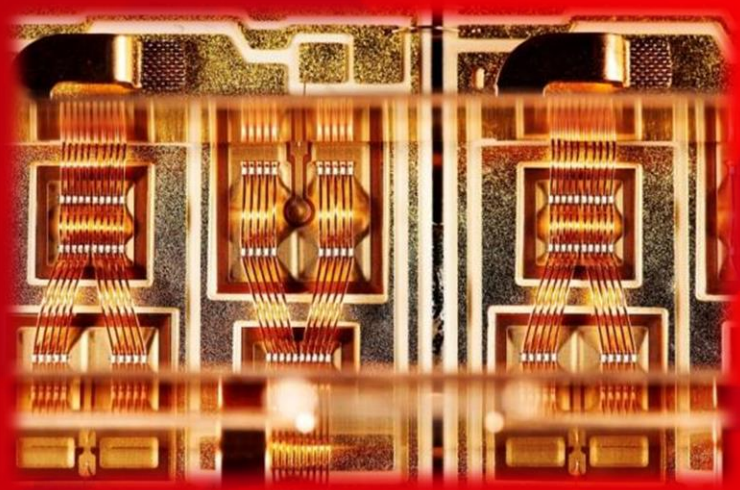
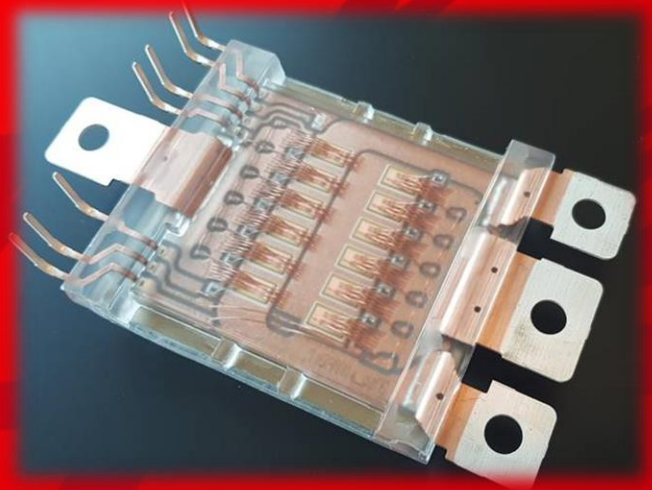
ENGINEERING
TOMORROW

Building-in Reliability into Power Modules

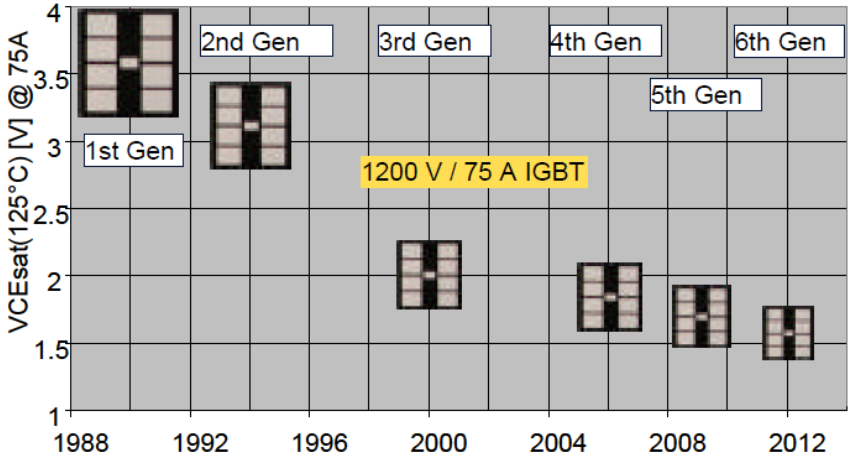




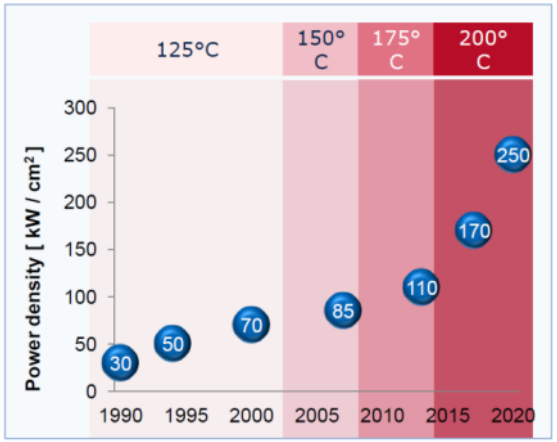
Chemnitzer Seminar 2019

Dr. Jacek Rudzki

Trends in Power Electronics

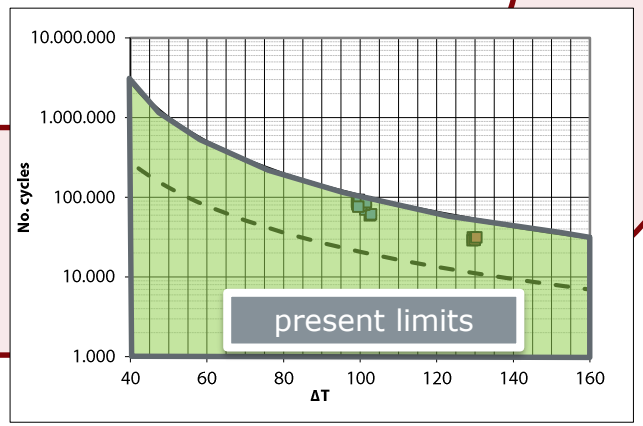


Source: Infineon



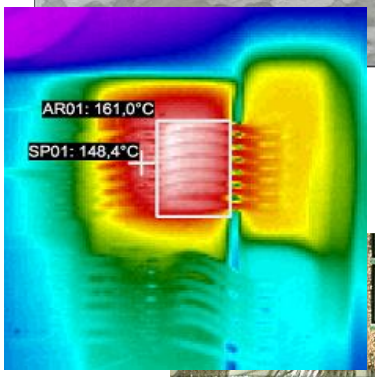
Source: Infineon

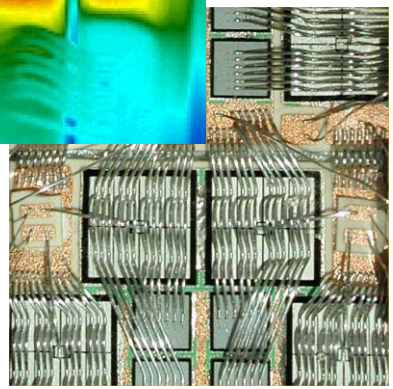
Power density	Junction temperature	Reliability demand
↗	↗	↗



Automotive applications – life time expectation

14	years life time
3000	max temperature cycling
15.000	starts (w/o start-stop)
200.000	max. excelerations
3.000.000	hard transistor switching

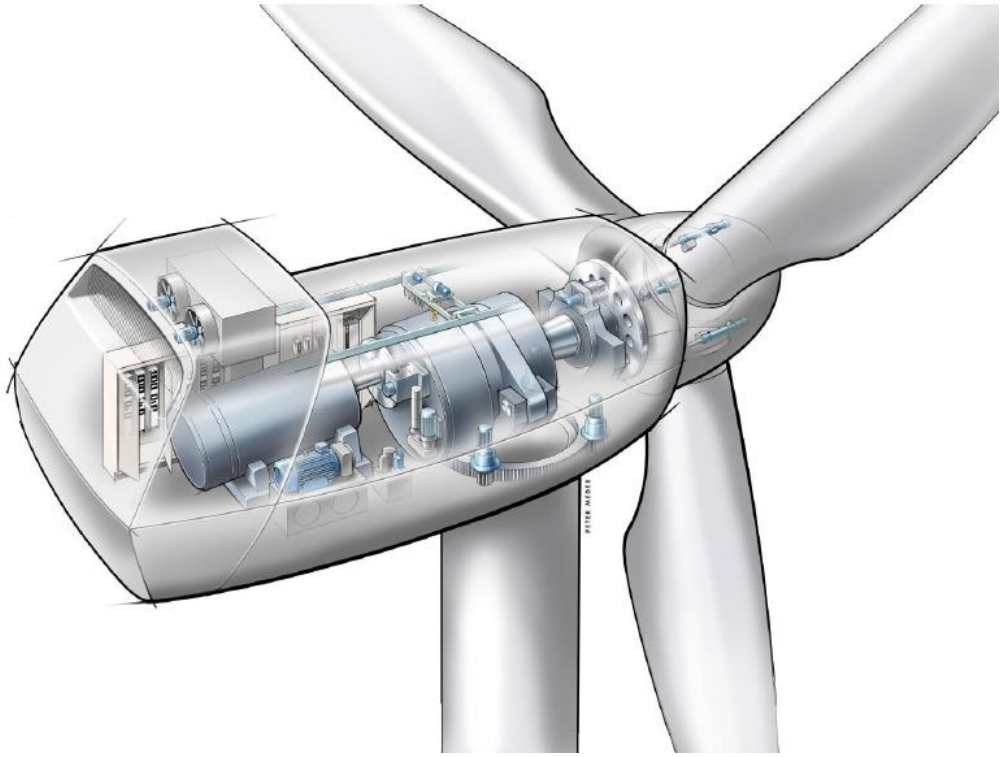




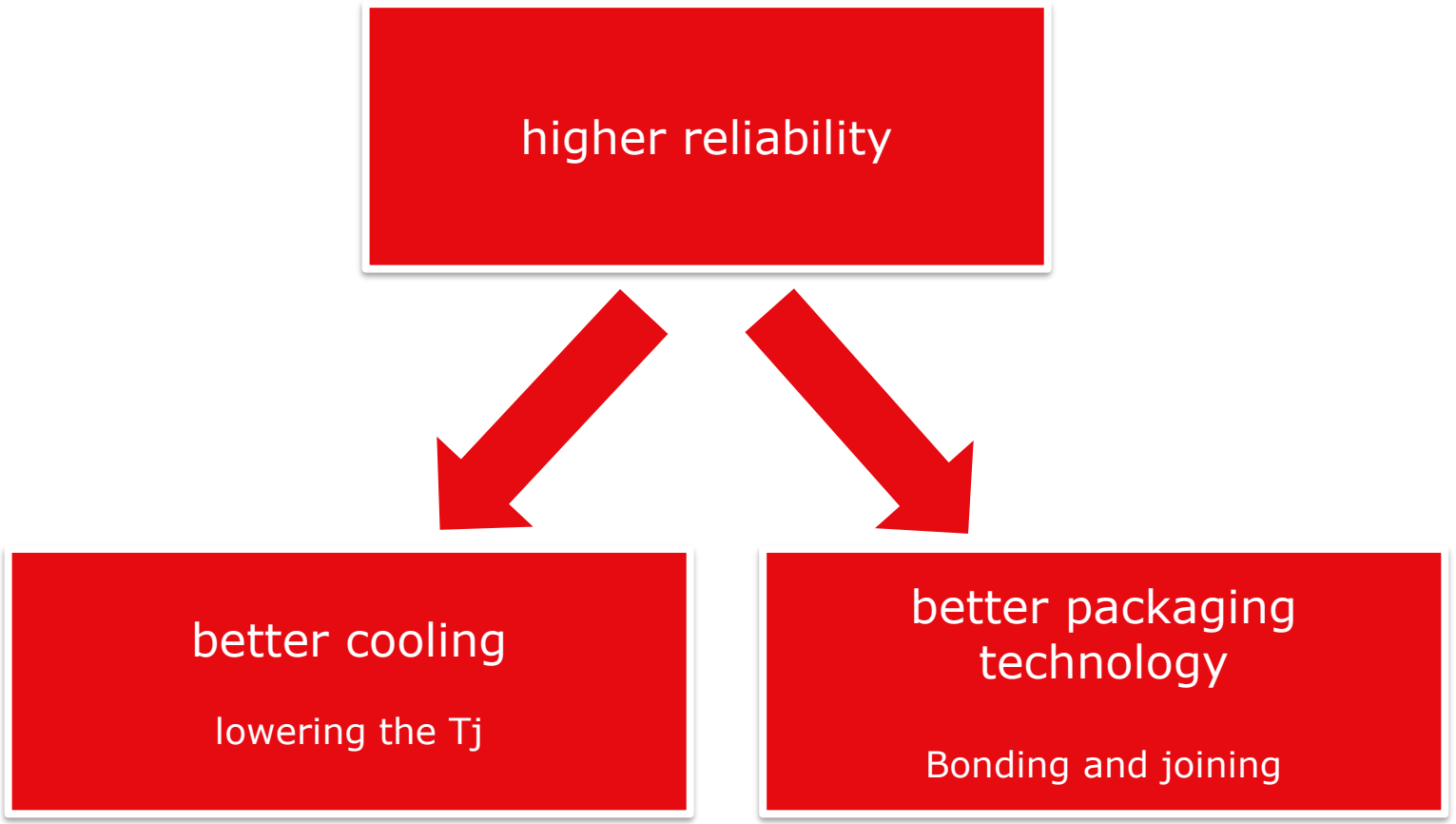
Life time expectation for modern applications

- How to verify the 20-25 years of service life required by the wind-energy industry for a liquid cooled power module setup

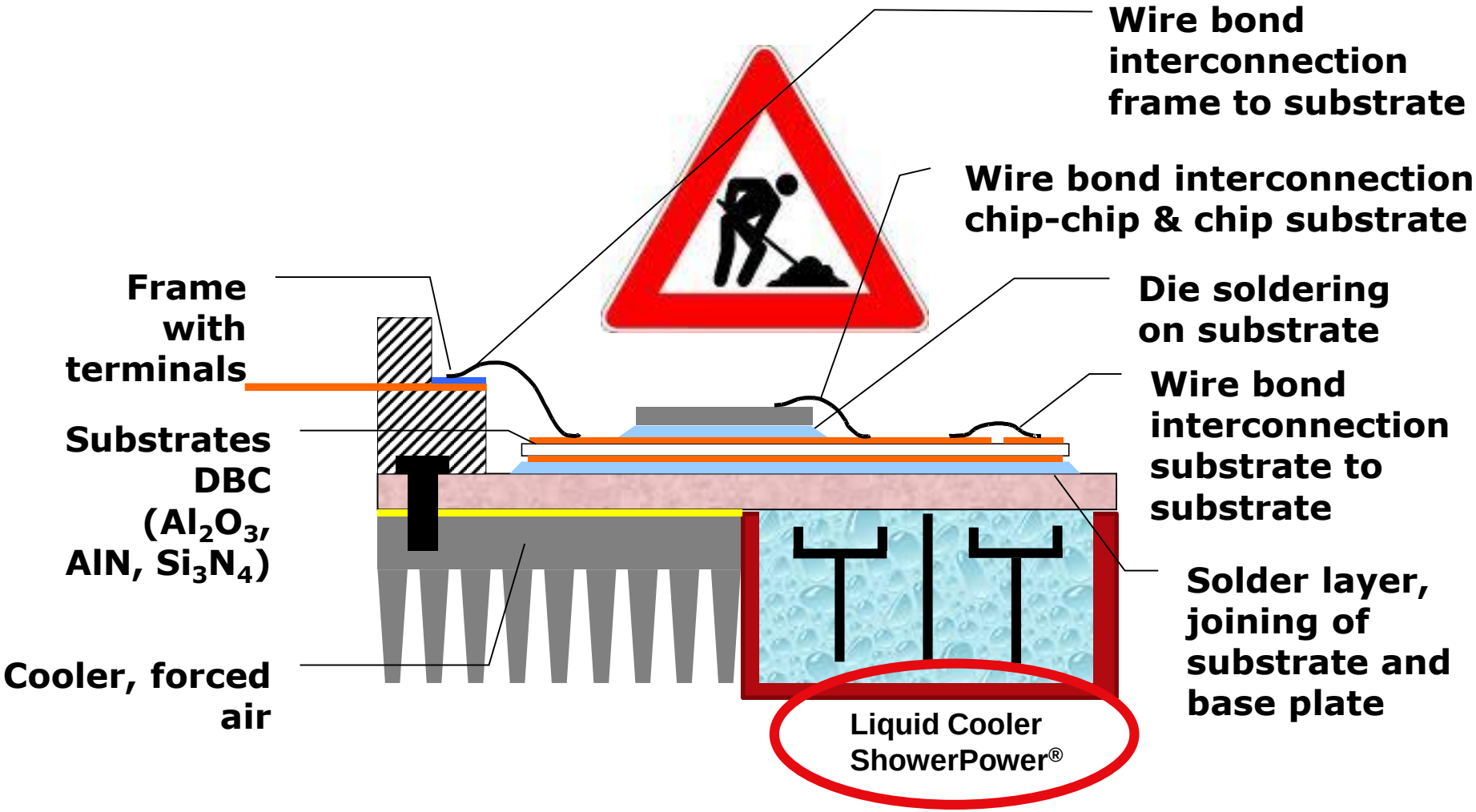
25 years lifetime



Two ways to improve the reliability in power module

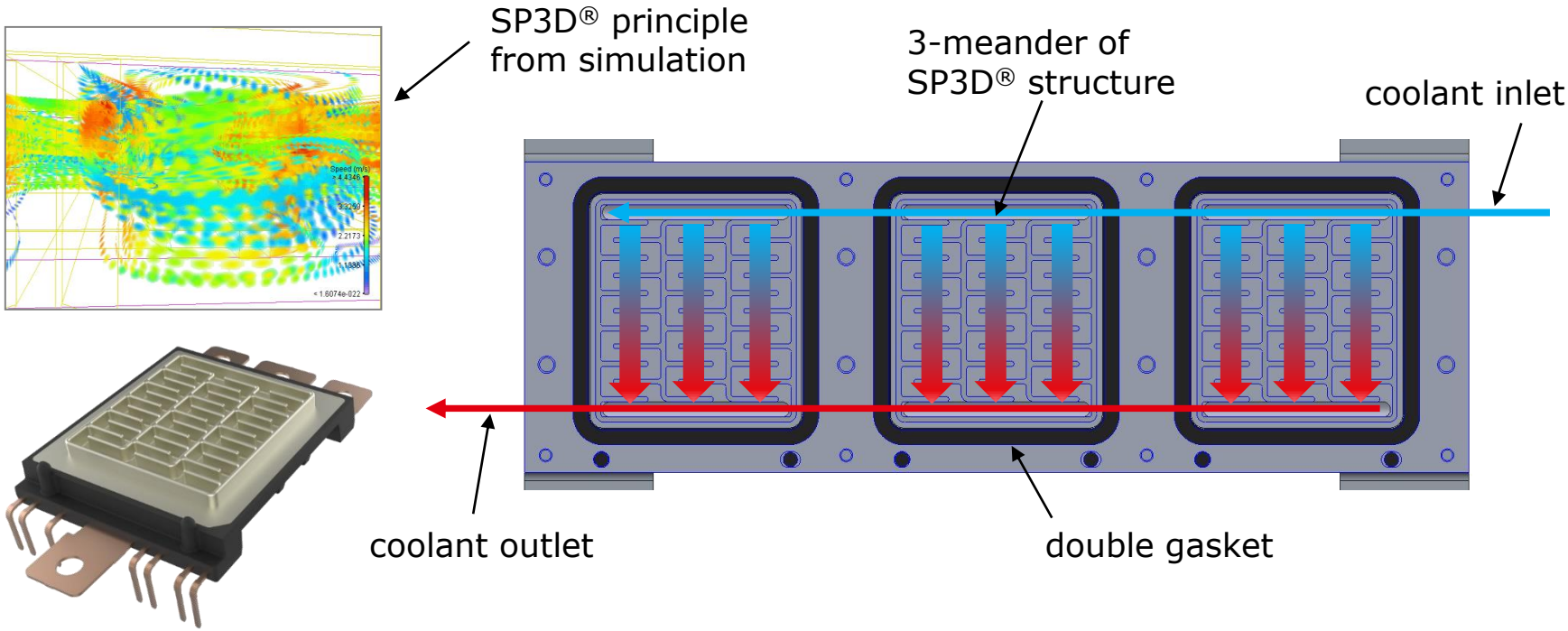


Power Module under Construction

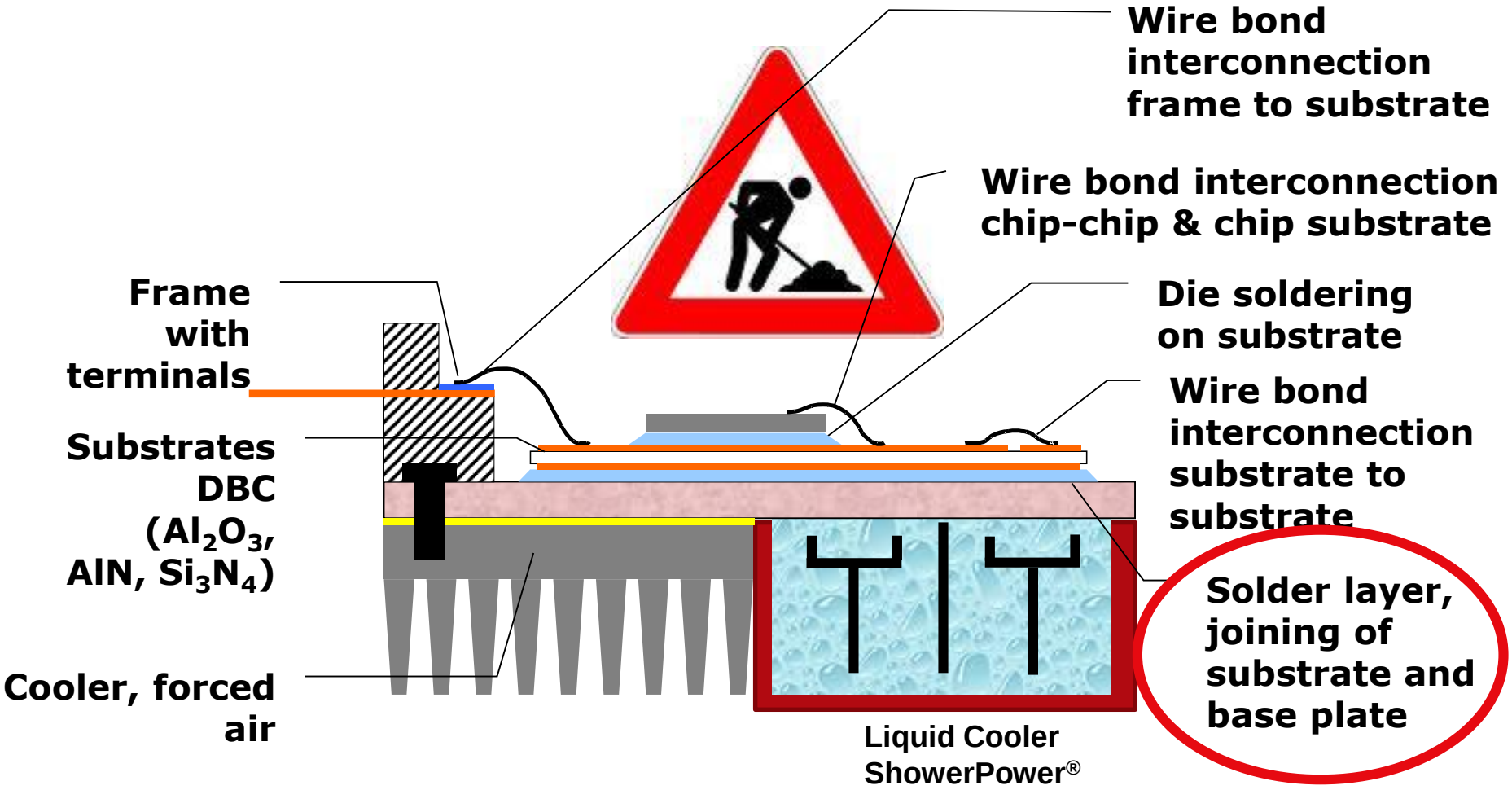


Shower Power® direct liquid cooling for lowest Rth

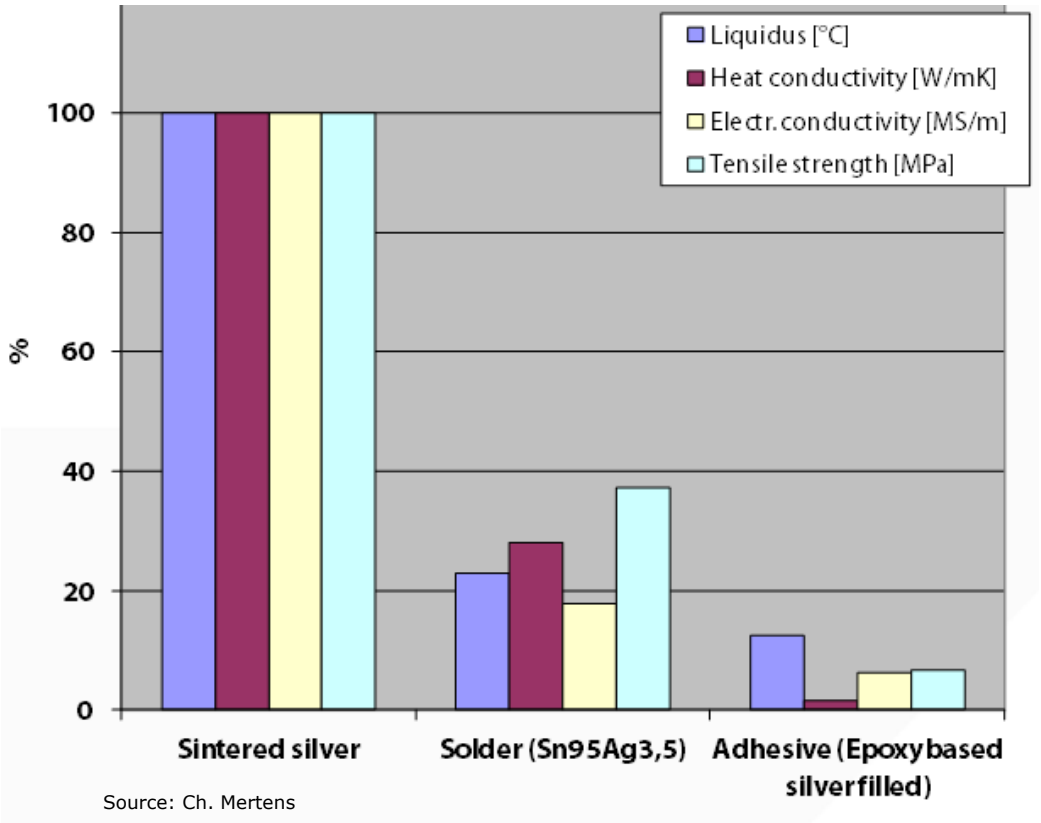
- Shower Power® is a direct cooling technology for lage power modules
- Eliminating the thermal interface material
- Offering high performance homogenous cooling at a low pressure drop



Power Module under Construction

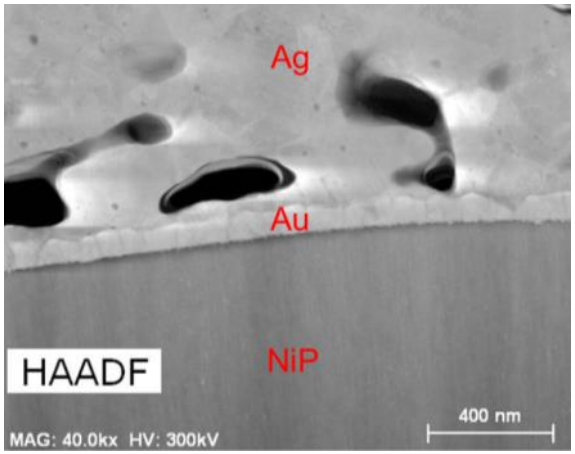


First Solution: Sintering Technology



Source: Ch. Mertens

TEM picture of sintered layer



Source: Böttge IWM Halle

- operation temperature at least 200°C
- high reliability
- excellent electrical and thermal conductivity
- no liquid phase at joining process
- high mechanical strength
- lead-free technology
- pressure sintering 10 – 30 MPa

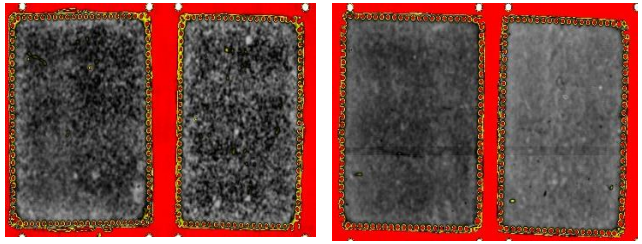
Large Area Sintering vs. Large Area Soldering after Temperature Cycling (-40°C – 125°C)

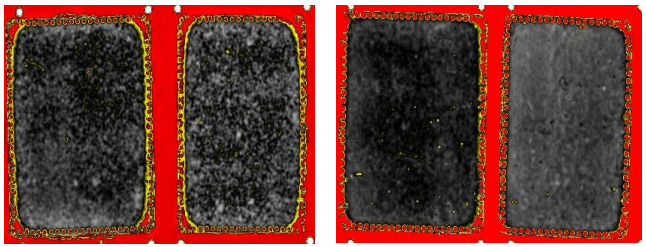
Sintering

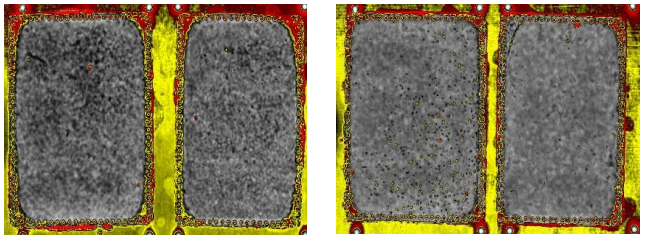
layer thickness

Cycles passed

layer thickness







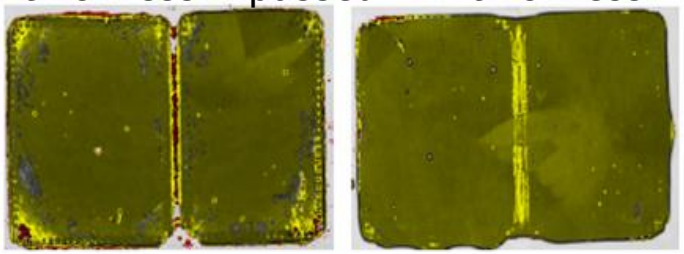
SAM-analysis

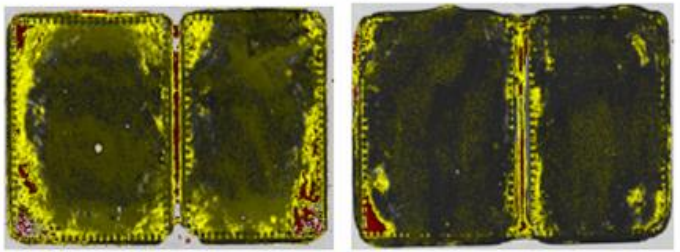
Soldering

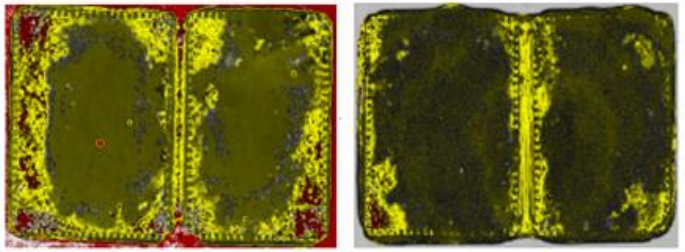
layer thickness

Cycles passed

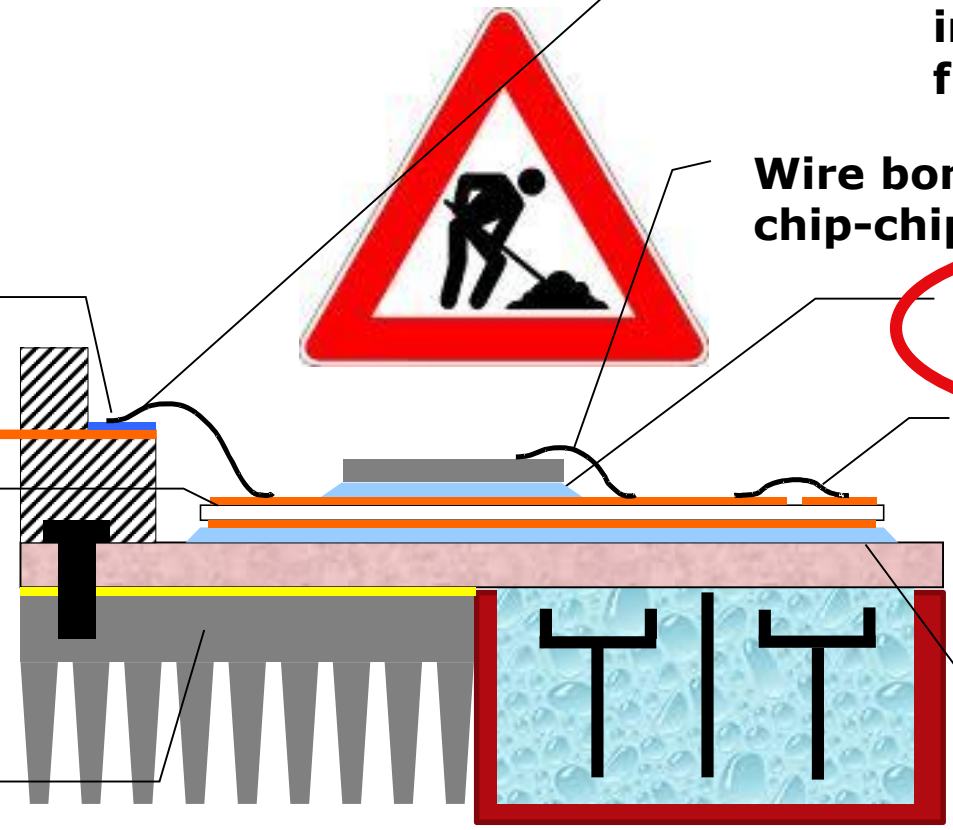
layer thickness





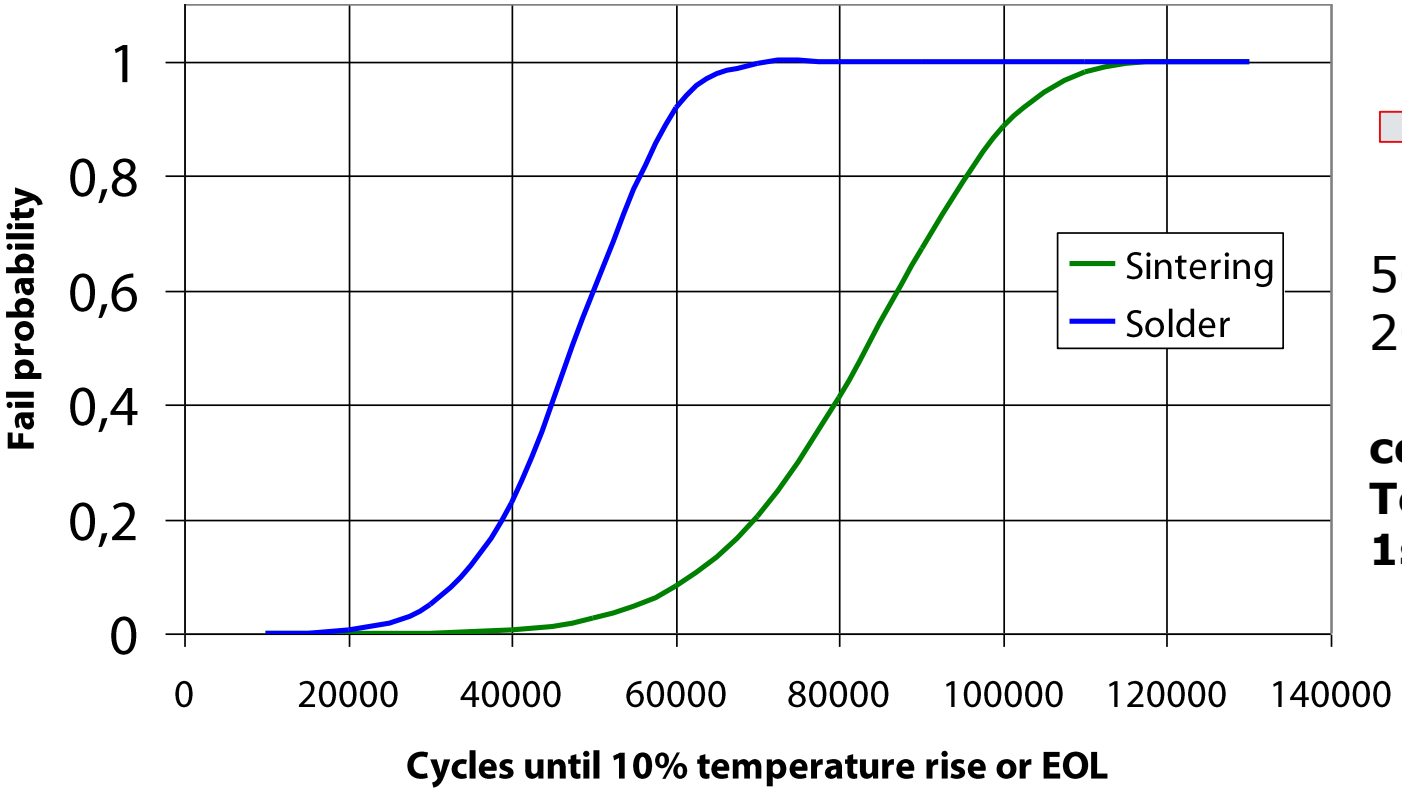


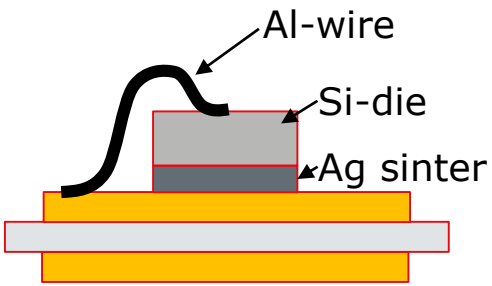
Power Module under Construction



Power Cycling Test – Solder and Ag-Sintering

Weibull data calculated from experimental results





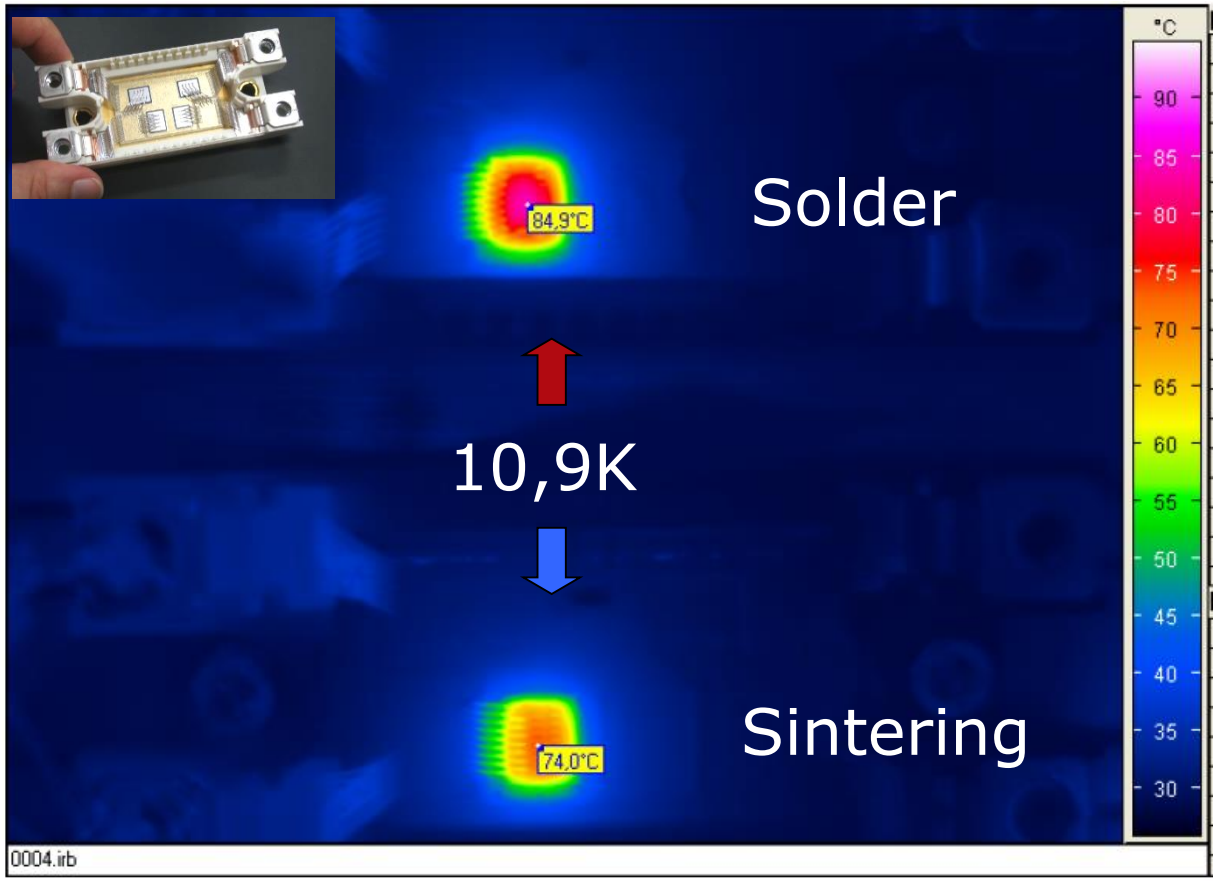
50V – MOSFet
20mm², 140µm thick

const. power
Temp. 20°C/120°C
1s on / 5s off

Factor of about 2 better reliability for sintered die

Lower Tj with Ag-Sintering Layers

Simultaneous thermography of soldered and sintered chips



current @ 90A
time @ 1s

Calculated Rth

	SnAg	Sinter.
Silicon	0,048	0,048
Solder NTV	0,026	0,002
Copper	0,010	0,01
AL2O3	0,165	0,166
Copper	0,007	0,007
Solder NTV	0,024	0,003
Copper	0,071	0,072
Rth	**0,350**	**0,309**
ΔRth		**13%**

Power Module under Construction

Wire bond interconnection frame to substrate

Wire bond interconnection chip-chip & chip substrate

Frame with terminals

Die soldering on substrate

Wire bond interconnection substrate to substrate

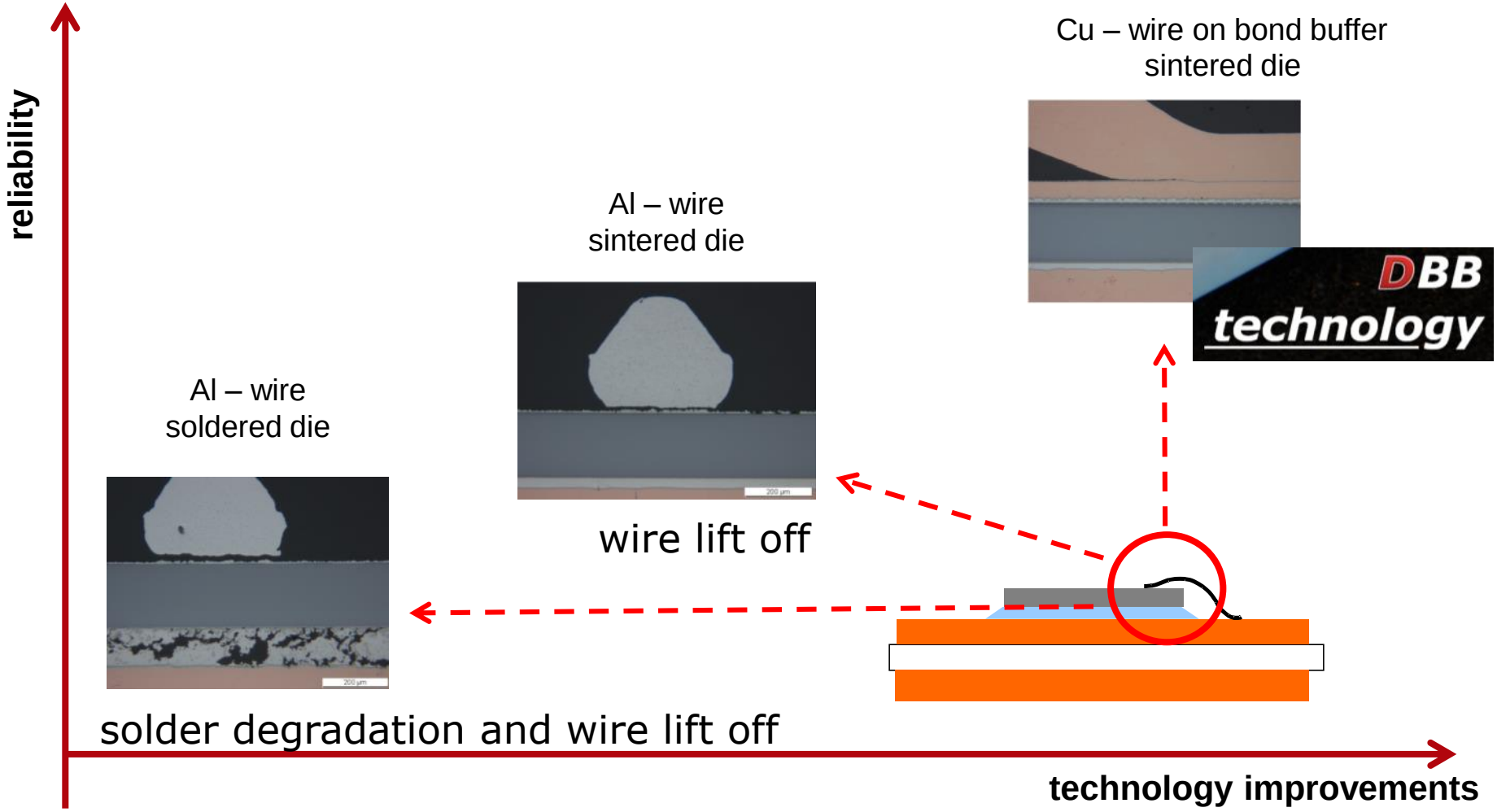
Substrates DBC (Al_2O_3, AlN, Si_3N_4)

Solder layer, joining of substrate and base plate

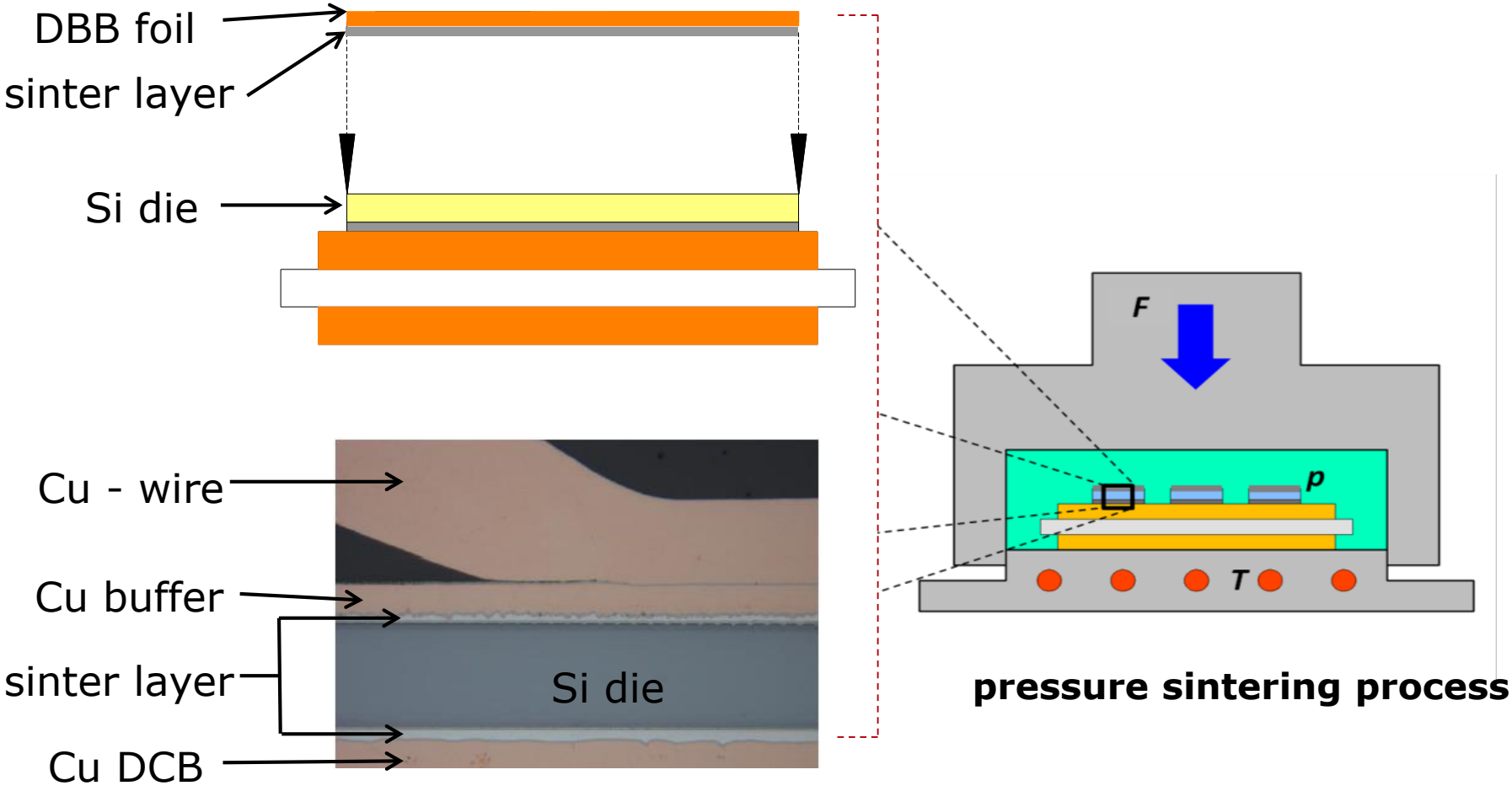
Cooler, forced air

Liquid Cooler ShowerPower®

Combination of Sinter Technology and Cu Wire Bonding Leads to DBB® Technology



Cross Section – Silicon Die with DBB® Technology



Power cycling reliability @ ΔT=130K

Test parameter:

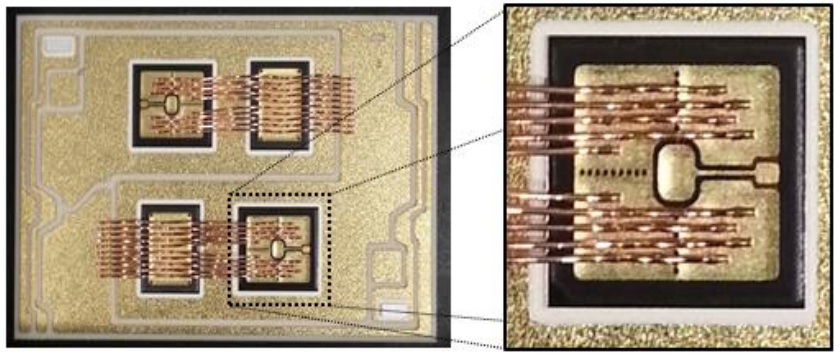
ΔT = 130K

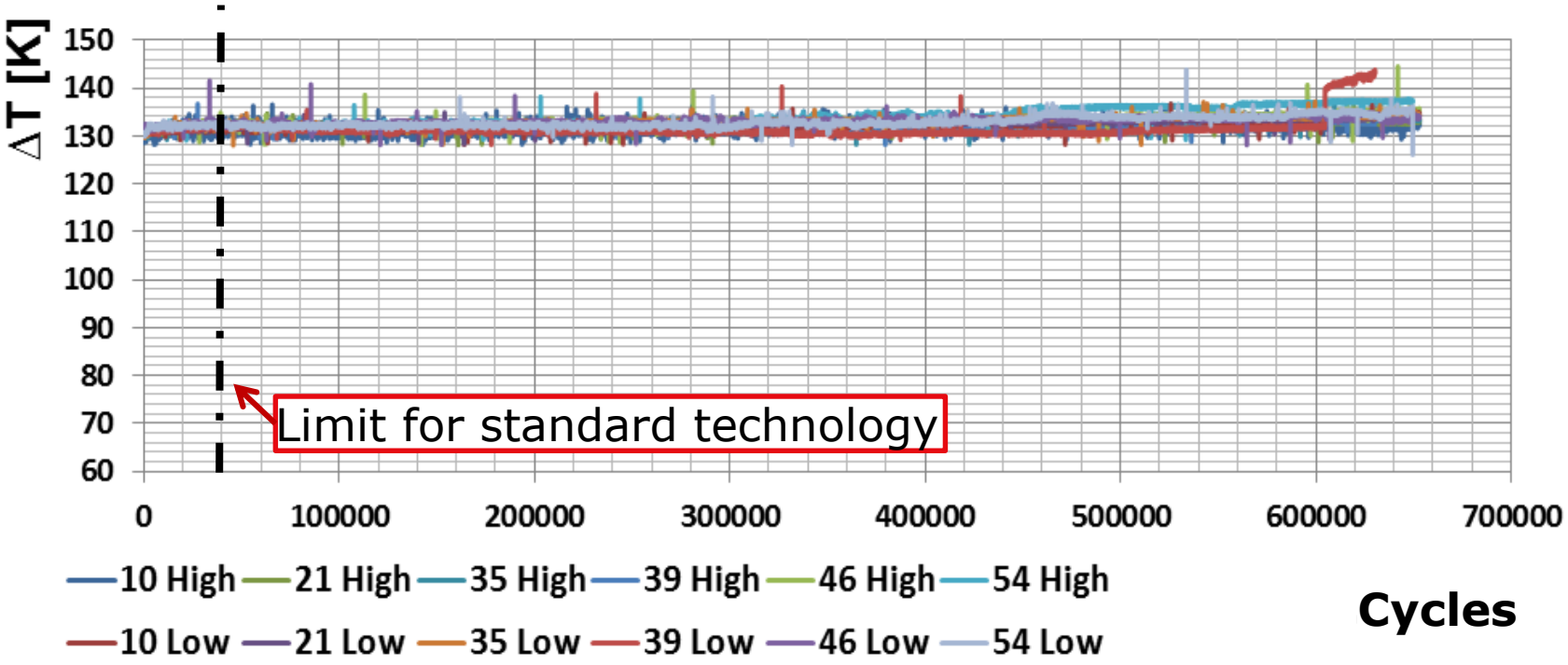
T_{min} = 20°C

P = const

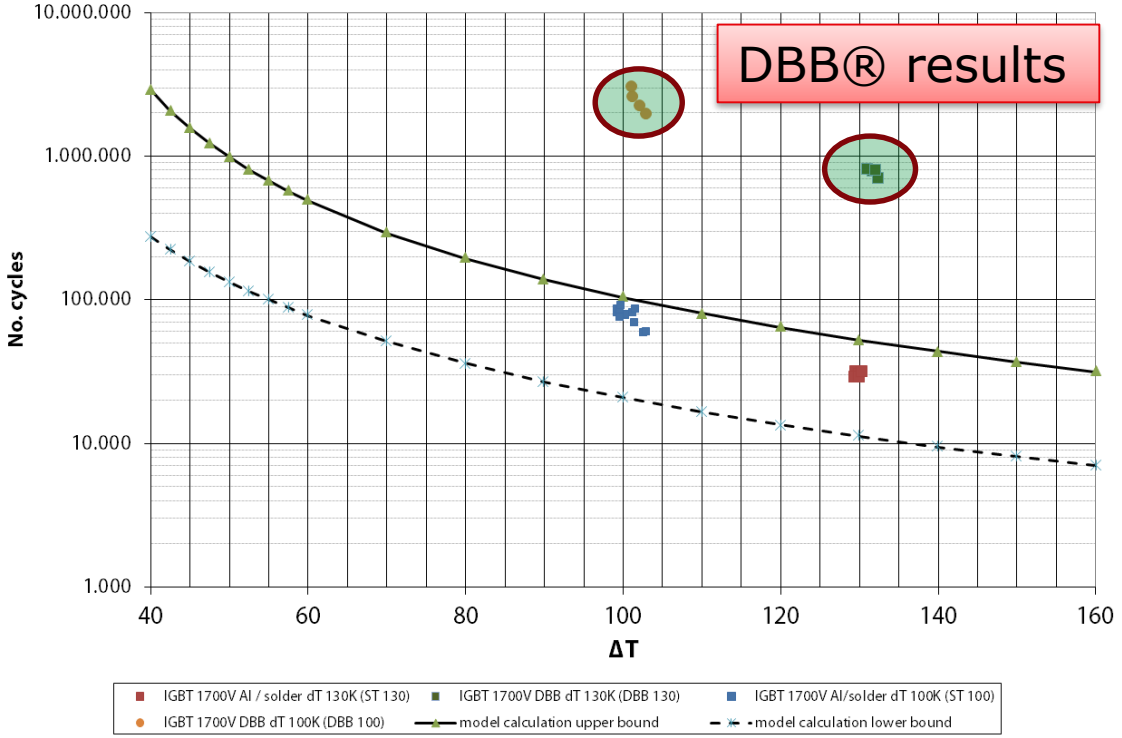
t_{on} = 1s

t_{off}= 10s





Coffin Manson Diagramm - DBB Results



Type	DBB 130	DBB 100	ST 130	ST 100
ton [s]	1	1	1	1
toff [s]	10	10	10	10
Ipulse [A/cm²]	100	100	100	100
Tj,min [°C]	20	20	20	20
Tj,max [°C]	150	120	150	120
DT [K]	130	100	130	100
Tm [°C]	85	70	85	70

Outstandig power cycling capability
Factor of 20 better reliability than standard technology

Conclusions

- Better cooling systems increase the reliability of power modules
- Better bonding and joining technology increase the reliability of power modules
- extended lifetime is achieved by using sintering technique between silicon die and DBC substrate
- heavy copper wires reduces the electrical resistance and improve the life time of power modules
- Combination of sintering technology and Cu wire bonding increases the reliability and leads to better products

Thank you for your attention

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