Heraeus

Electronics

“ELECTRONIC PACKAGING MATERIALS FOR SIC POWER MODULES”

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WORLD BECOMES ELECTRIC

POWER ELECTRONICS HAS **SIGNIFICANT POTENTIAL FOR CO_2 REDUCTION** AND IS **INEVITABLE TECHNOLOGY TOWARDS ZERO EMISSION WORLD**

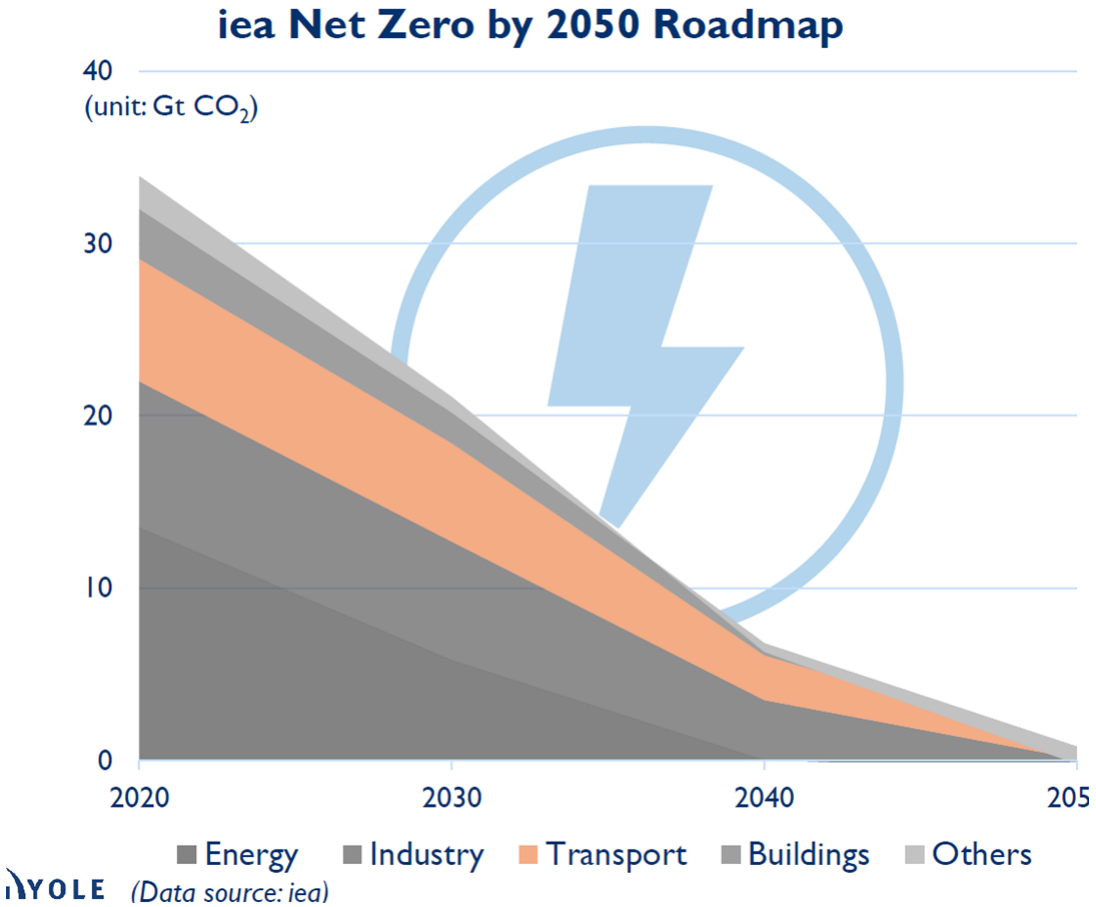
Megatrends

Climate change & sustainability

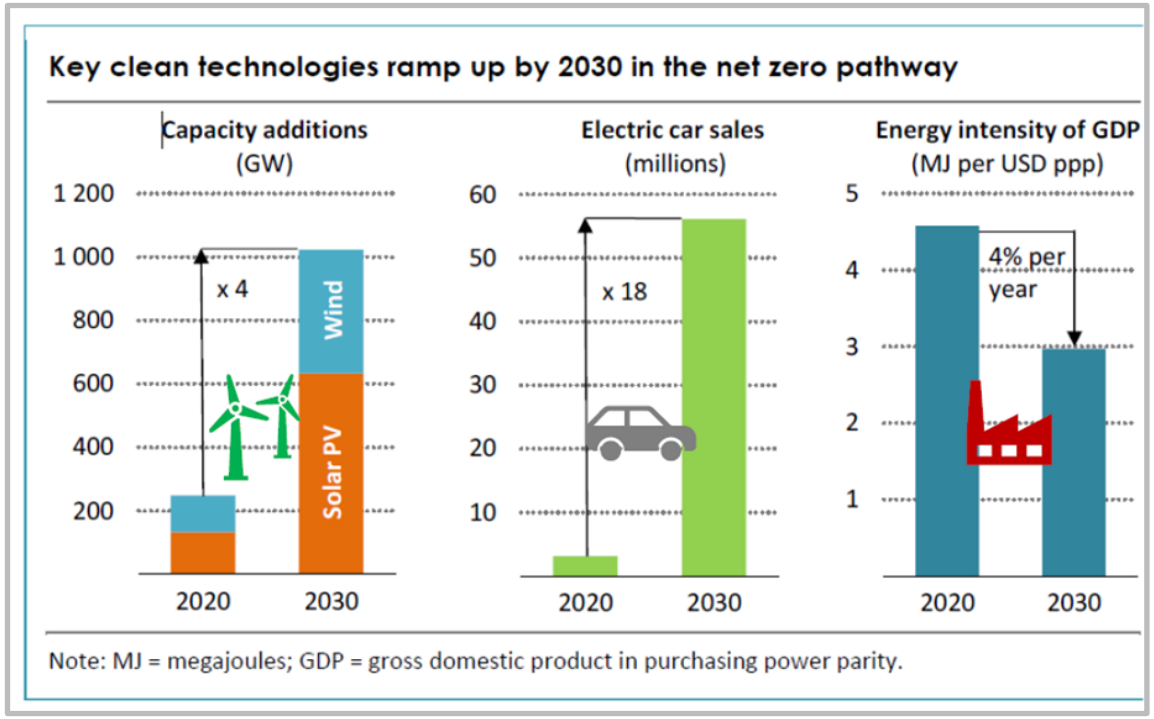
Shortage of energy & resources

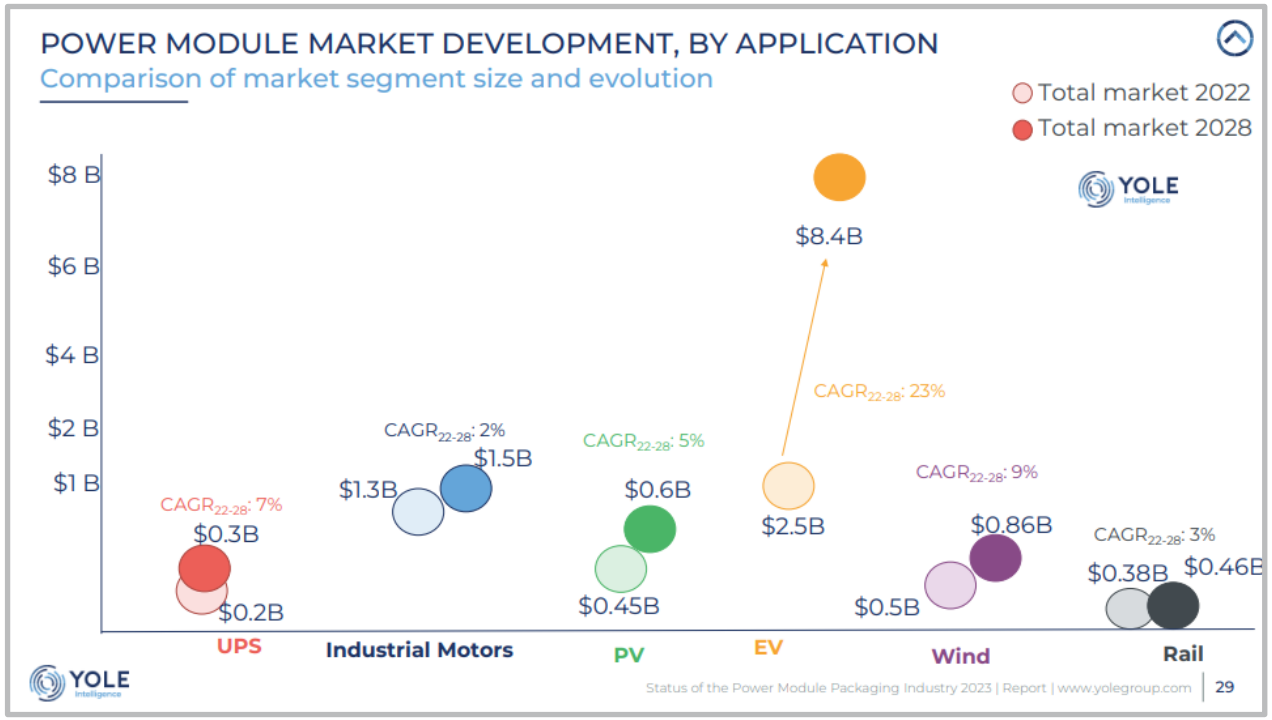
Seamless mobility

Urbanization & megacities



Power Electronics play a key role in today's **increasingly electrified world…**



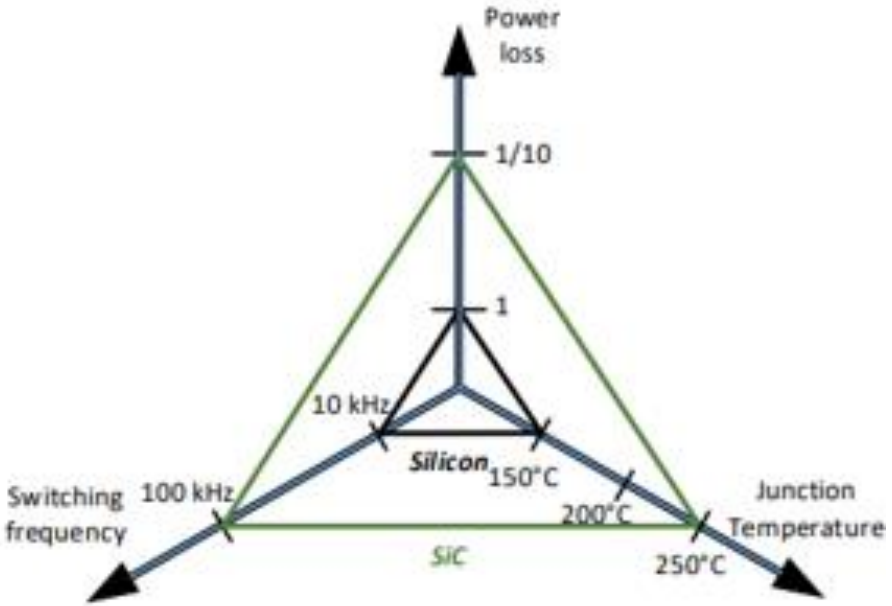


….from generation to distribution and consumption in industrial, automotive, renewable energies, appliances …

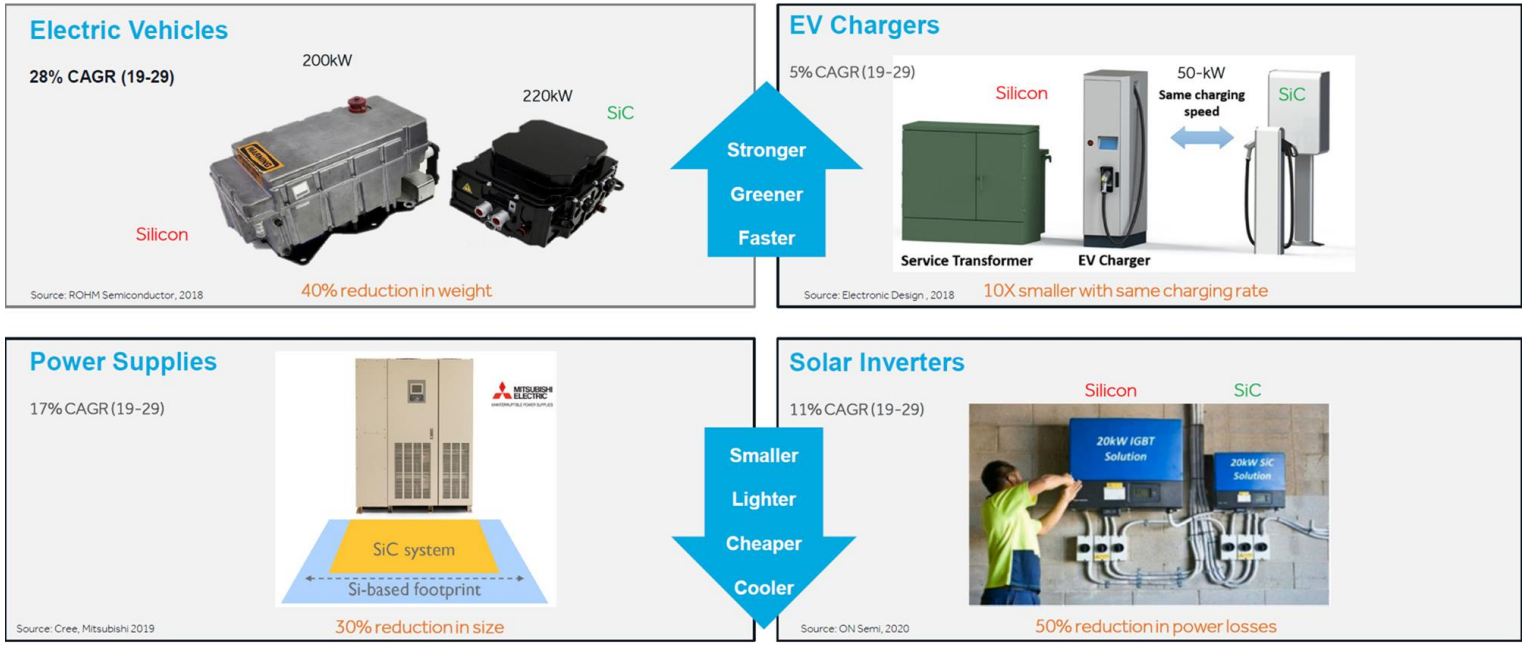
Source: Yole Report Status of the Power Electronic Industry 2023

POWER MODULES SHIFT FROM SI TO SIC

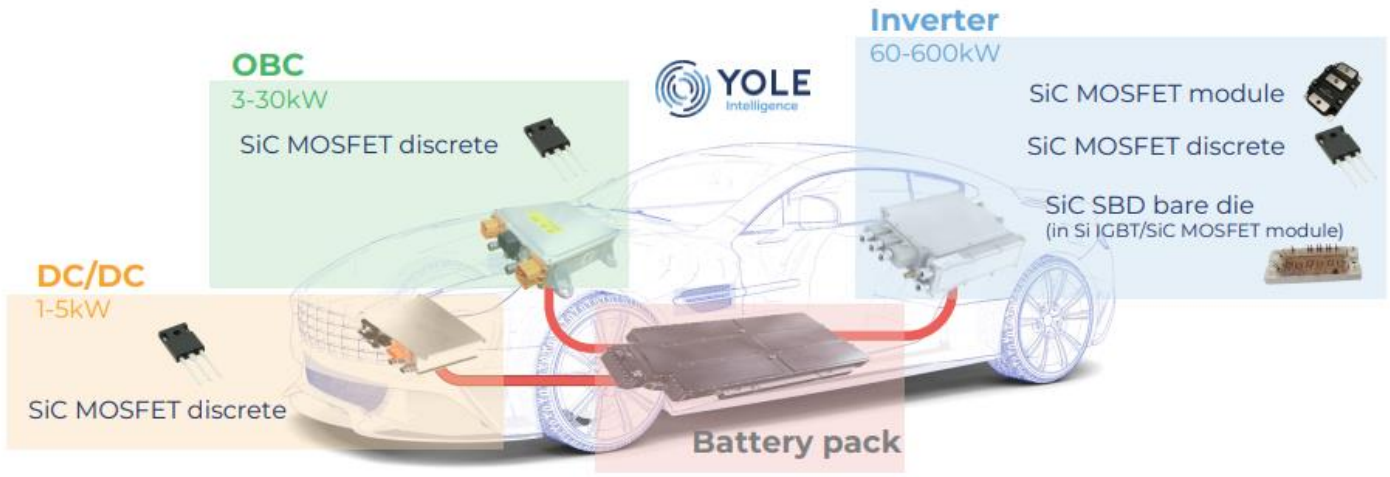
SUPERIOR PROPERTIES OF SIC DRIVES PERFORMANCE GAINS

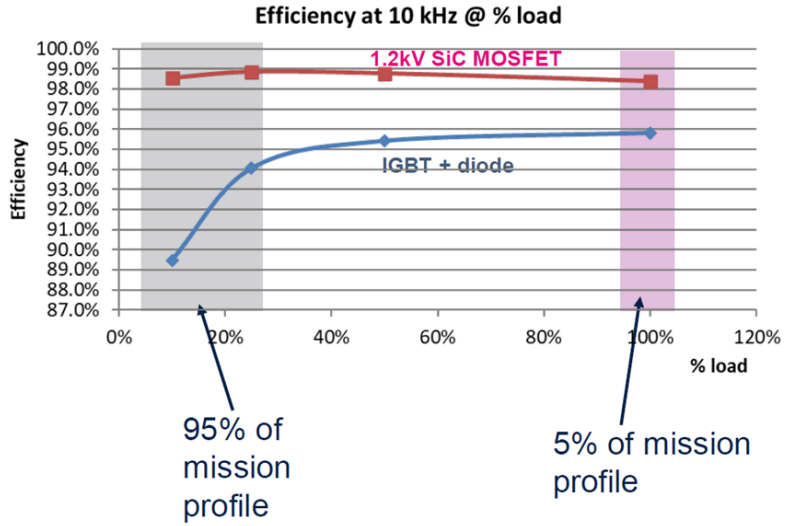


Source: Dr T Blank, KIT, Electronic Packaging Conf 2018,



E-MOBILITY: IT IS ALL ABOUT EFFICIENCY





- Extend driving range
- Increase charging speed
- Reduce weight and cost of cooling systems
- Reduce system costs
- Growth Area for SiC Power Modules – xEV – $CAAGR_{2022\text{-}28}$: 32%

Source: Yole, Power Electronics for eMobility 2023
ST, Power Electronics Conference Brussels Apr. 2023

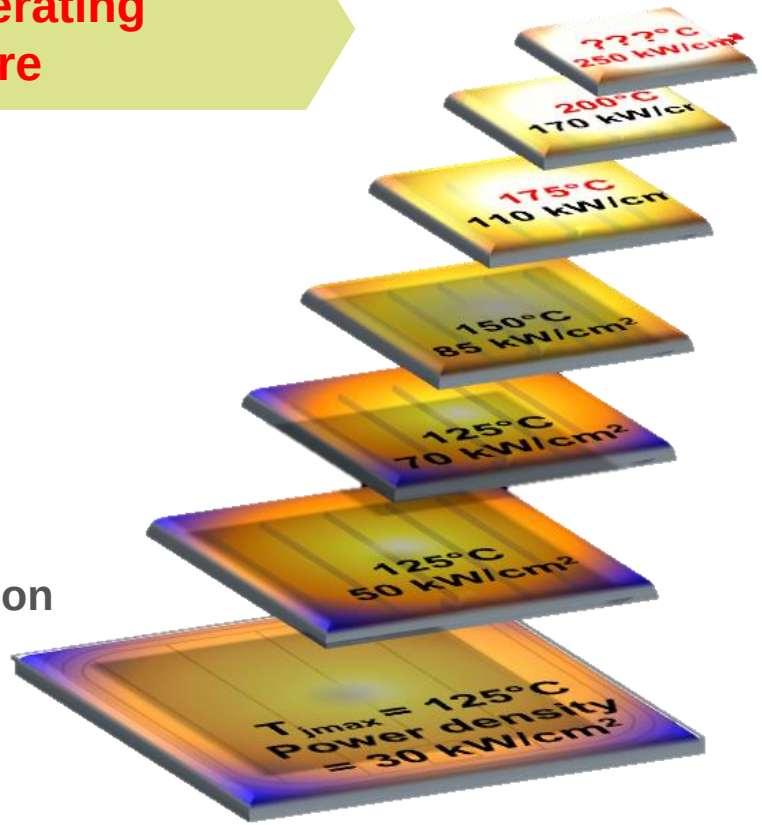
CONSEQUENCES FOR ELECTRONIC PACKAGING

SEMICONDUCTOR DEVELOPMENTS DRIVE NEED FOR NEW PACKAGING SOLUTIONS

WBG SiC & GaN
Smaller & Thinner Dies

Increased Power Density

Higher Operating Temperature



Benefit through smaller dies

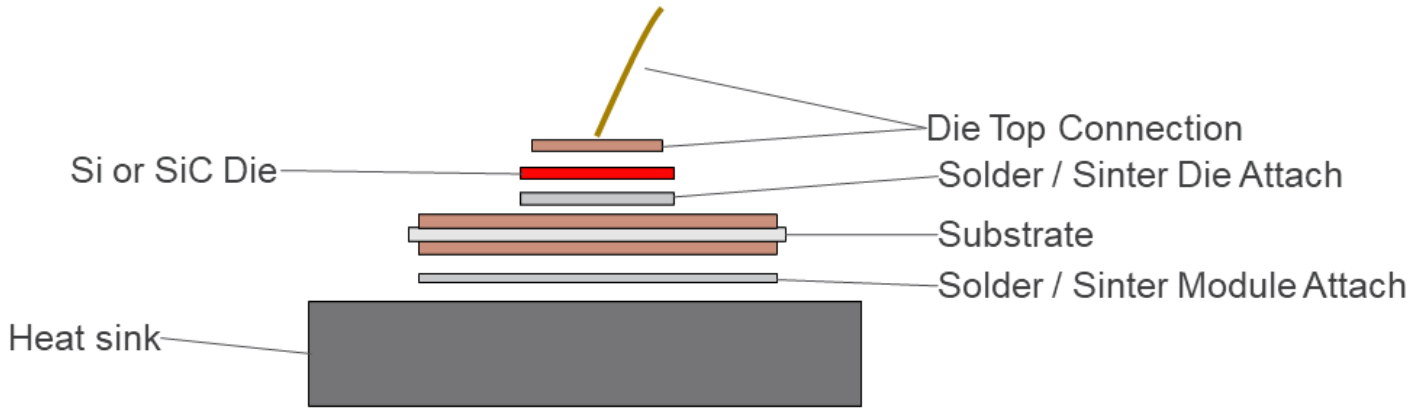
- Reduction of chip size / cost
- Lower losses / higher efficiency
- Increase of power & current density per chip

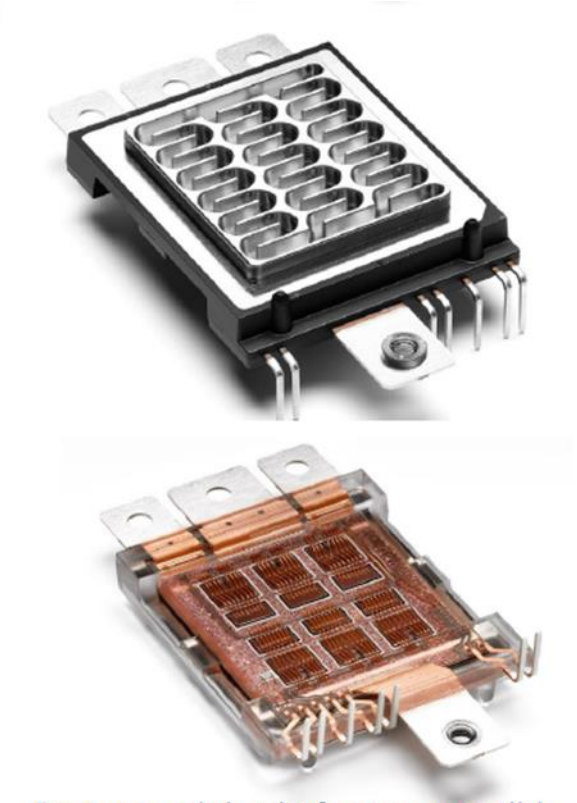
Improved Performance of packaging solutions required

- Increased power loss per chip area requires materials with **improved heat dissipation**
- More power needs **better current carrying capability** of packaging materials
- Increased operating temperatures and **reliability** challenges
- Higher switching frequencies require solutions for **reduced parasitic inductance**

Source: Challenges of New Packaging Solutions for Power Modules, Prof. R. Eisele FH Kiel, Anton Miric HDE, PCIM Conference May 2021

SIMPLIFIED POWER MODULE PACKAGE

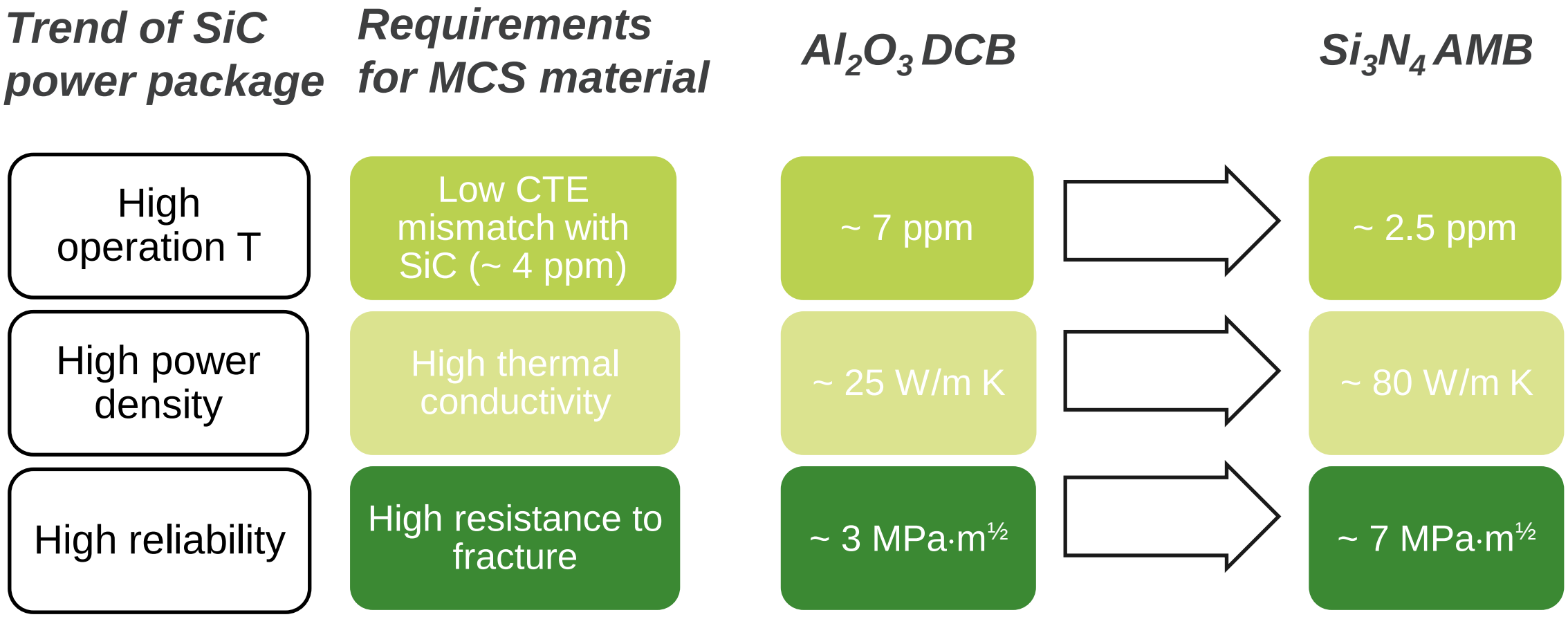




Power module platform compatible both with IGBT and SiC technologies (Source: Danfoss)

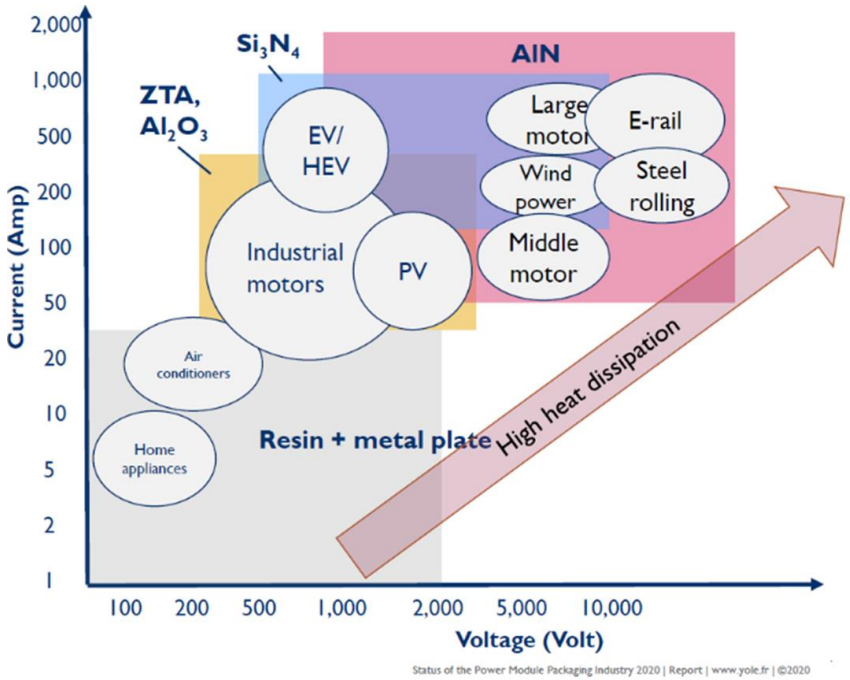
SUBSTRATE TECHNOLOGIES
DCB VS AMB SUBSTRATES

WHY DO WE NEED NOVEL SOLUTION FOR SUBSTRATE?



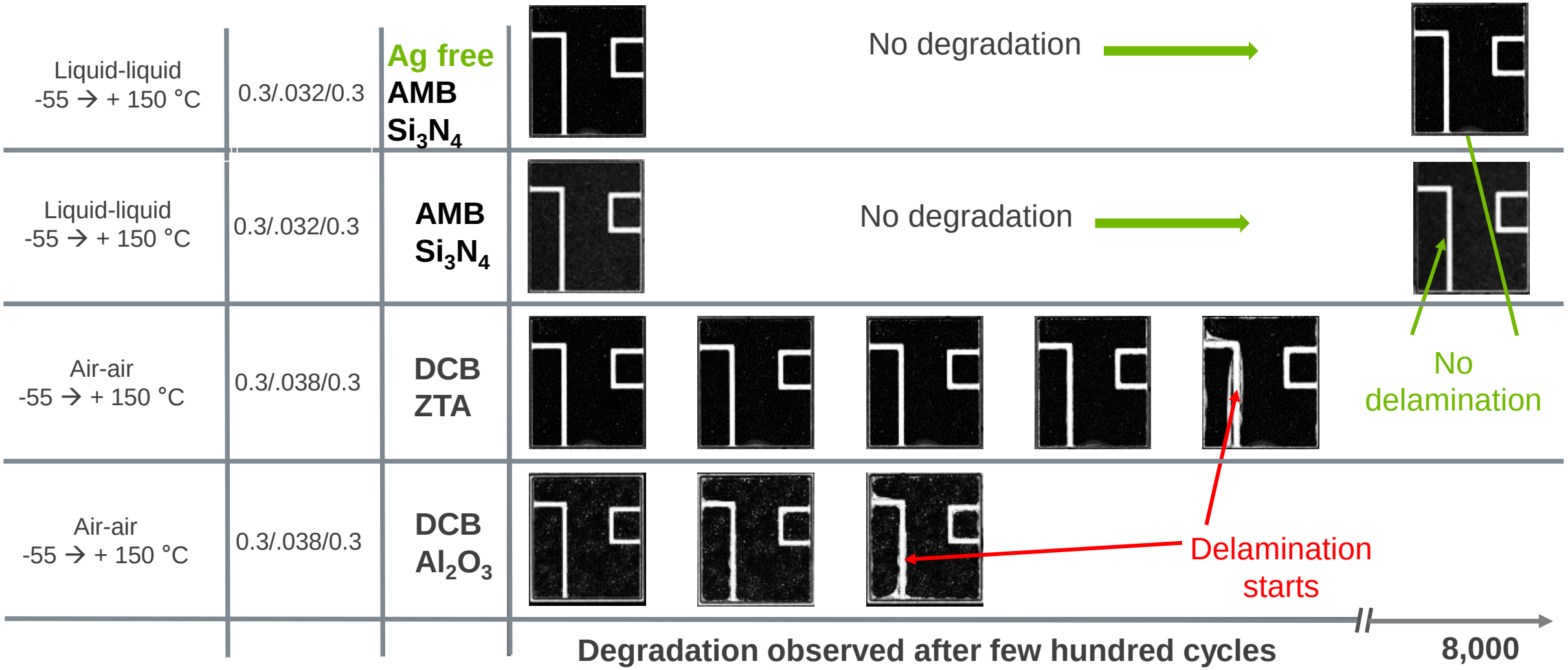
Si_3N_4 SUBSTRATE IS THE MOST SUITABLE SOLUTION FOR SIC PACKAGE

Ceramic Material	Thermal conductivity @ 20°C [W/(m·K)]	Fracture Toughness [MPa·m$^{1/2}$]	Bending strength [MPa]	Coefficient of thermal expansion [ppm/K]	Substrate reliability	Substrate cost
Al_2O_3	≥ 20	4	> 450	6.7-8.7 (@100-600°C)	0	+++
ZTA	≥ 22	≥ 4.5	> 600	<7 (@40-400°C)	+	++
AlN	≥ 170	> 3	400	4.7 (@20-300°C)	0	-
Si_3N_4	≥ 80	6-7	> 650	2.6 (@20-500°C)	+++	-



Source:
Challenges of New Packaging Solutions for Power Modules, Prof. R. Eisele FH Kiel, Anton Miric HDE, PCIM Conference May 2021
Silver-free thick film copper bonding for highly reliable metal ceramic substrates, Dr. Andre Schwöbel HDE, CIPS Conference 2022

C-SAM IMAGES SHOW SUPERIOR THERMAL CYCLING PERFORMANCE OF Si_3N_4 AMB

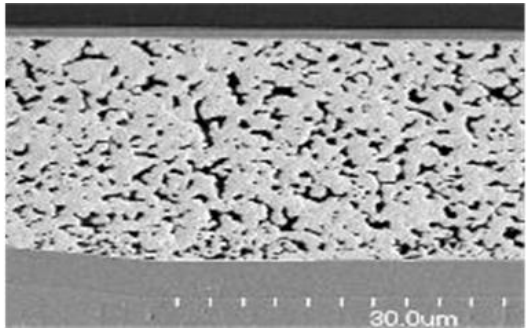


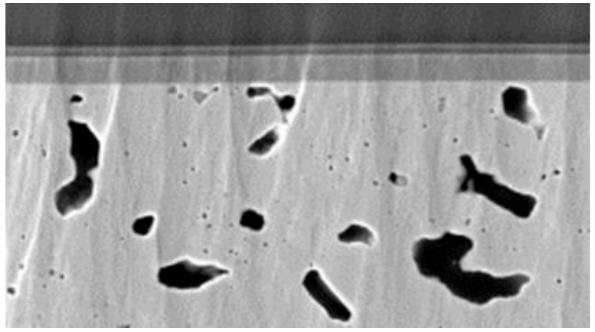
DIE ATTACH & MODULE ATTACH
SINTER VS SOLDER

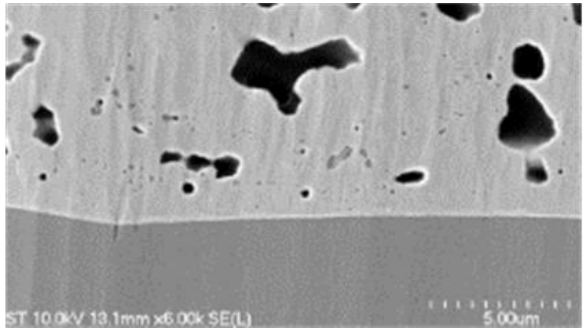
WHY DO WE NEED NOVEL SOLUTION FOR DIE AND MODULE ATTACH

Trend of SiC power package	*Requirements for DA material*	*Solder*	*Ag Sinter*
High operation T	High melting point	~ 220 °C	~ 960 °C
High power density	High thermal conductivity	~ 50 W/m K	~ 250 W/m K
High reliability	High creep resistance	$T_w/T_m > 0.7$	~ $T_w/T_m < 0.3$

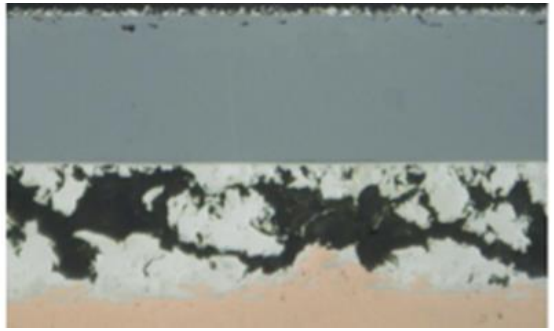
AG-SINTER JOINT SHOWS NO DEGRADATION AFTER 130K THERMAL CYCLES

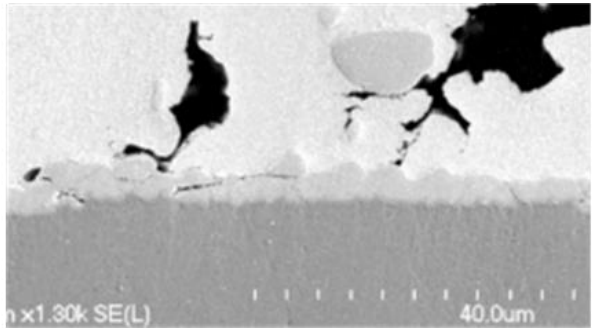


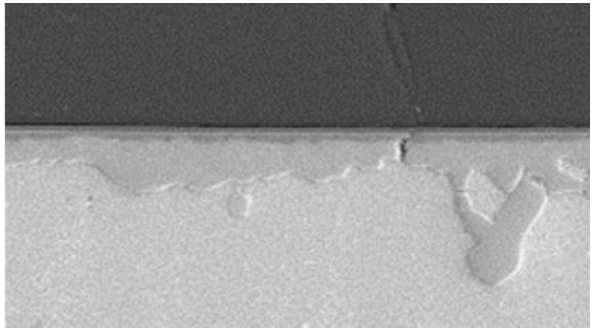




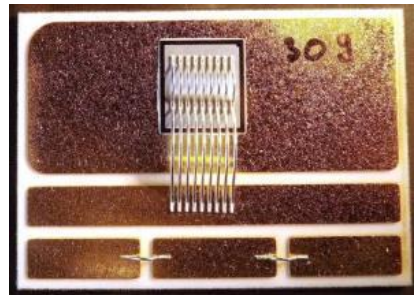
Sintered Module with AlCu-Wire after 130.000 Power Cycles







Soldered Module with AlCu-Wire after 56.000 Power Cycles



Test parameters:
$T_{on} = T_{off} = 15$ sec
$T_C = 40°C$
$dT_{max} = 110$ K
$T_{max} = 150$ °C

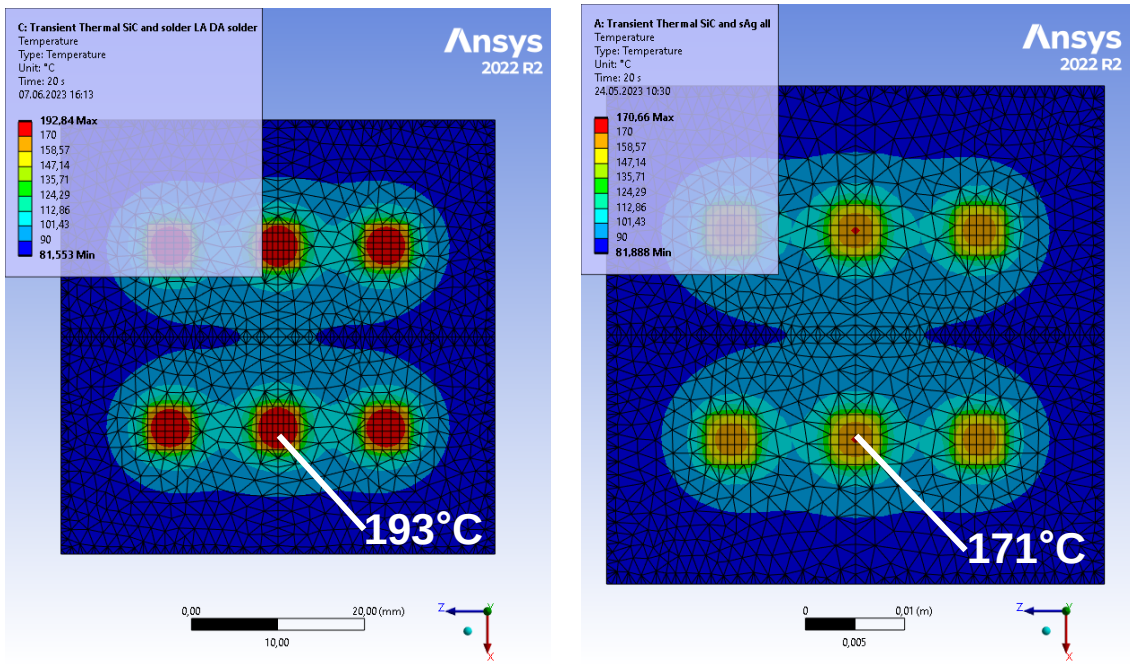
Source: T.Krebs et al, 63rd ECTC, 2013

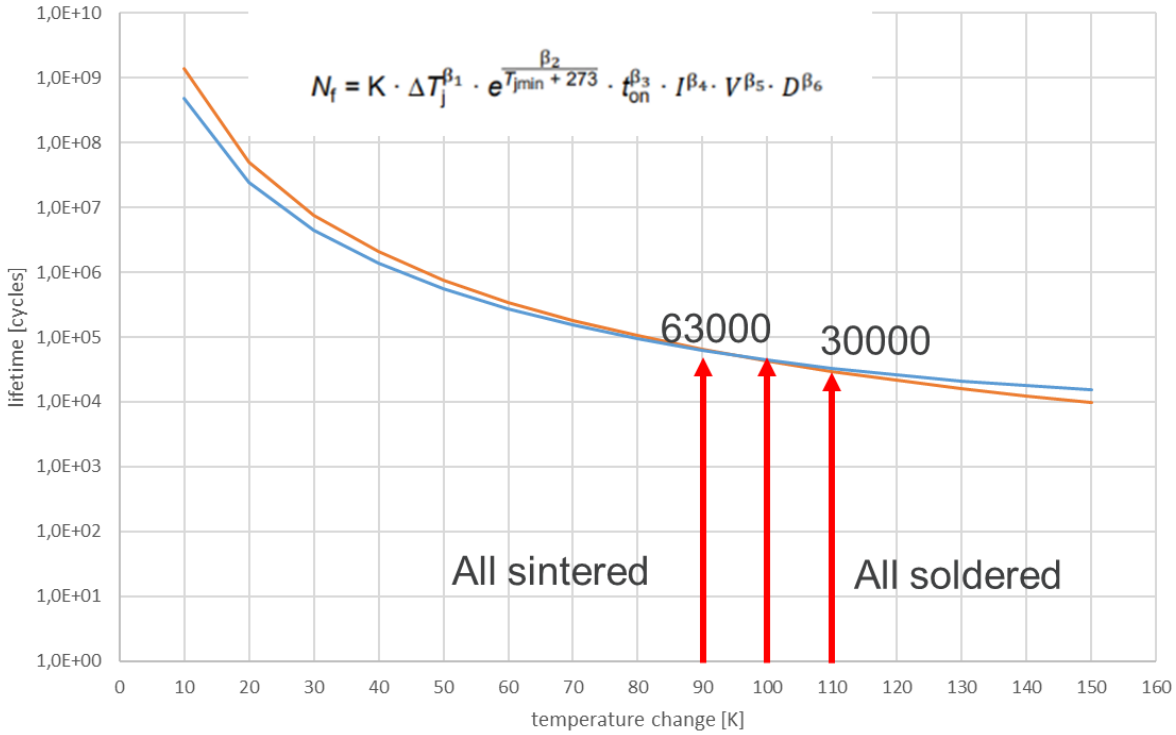
ALL SINTERED MODULE HAS A SIGNIFICANTLY INCREASED LIFETIME

Die attach and baseplate

soldered

sintered



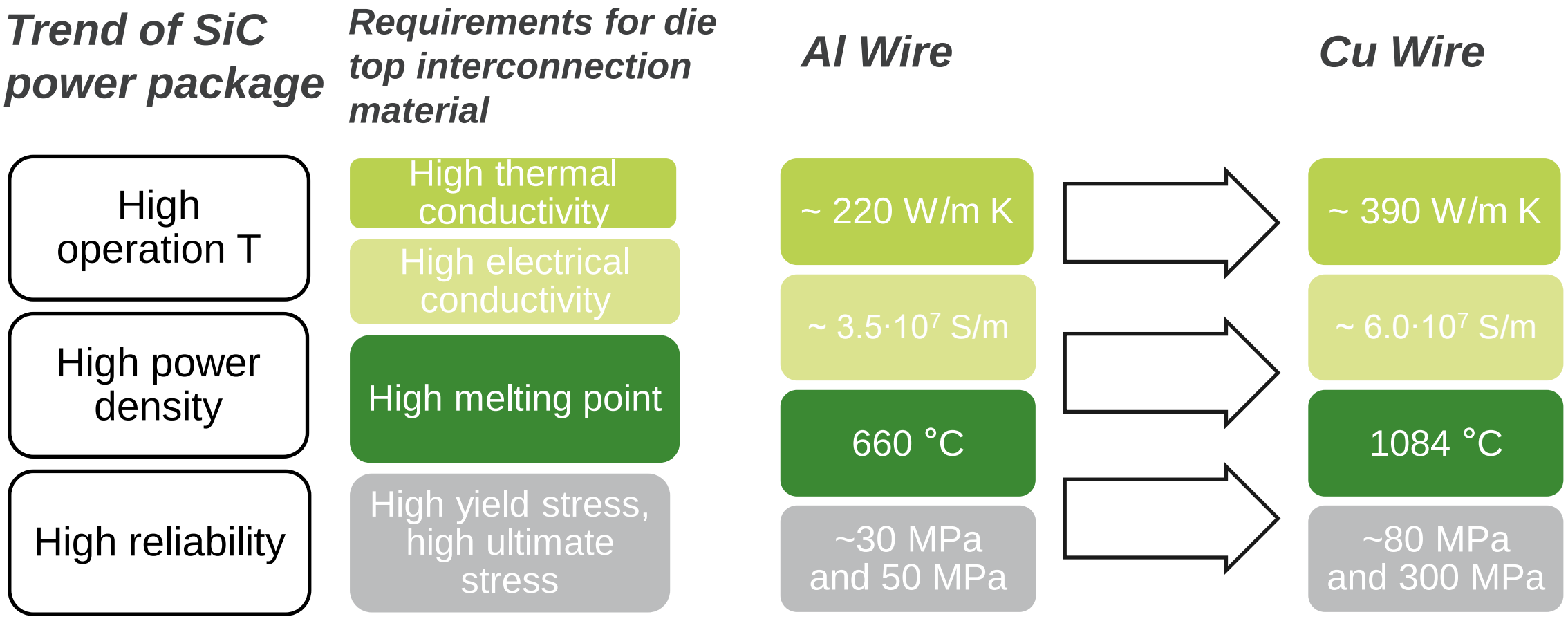


22 K difference completely soldered vs sintered device
-> All sintered module can significantly increase the lifetime of the system

Source: B. Fabian, Heraeus Sinter Seminar

DIE TOP CONNECTIONS
AL VS CU DIE TOP CONNECTIONS

WHY DO WE NEED NOVEL SOLUTION FOR DIE TOP CONNECTION?

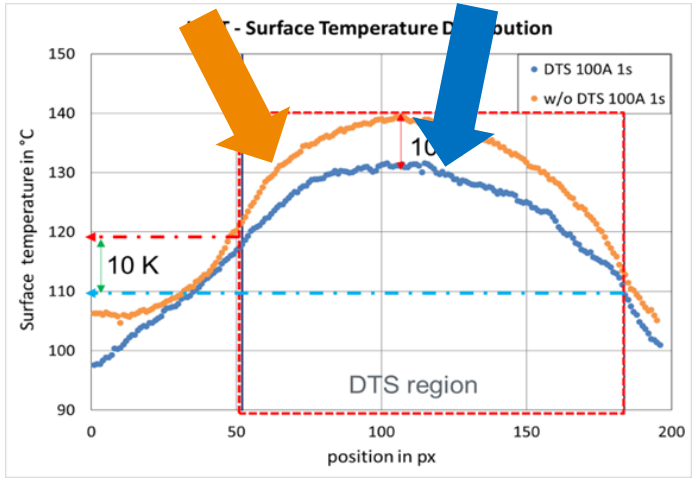


POWER CYCLING SOLDER & AL WIRE VS. SINTER & CU WIRE

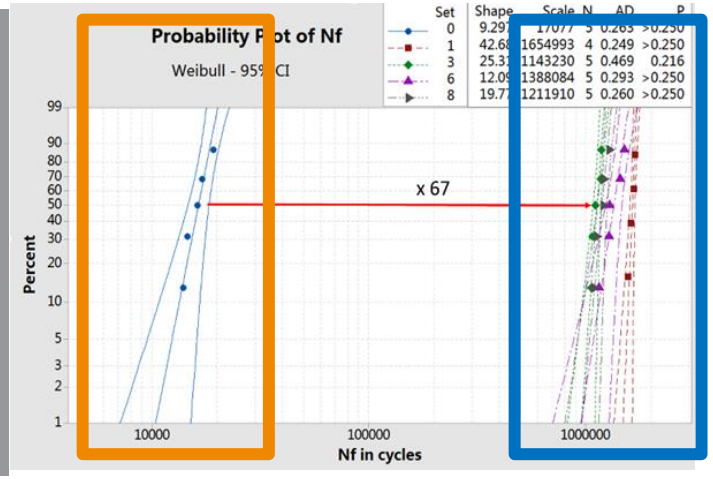
SOLDER / AL WIREBONDING

- **Bond wires:** 400µm Al wire
- **Die attach:** SnAg solder

TEMPERATURE



RELIABILITY



Powercycling: I(const.)=136A/ton=1s, toff=2s, DT=130K, Tmax=175°C, failure 5% increase VCE

SINTER / CU WIREBONDING

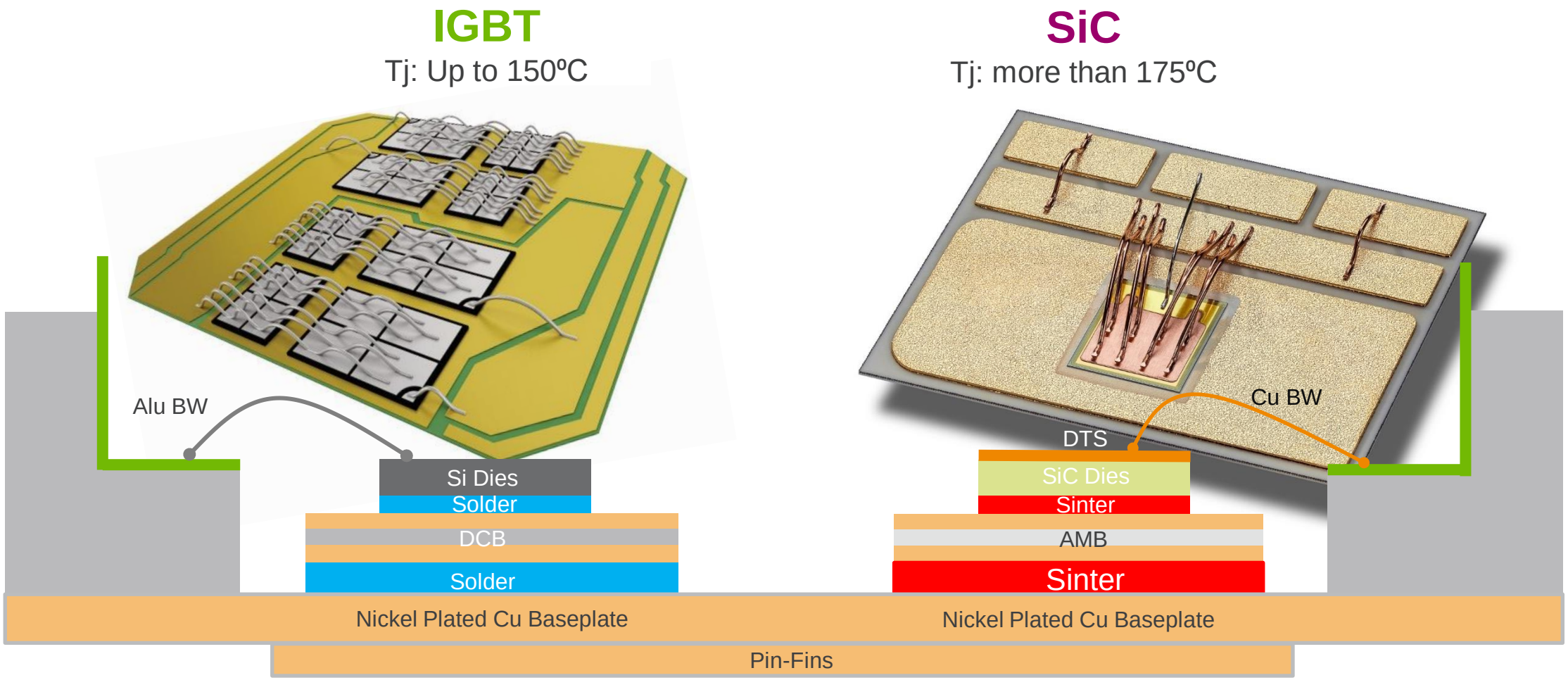
- **Bond wires:** 400µm Cu wire
- **Die attach:** Ag sinter

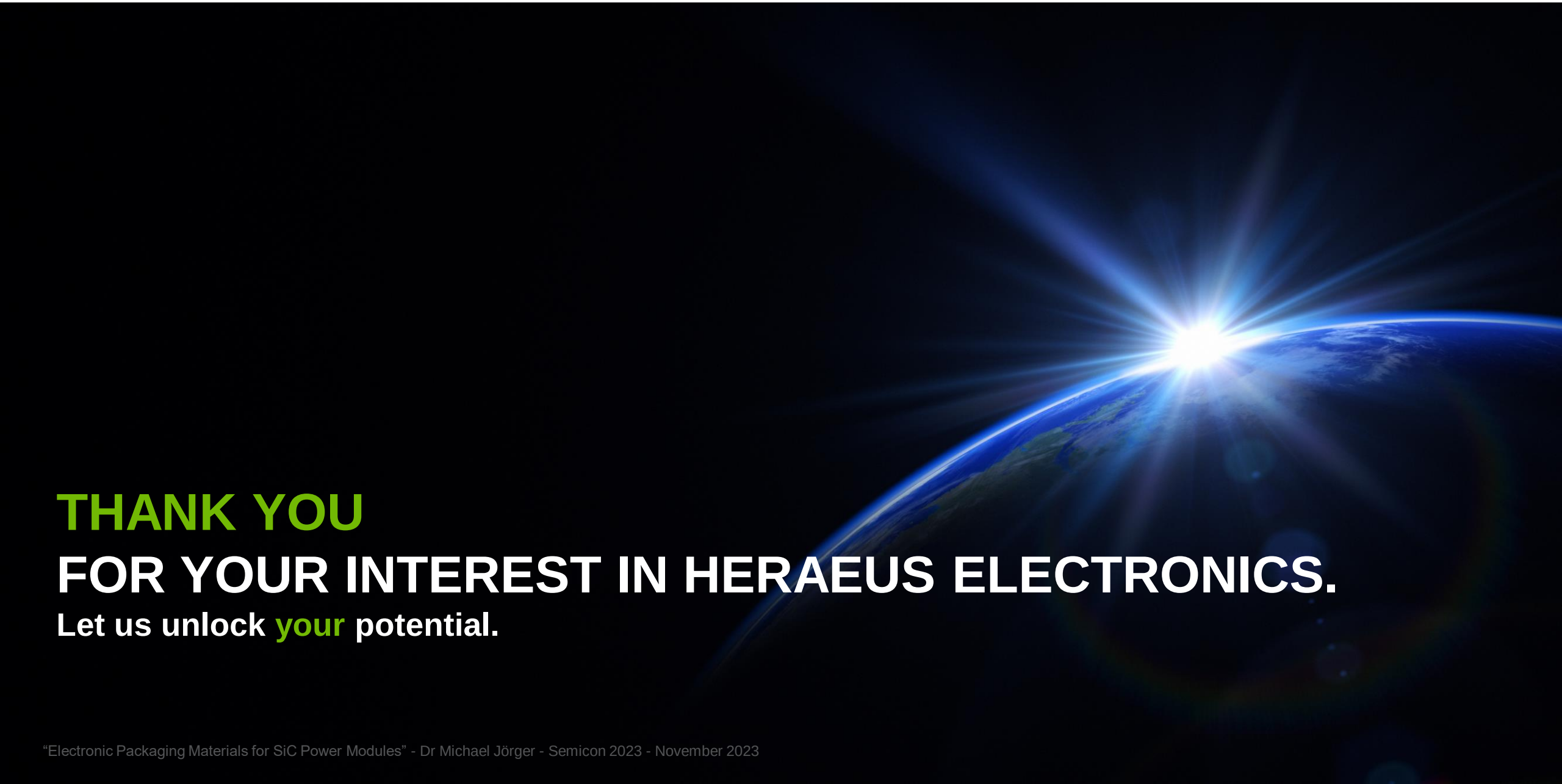
- **More homogenous heat distribution**
- **Reduced thermal stress on die topside**
- **Number of cycles increased by a factor > 60**
- **Highest lifetime and performance**

Source: C.Fery, A. Hinrich – PCIM 2021

CONCLUSION

IN SUMMARY – TO BENEFIT FROM THE CHANGE OF SI TO SIC BASED POWER MODULES A CHANGE IN ELECTRONIC PACKAGING MATERIALS IS REQUIRED





THANK YOU

FOR YOUR INTEREST IN HERAEUS ELECTRONICS.

Let us unlock your potential.