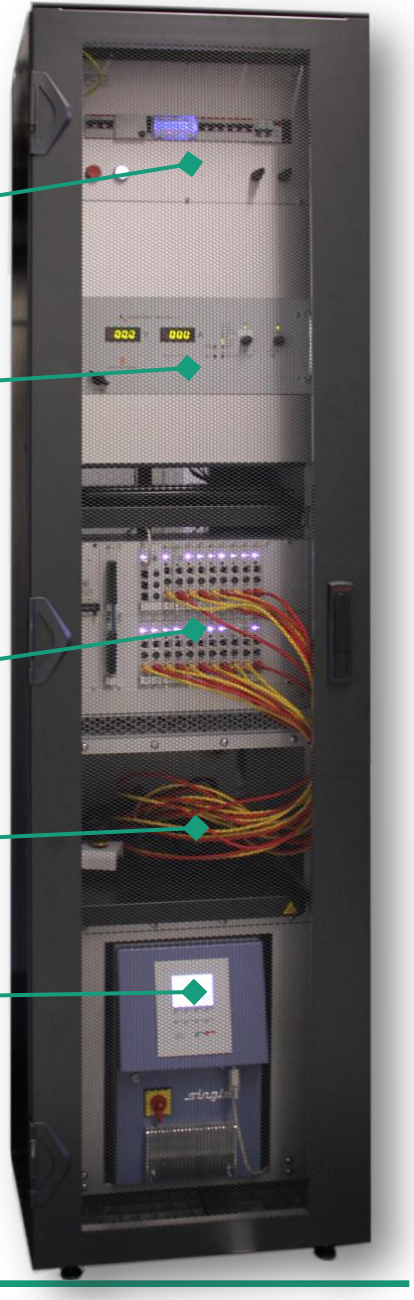
Experimental Part

- Energy Input
- Heat Source
  - 400A / 35V
  - 800A / 15V
  - 2000A / 20V
- PC and Data Logging
- Chamber for up to 20 Devices Under Test
- Temperature Control
  - -60..200°C



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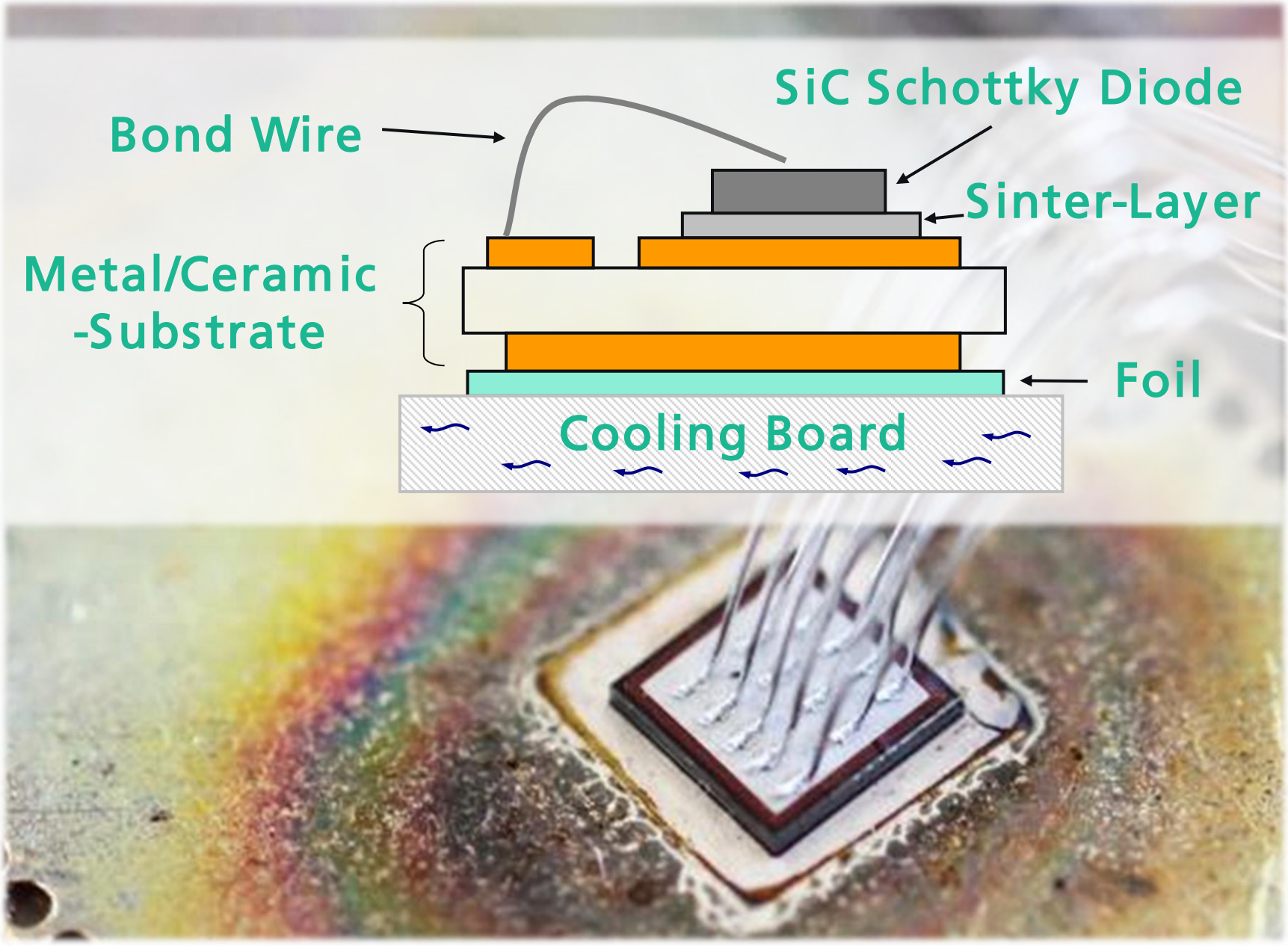

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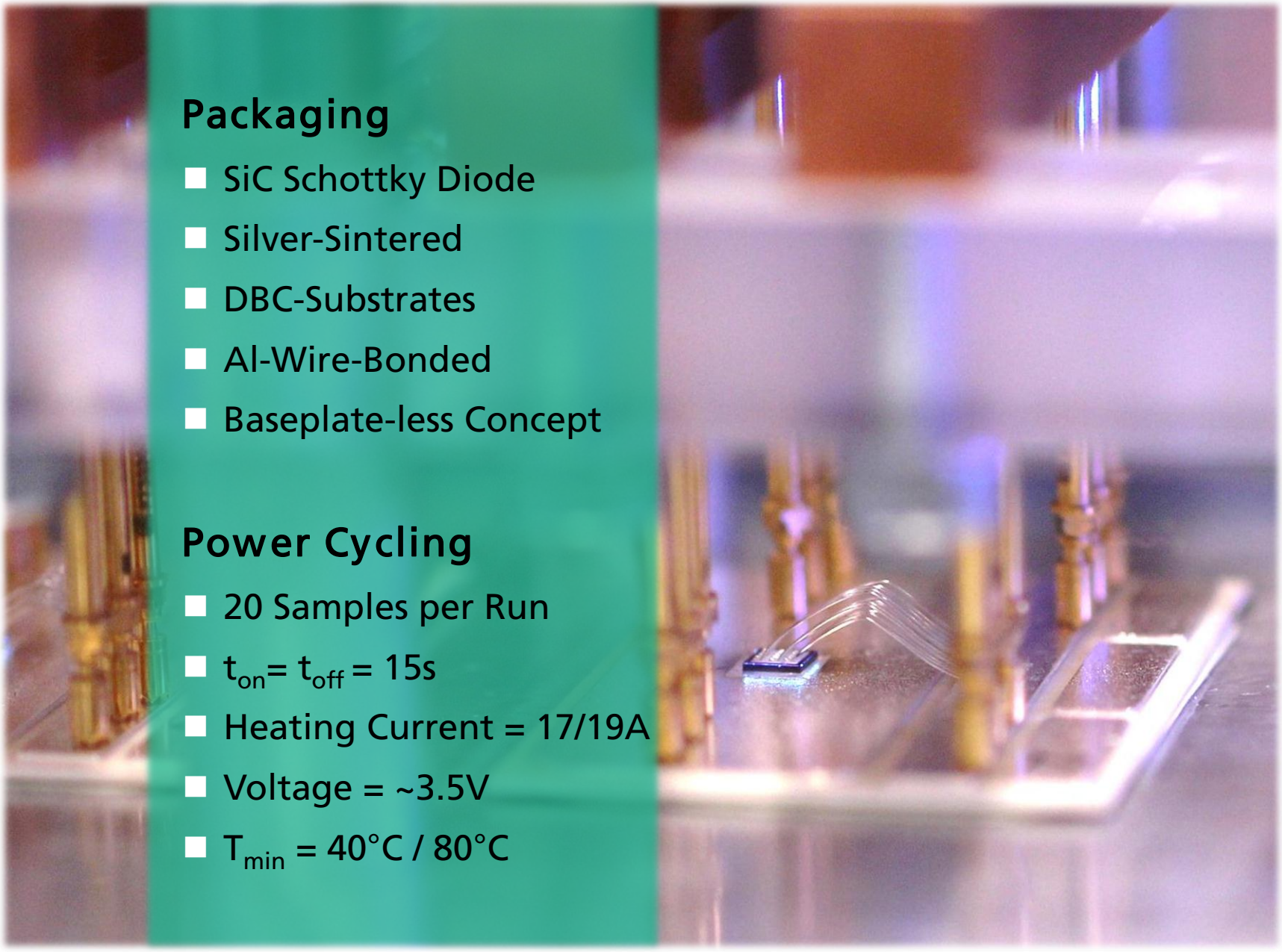

Packaging

- SiC Schottky Diode
- Silver-Sintered
- DBC-Substrates
- Al-Wire-Bonded
- Baseplate-less Concept

Power Cycling

- 20 Samples per Run
- $t_{on} = t_{off} = 15s$
- Heating Current = 17/19A
- Voltage = ~3.5V
- T_{min} = 40°C / 80°C

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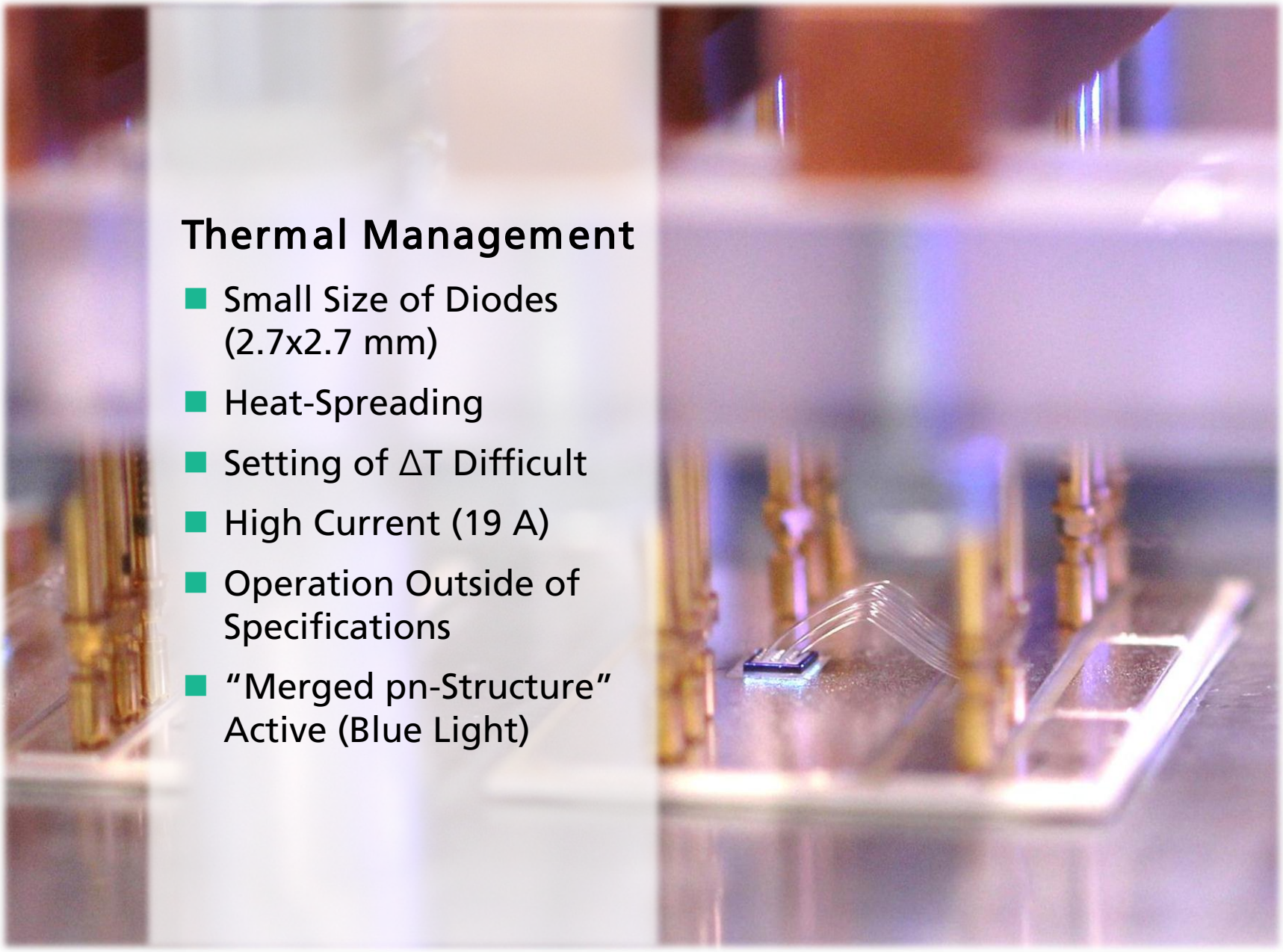

Thermal Management

- Small Size of Diodes (2.7x2.7 mm)
- Heat-Spreading
- Setting of ΔT Difficult
- High Current (19 A)
- Operation Outside of Specifications
- “Merged pn-Structure” Active (Blue Light)

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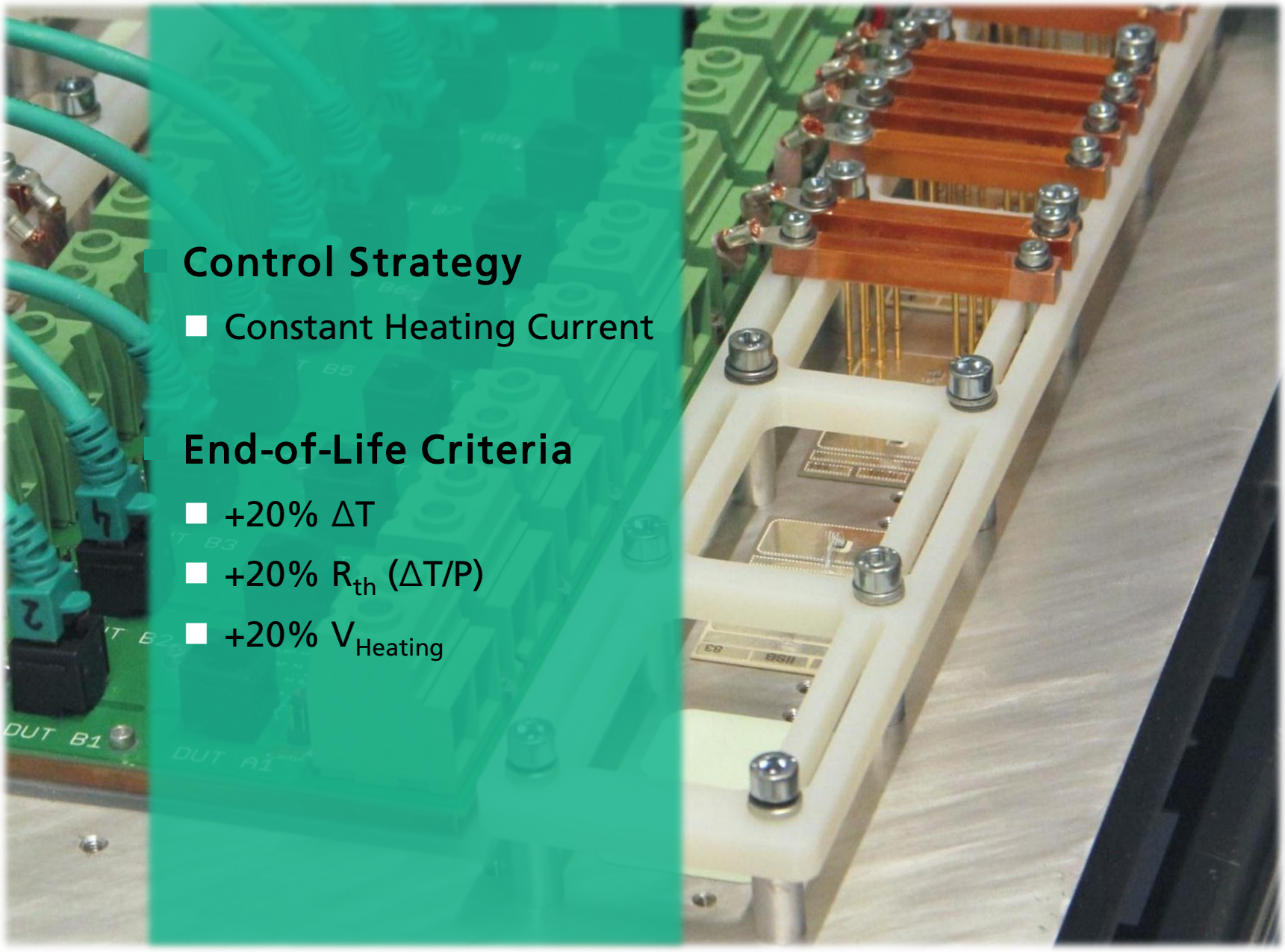

Control Strategy

- Constant Heating Current

End-of-Life Criteria

- +20% ΔT
- +20% R_{th} ($\Delta T/P$)
- +20% $V_{Heating}$

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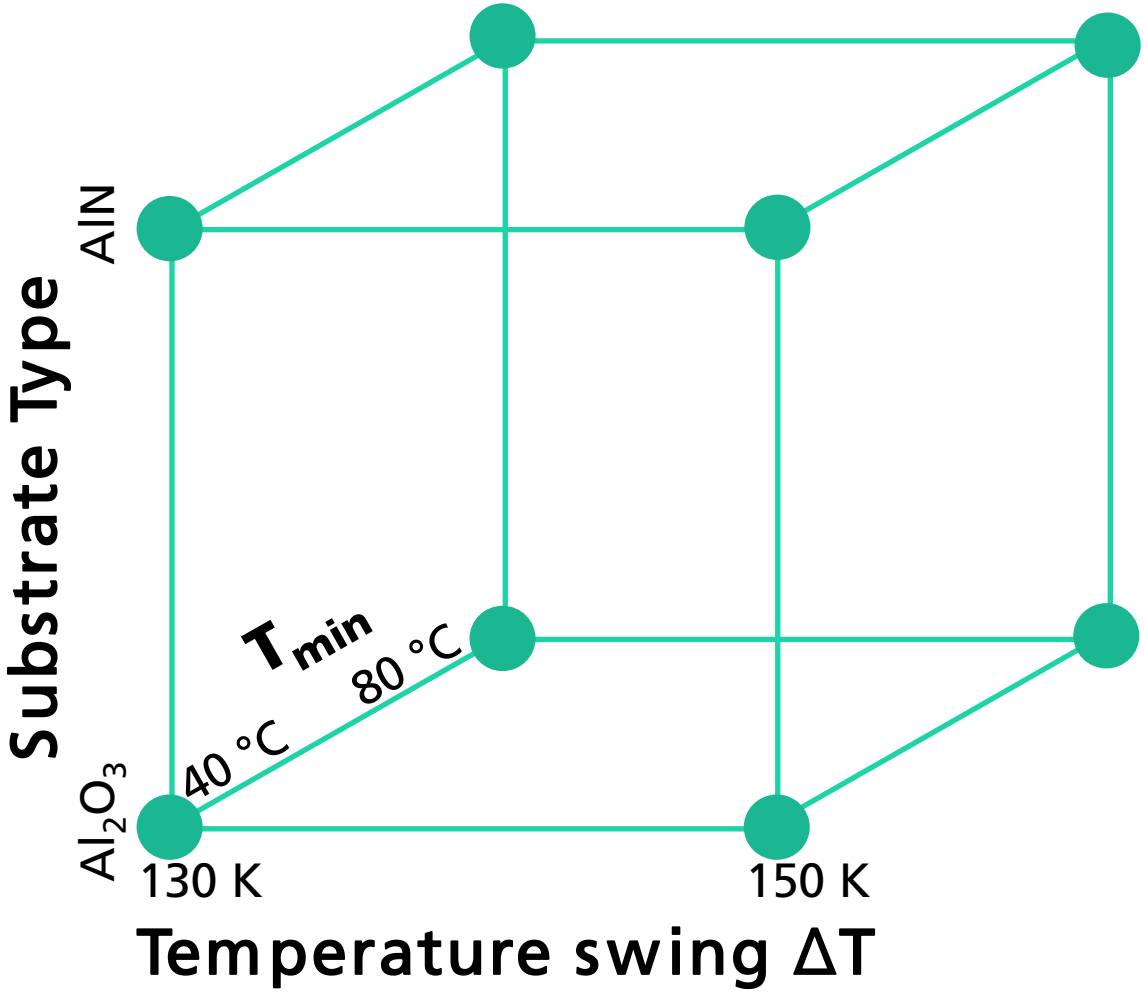
Design of Experiments



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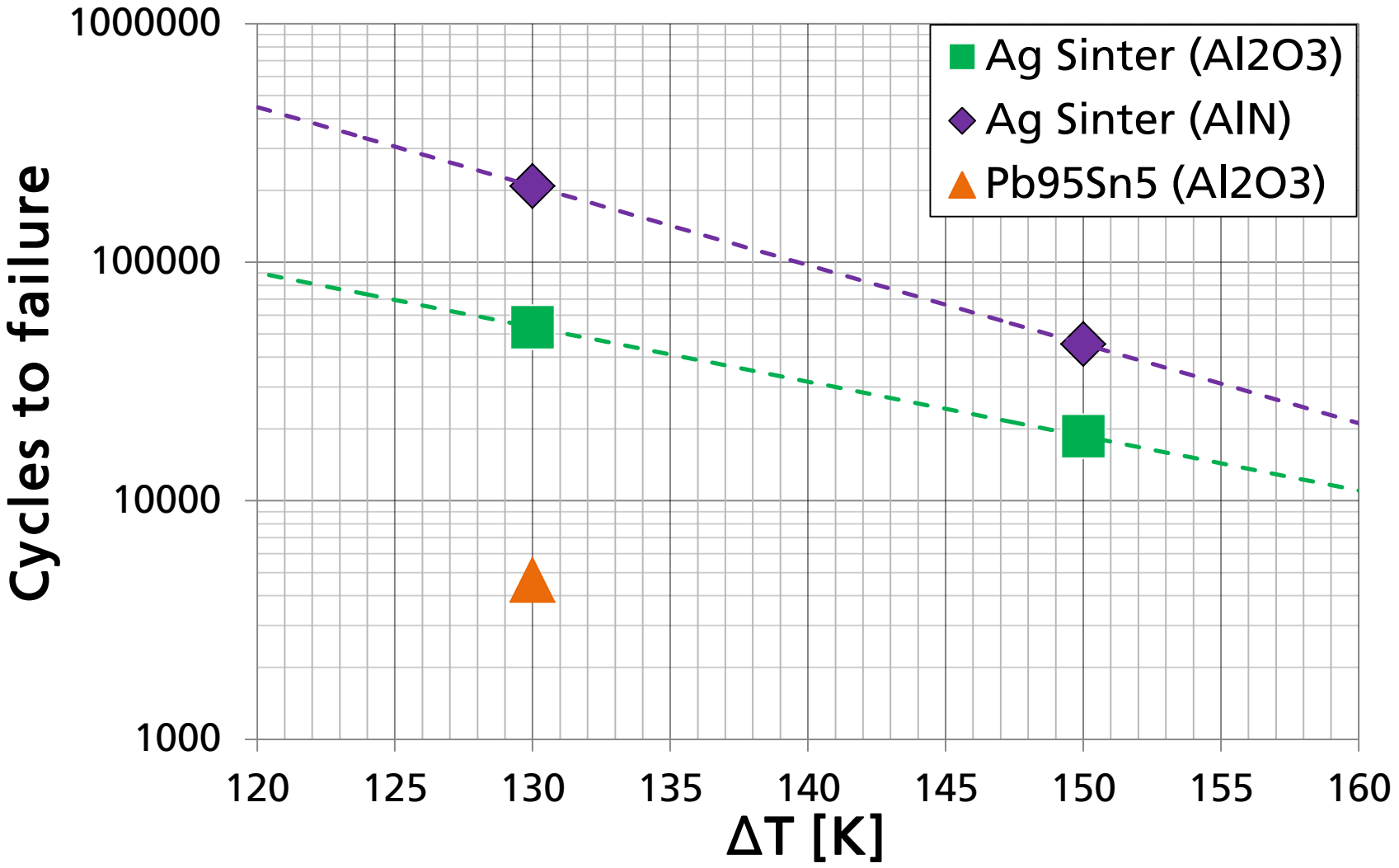
Results for T_{min} = 40 °C (Weibull Scale)



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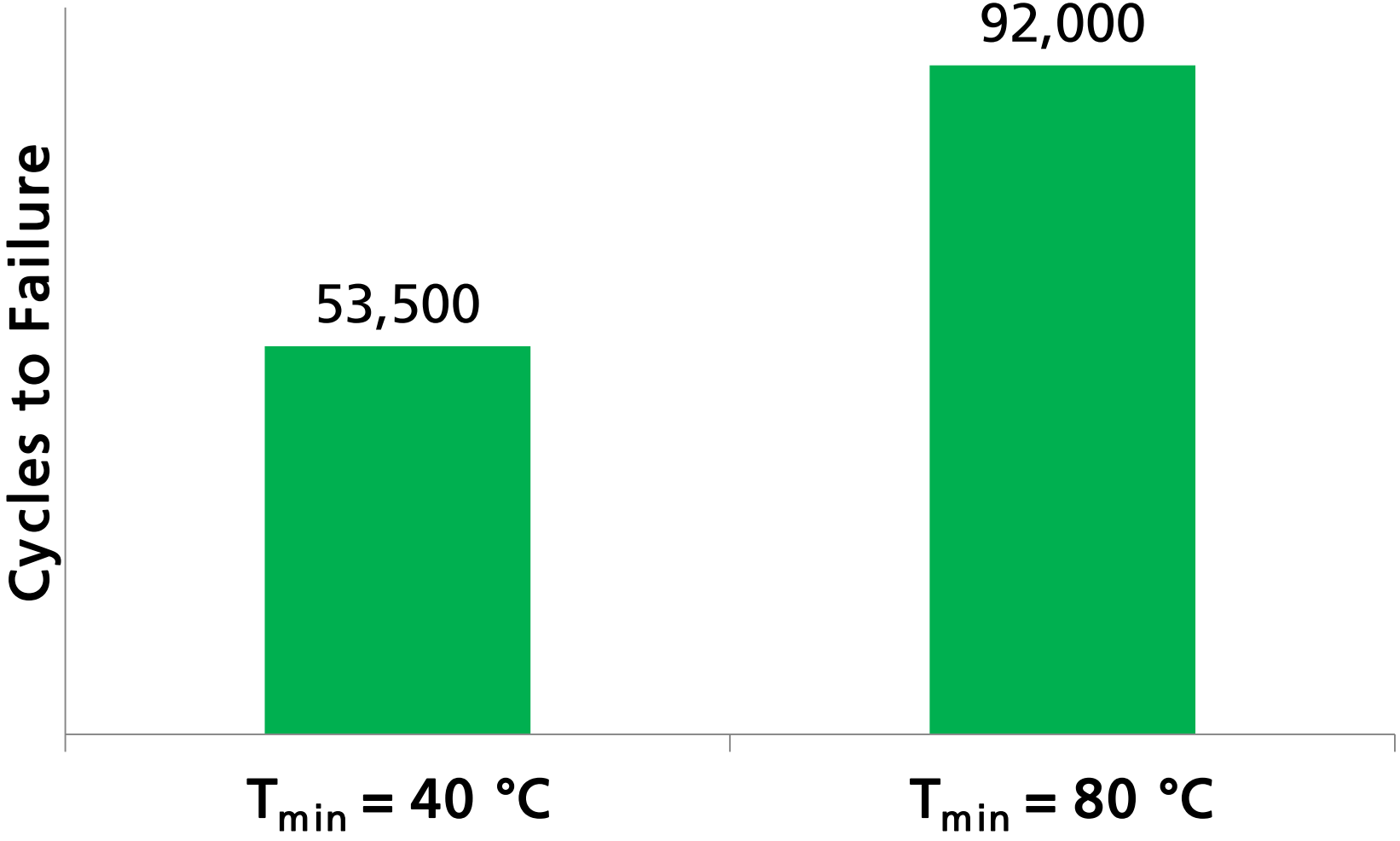
Ag Sinter Al_2O_3, ΔT = 130 K (Weibull Scale)



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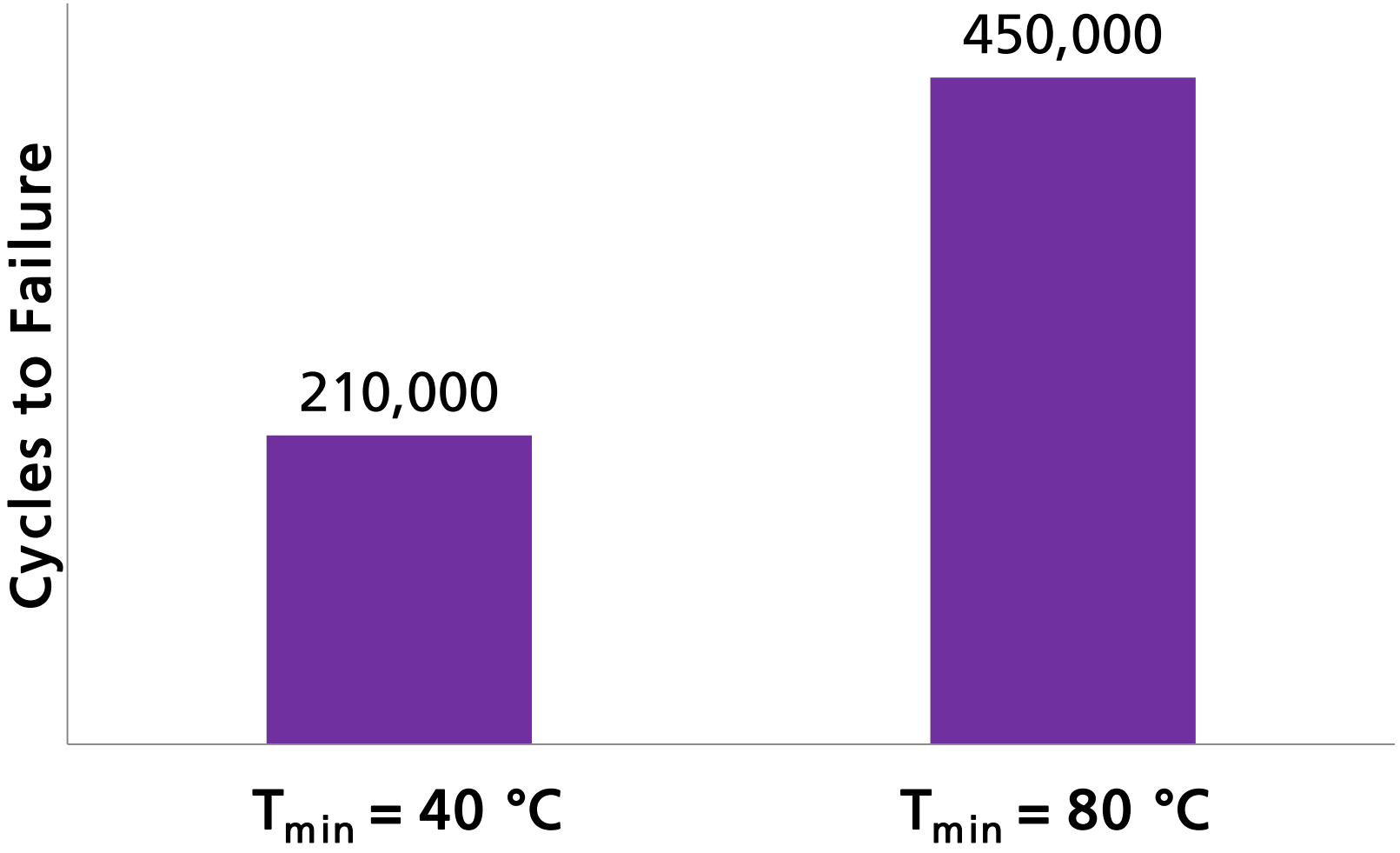
Ag Sinter AlN, ΔT = 130 K (Weibull Scale)



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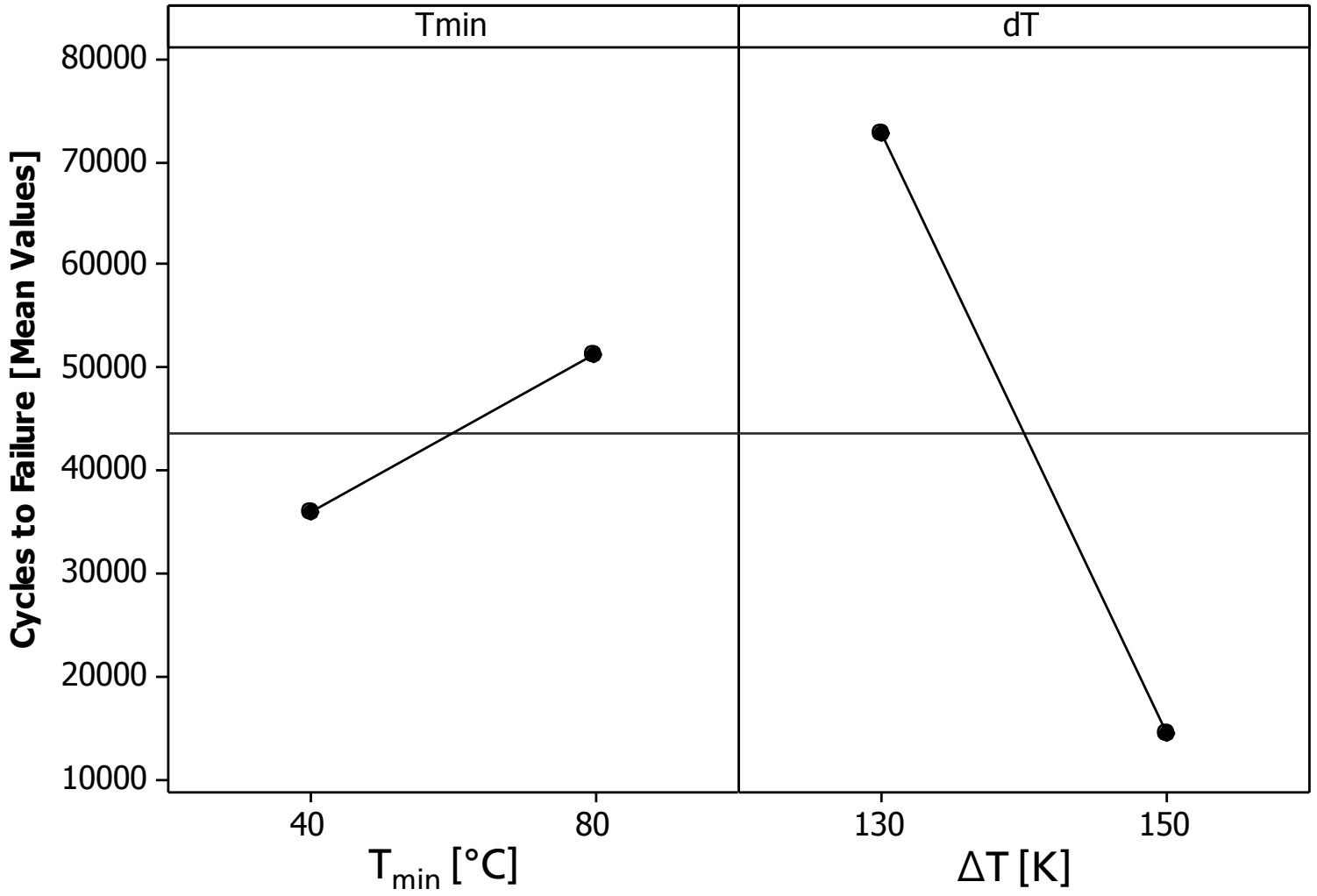
Influence of T_{min} and ΔT (Regression)



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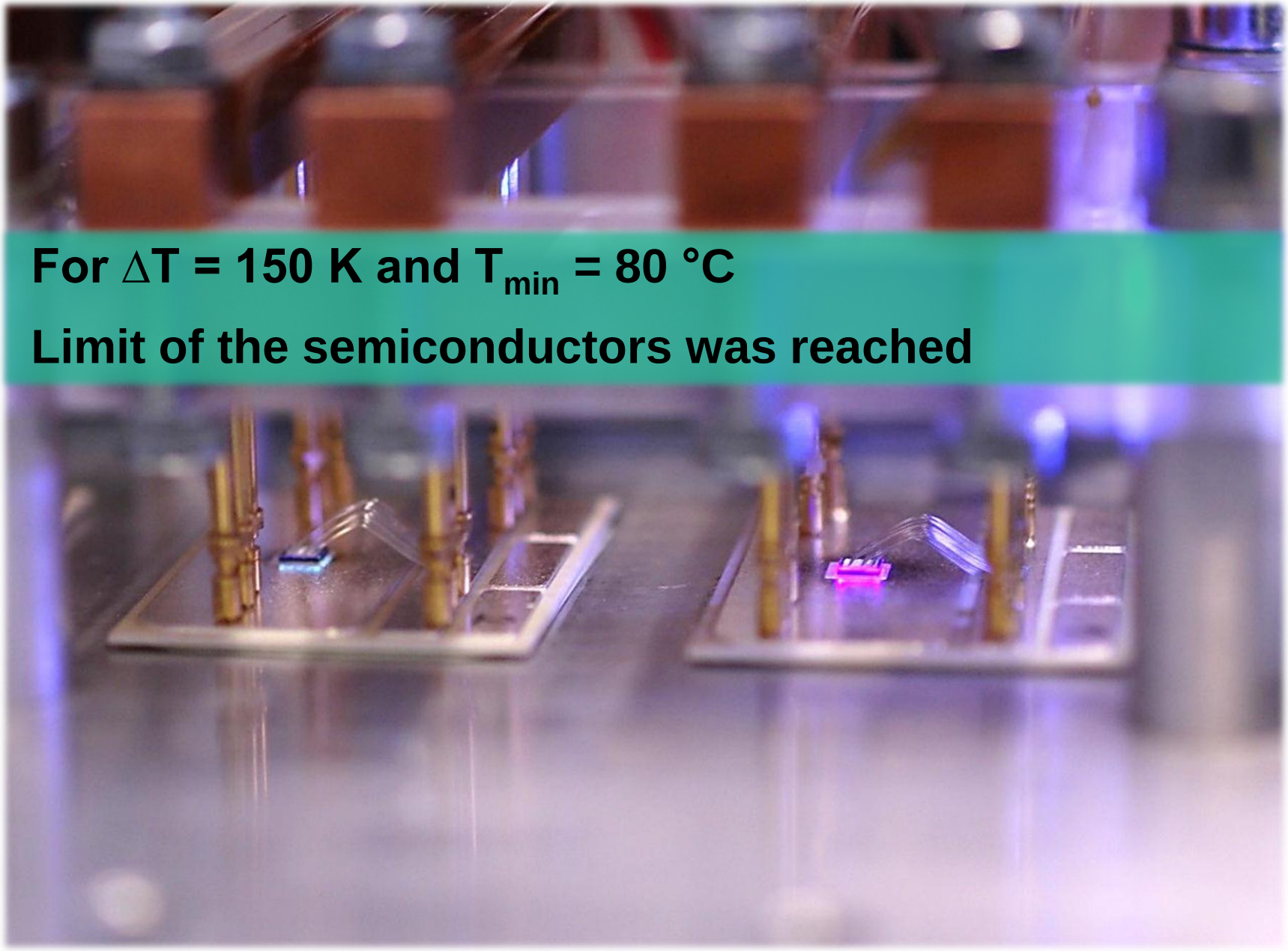

For ΔT = 150 K and T_{min} = 80 °C

Limit of the semiconductors was reached

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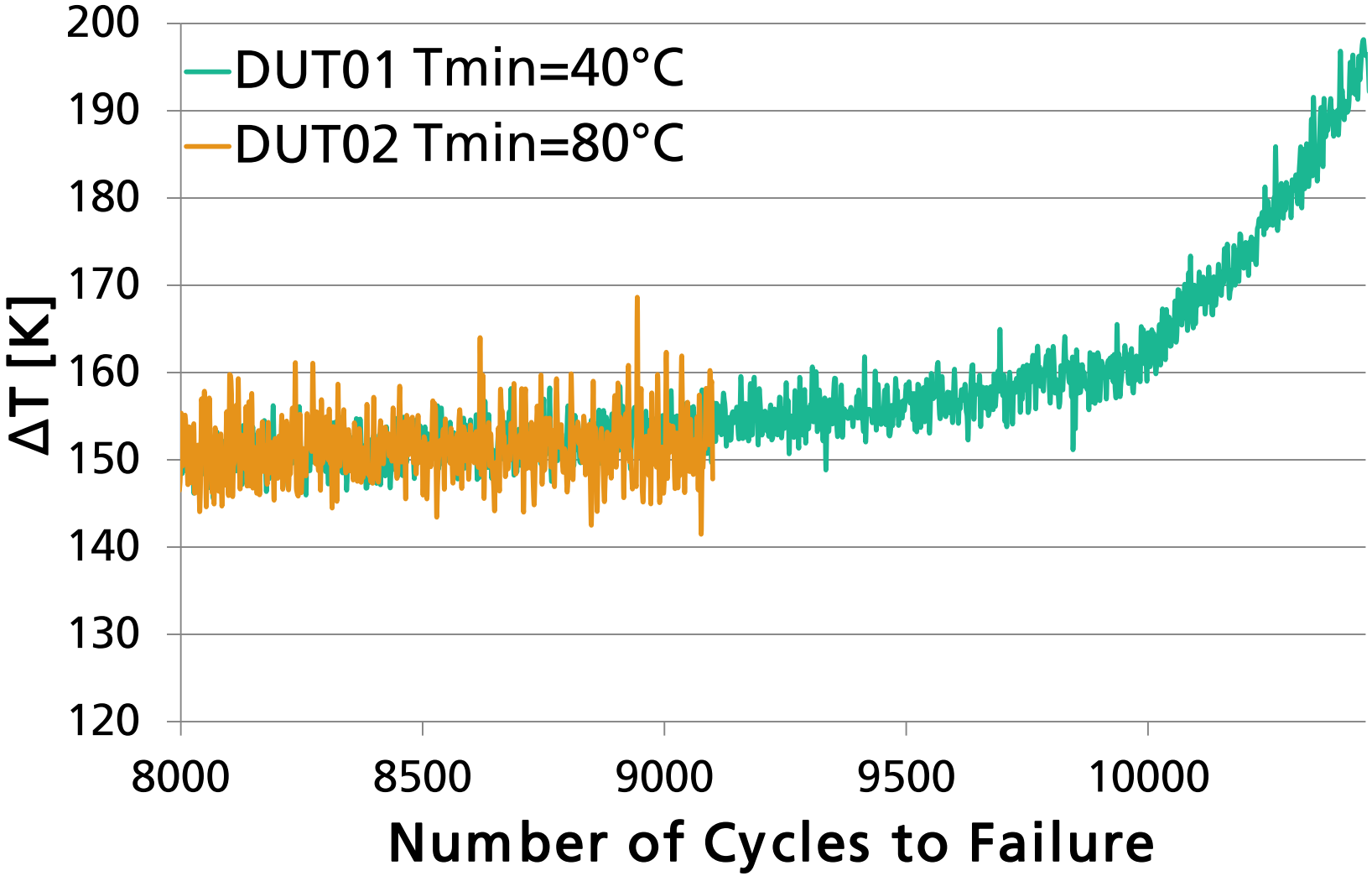
Limits of SiC devices



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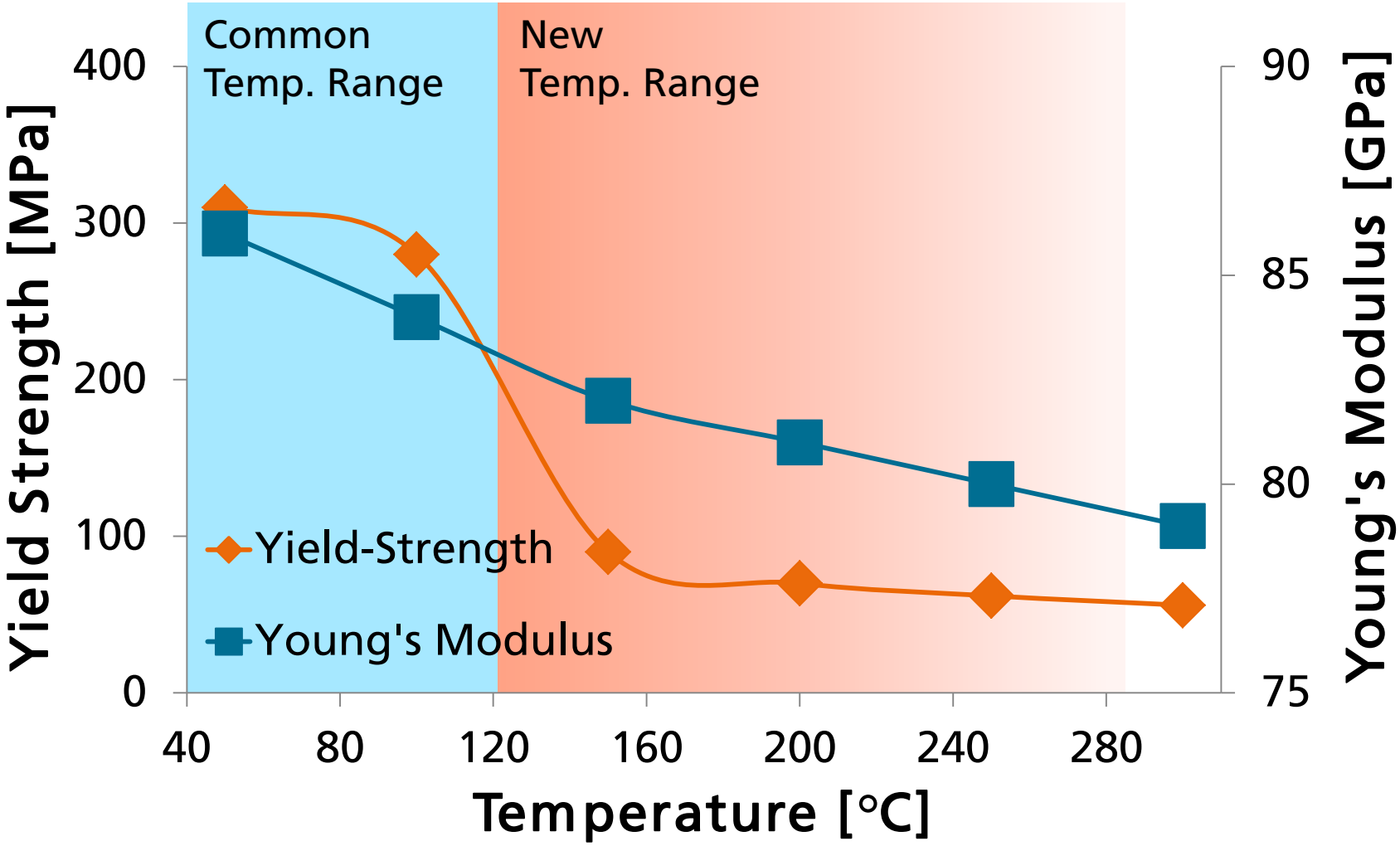
Test Result Explanation – Material Properties of Silver



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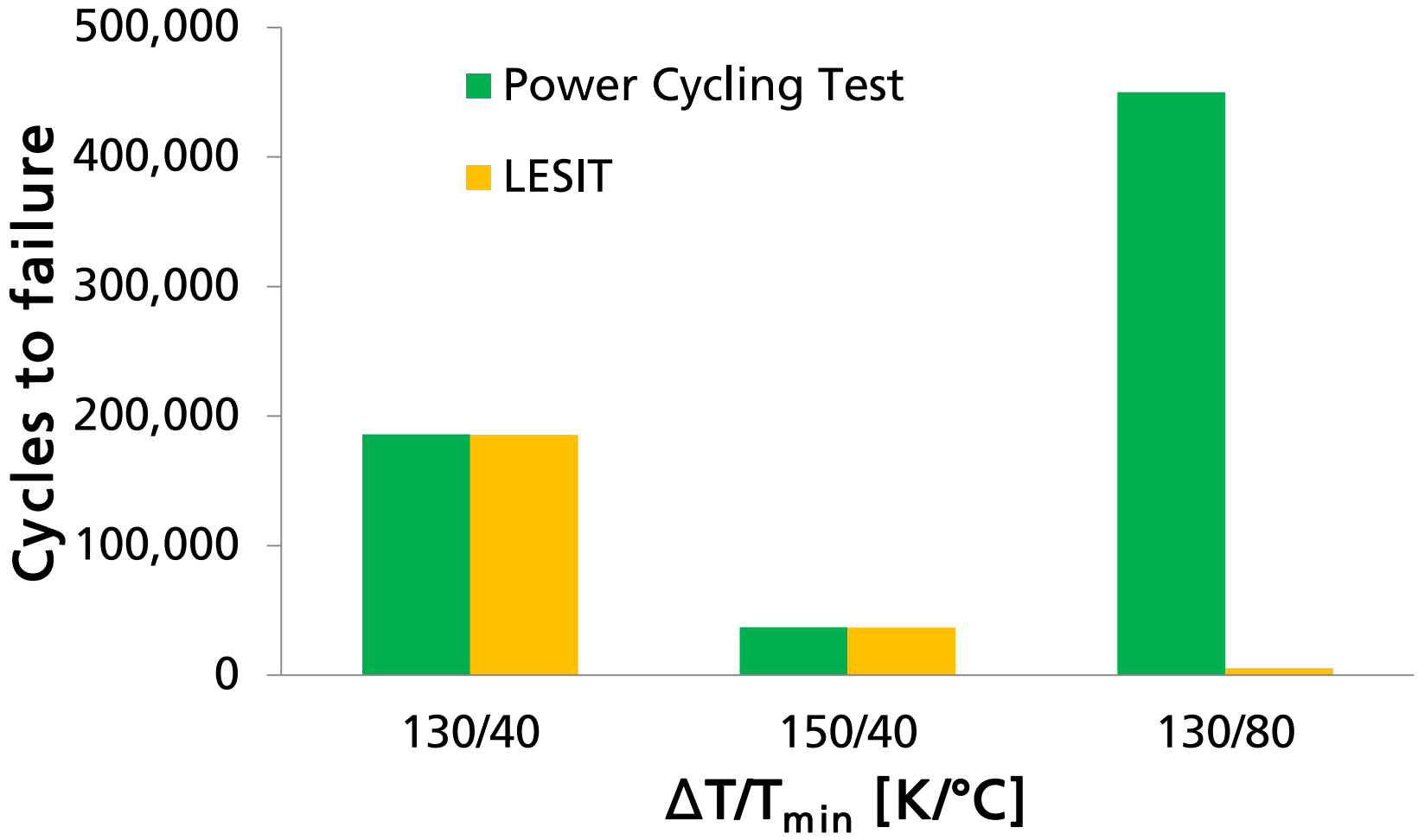
Test Results and Empirical Lifetime Modeling (AlN)



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Conclusion

- SiC devices can easily deal with higher temperatures
  (Electrical performance of unipolar devices excluded)
- Increased cooling temperature can **extend** the lifetime
- Empirical lifetime models can only be applied for the kind of assemblies and test condition that they were meant for
- Temperature swing and cooling temperature have to be separately considered
- Temperature dependent material characterization is needed

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Outlook

- SiC devices with the sintering technology have a huge potential
- The temperature of their applications can be significantly increased
- But silver-sintering is only one part of a power module
  - High temperature behavior of…
  - molding, housing, terminals, sensors, insulating material…
  - and their electrical, thermal, mechanical interconnections

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Last but not least…

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