Power modules for E-vehicles – available solutions and future challenges

Marcus Lipppert – Key Account Manager at Starpower Europe

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Key design objectives for Power Modules

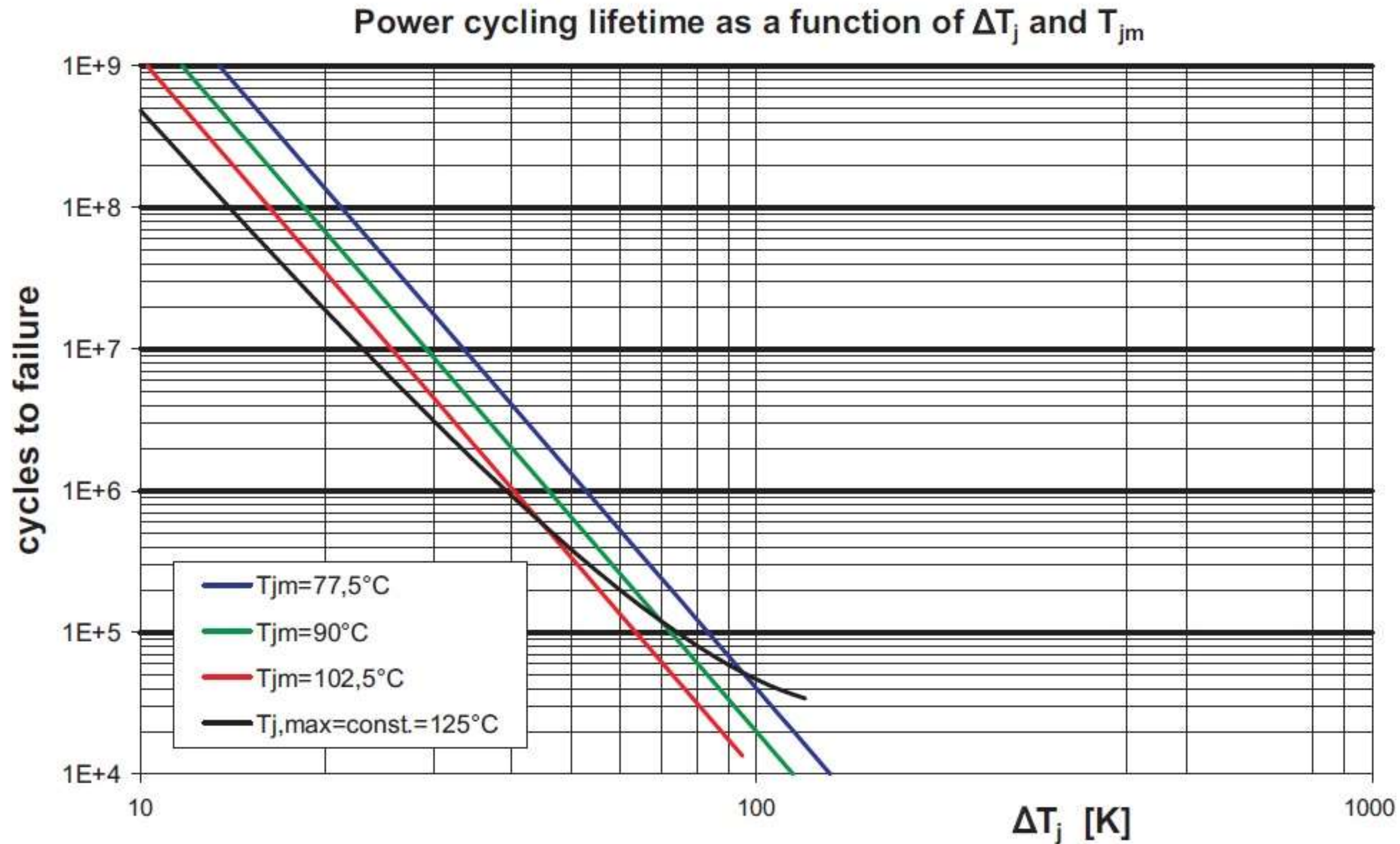
1. Increase Power Density per package
   - Chip technology → lower V_{CEsat}
   - Contacting technology within the power module → lower R_{thJC}, higher T_{jop}

$$I_c = \frac{\sqrt{R_{thJC} \cdot VT0^2 + 4 \cdot RCE \cdot (T_{j(max)} - T_c)}}{2 \cdot \sqrt{R_{thJC}} \cdot RCE} - \frac{VT0}{2 \cdot RCE}$$

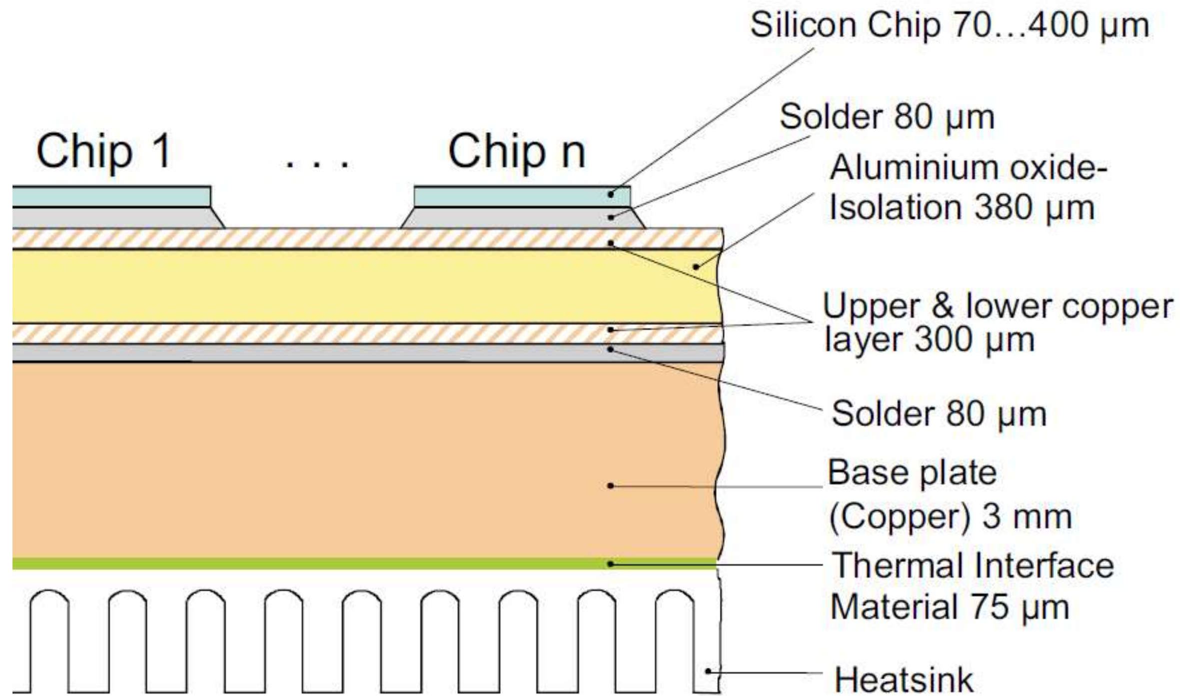
2. Increase reliability → number of power cycles
   - Number of power cycles will decrease with increasing T_{jop}

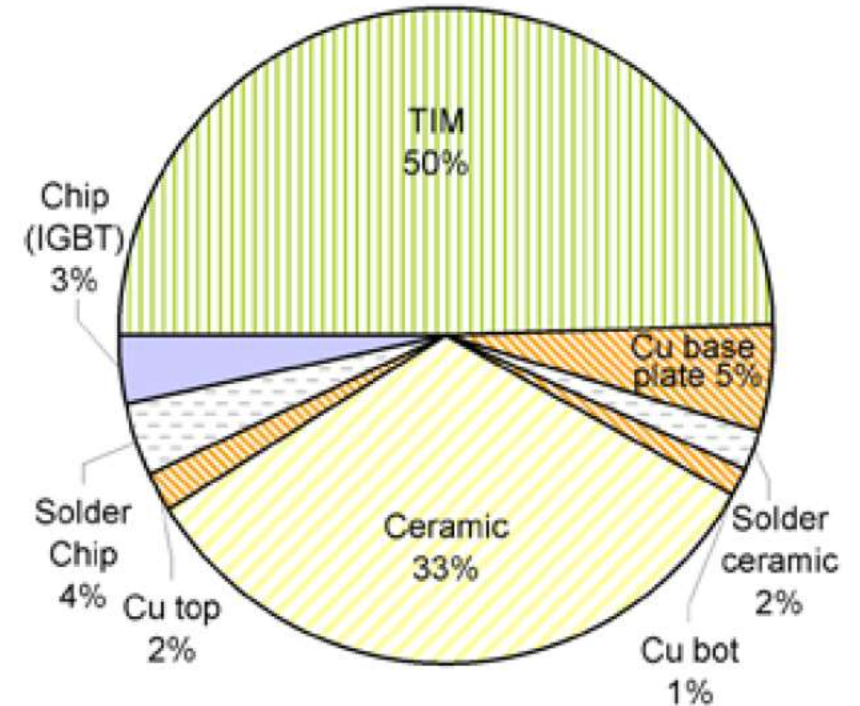
3. Cost optimization

Lifetime Industrial Standard



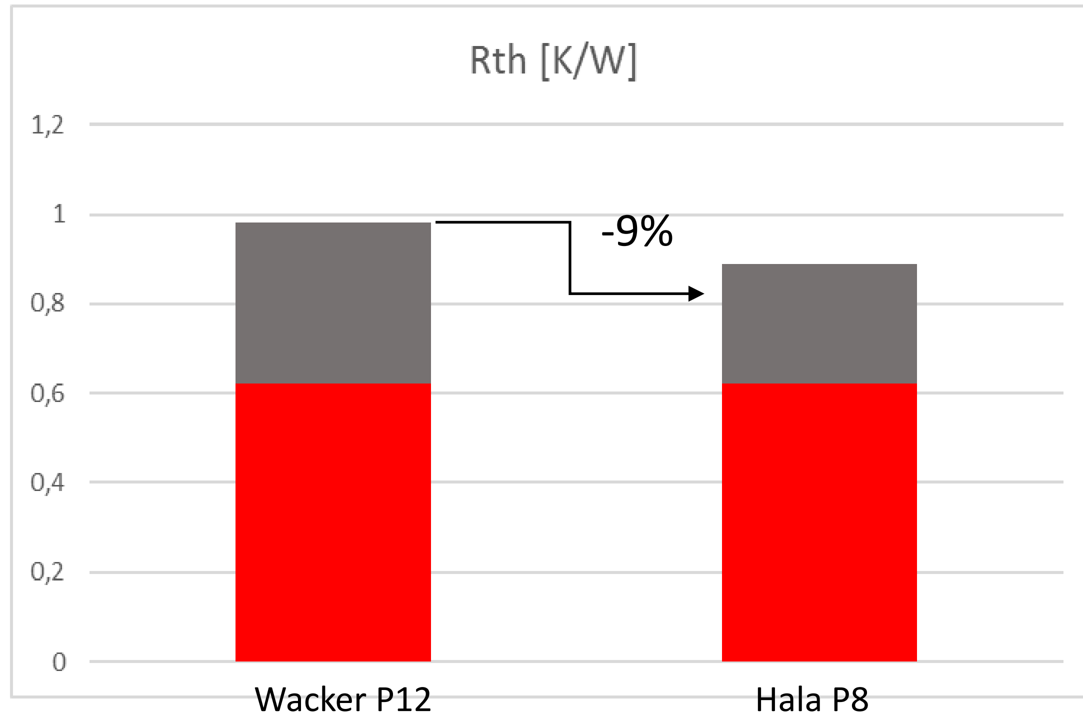
Thermal losses for standard modules



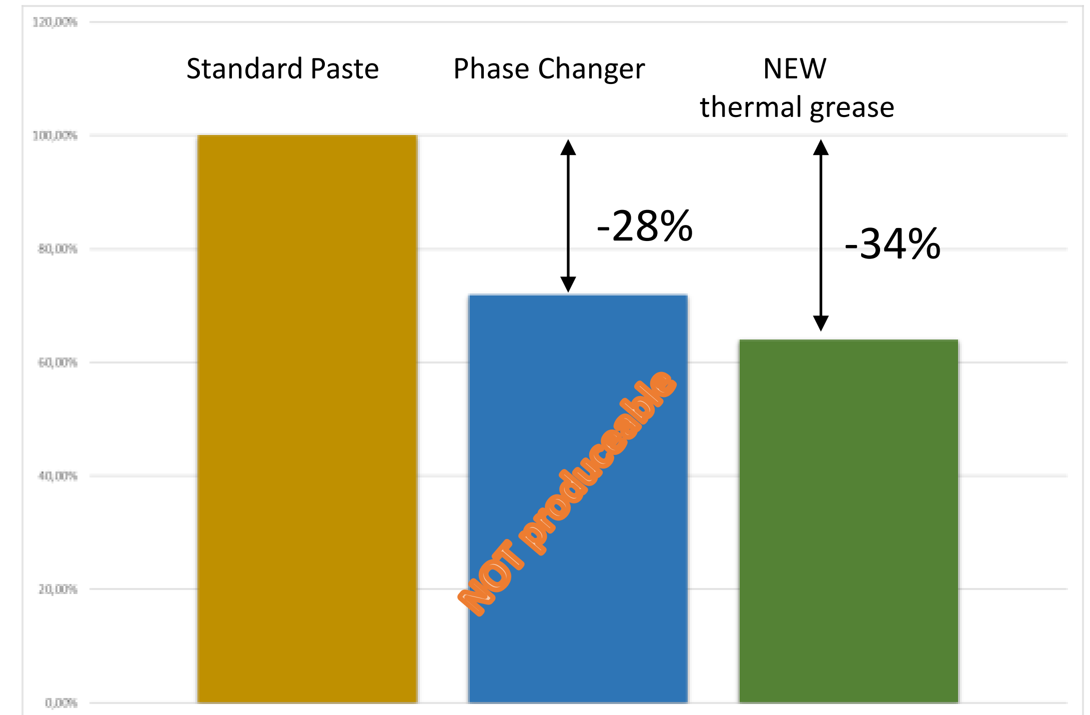


Source: Semikron Application Handbook

Pre-applied TIM

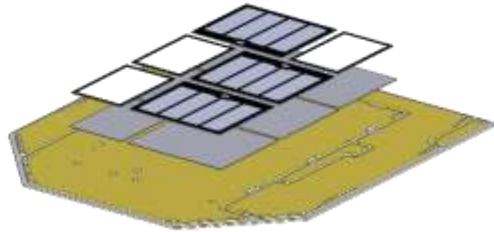


Modules with Baseplate



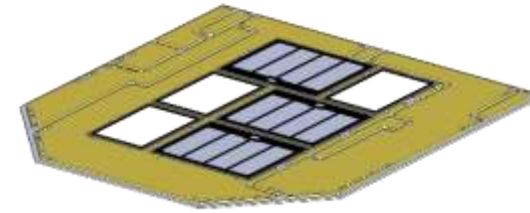
Modules without Baseplate

Sintering instead of Soldering

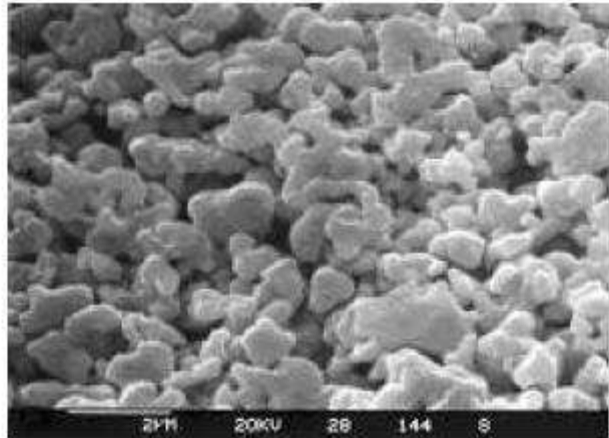


Ag nano particles

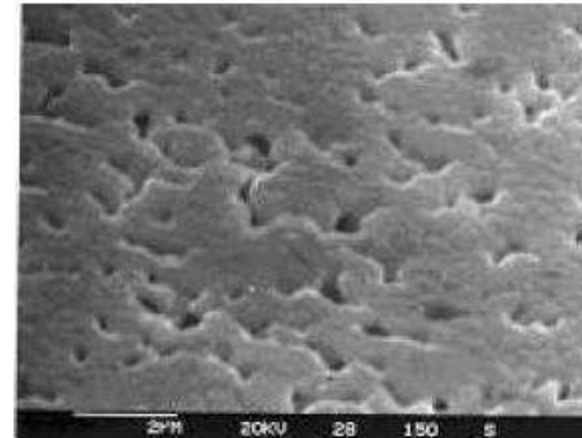
Sintering press



Density of sintered layer very close to density of Ag

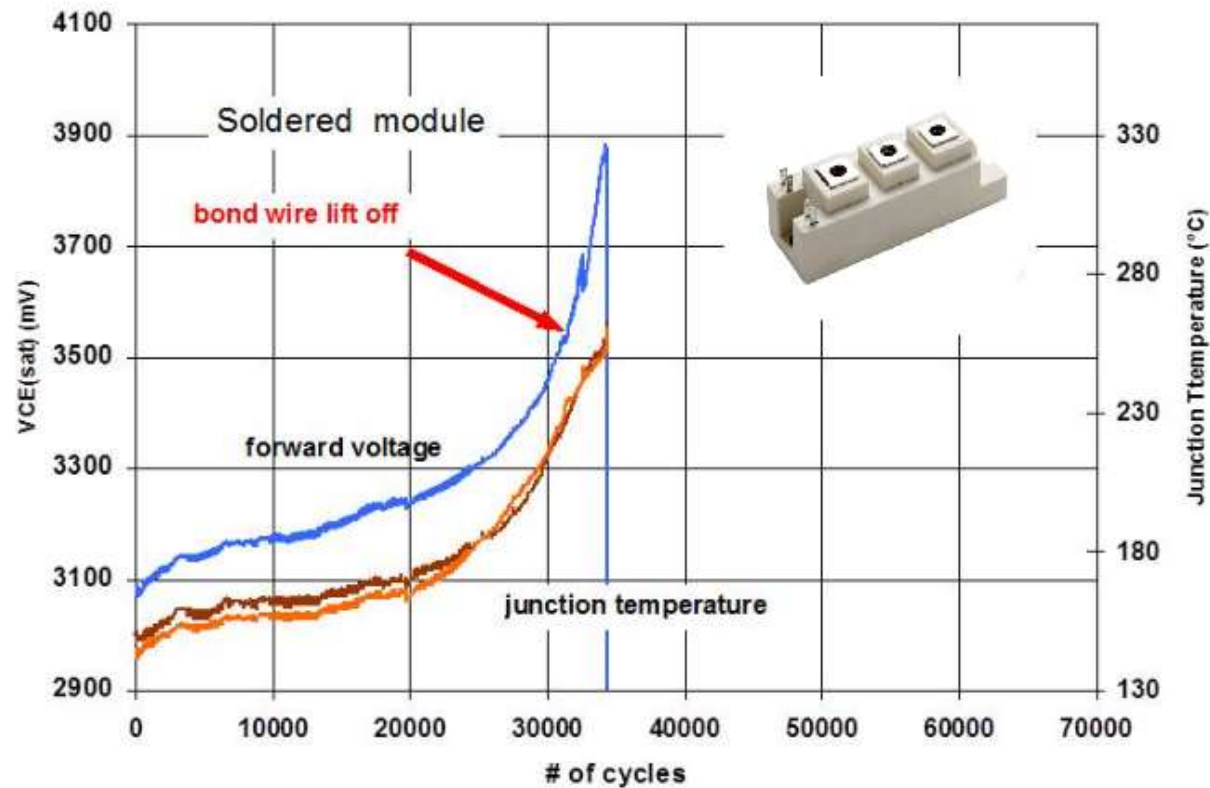


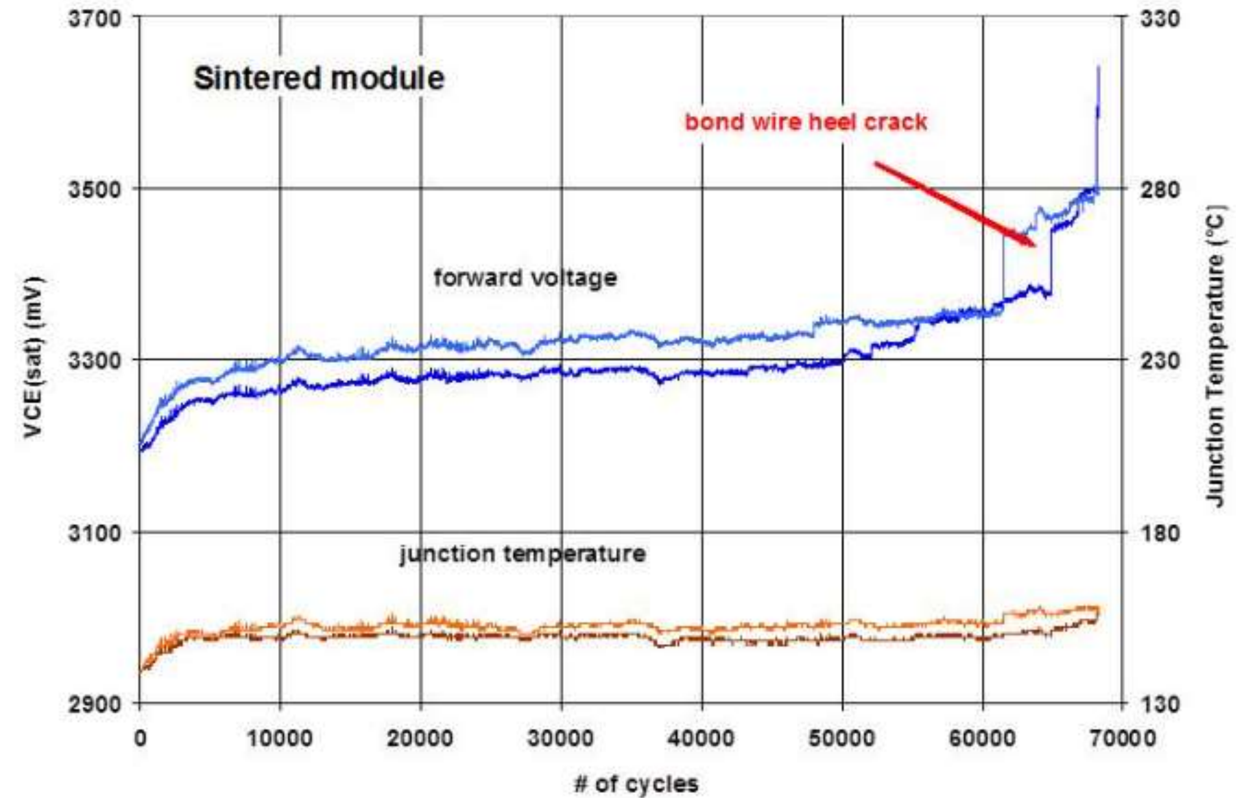
Temperature & Pressure



- Fine grained Ag particles sintered at 250°C
- Achieving a very stable connection chip-DBC up to Ag melting point of 962°C
- 4 x increased melting temperature of Ag compared with standard solder results in 3 x higher power cycling capability

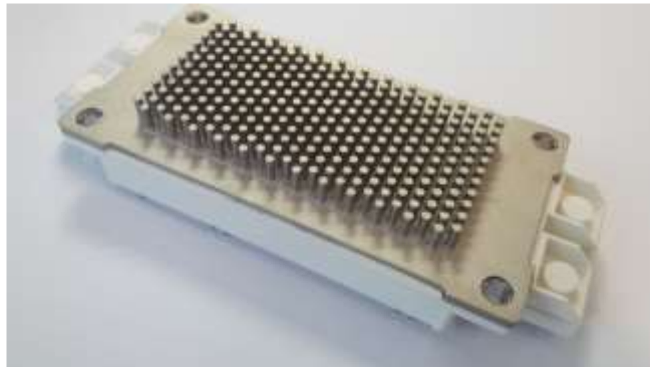
Sintering instead of Soldering

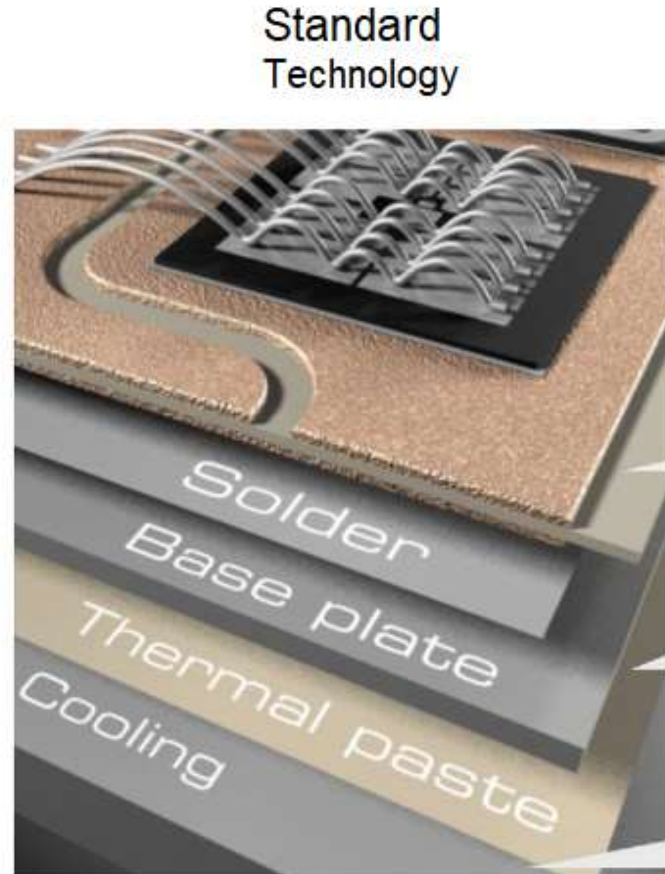




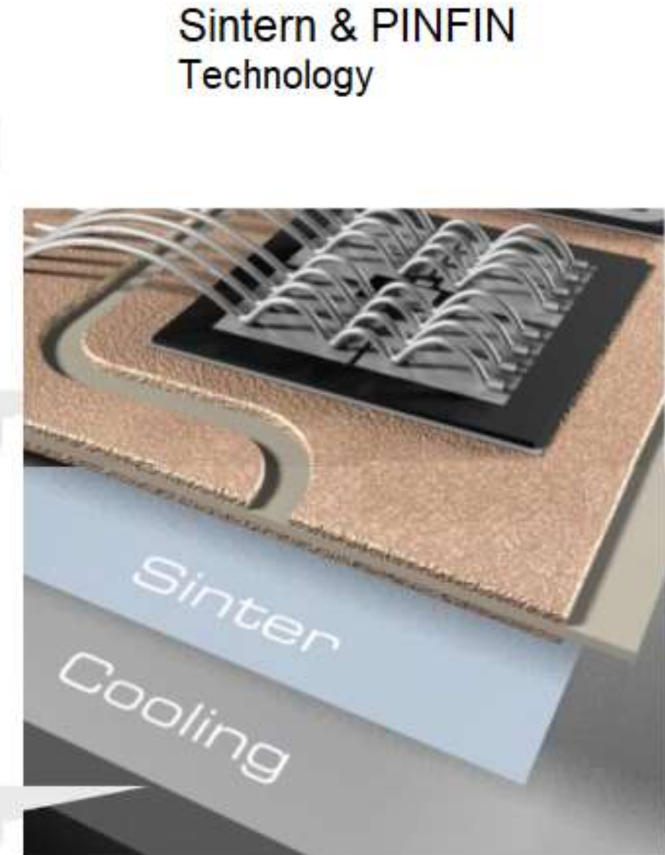
PINFIN

- Sintering DBC with sintered chips straight to the heatsink will allow a design without baseplate and TIM
- Achievable reduction in $R_{thj\text{-}a}$ of about 25%



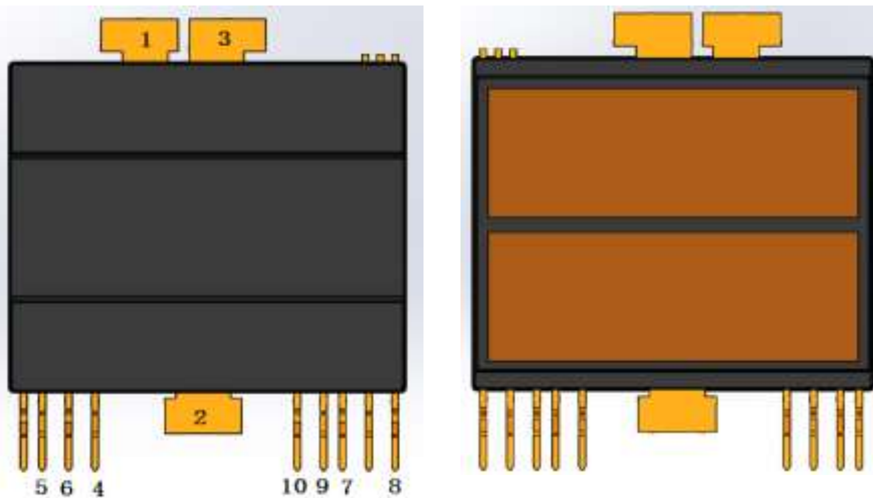


$R_{th[j\text{-}a]}$ [K/W]	Standard	Sintern & PINFIN
Total	0.85	0.61
Chip + DCB	0.25	0.24
Thermal paste	0.25	
Cooling	0.35	0.37



Single & Double Side Cooled Modules

- Highest power density per module size in order to facilitate space and performance requirements for EV-applications
- Better thermal management due to double side cooling



Level of electrification / Power of the module

BEV

PHEV

Full HEV

Mild HEV

Major companies already have overmolded double-side cooled modules in their portfolio

MITSUBISHI ELECTRIC

TOYOTA

BOSCH

infineon

starpower

Overmolded double-side cooled modules

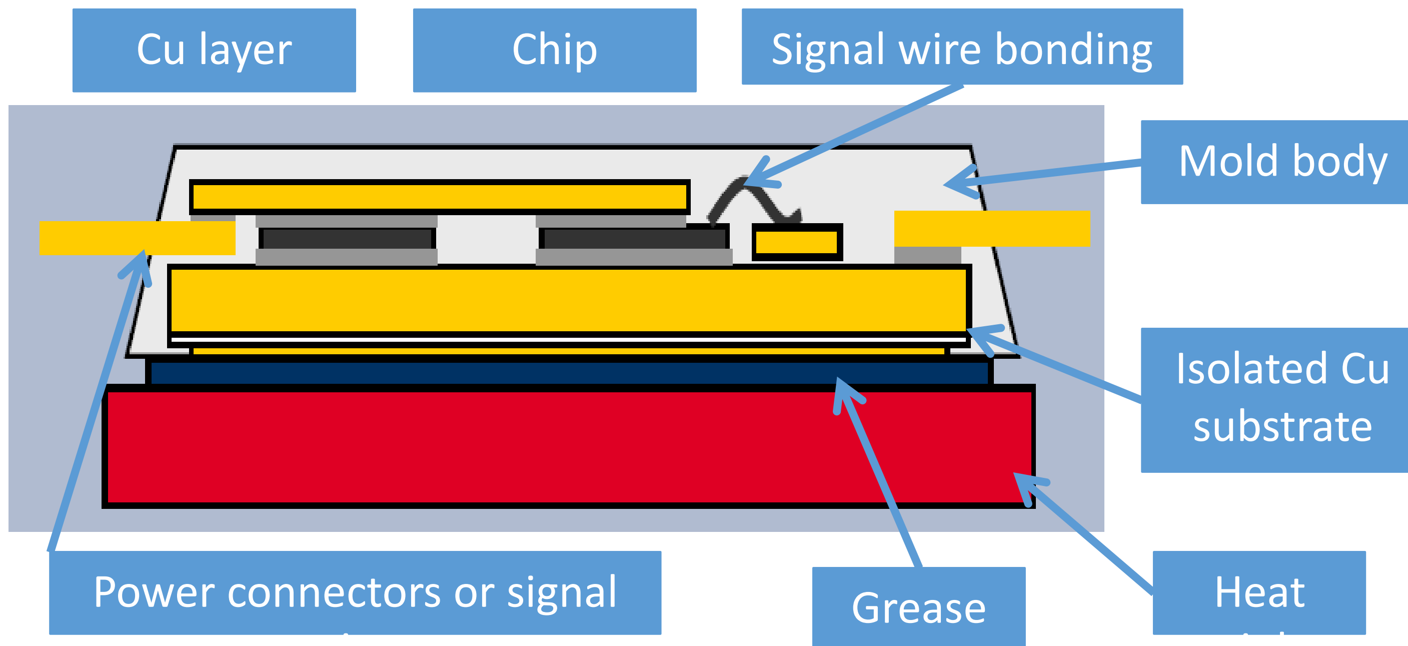
Better thermal management needed

Cost reduction

2010 2015 2020 2025

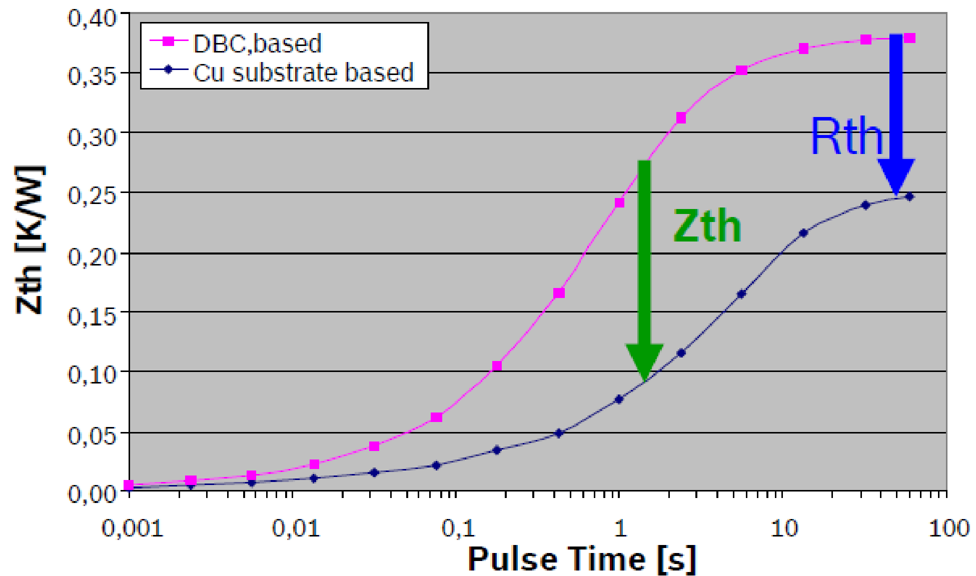
Time

Single & Double Side Cooled Modules



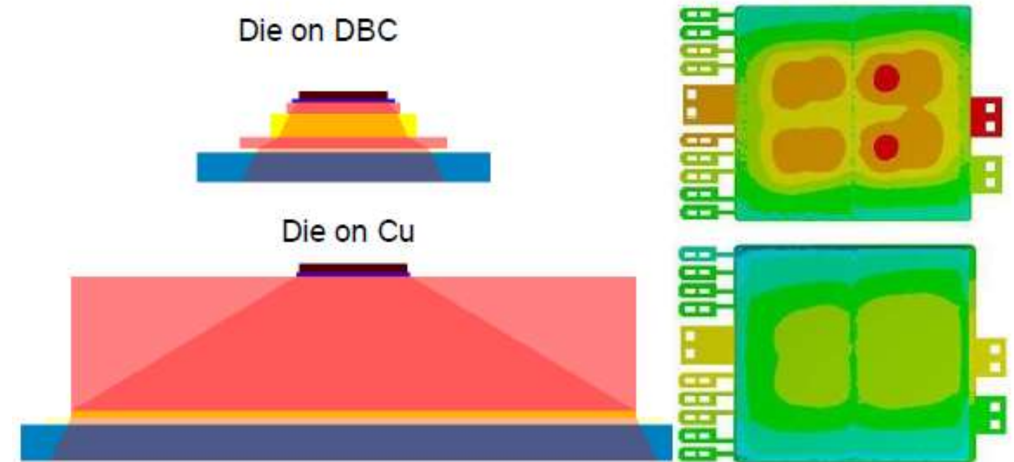
- Smallest package size / A
→ Low cost
- Heat can be dissipated in two directions
→ Efficient heat dissipation
→ High power density
- Small package height, DC+/- close together, no bond wires
→ Low parasitic inductance
- Massive copper terminals around the dies
→ Low losses
→ Large thermal capability
→ Low Tj fluctuation

Core Technologies: Current Density by Design



Reduced power dissipation:

- Low ohmic module design and IGBT-contacting
- Low inductive module design



Improved heat flow to heat sink:

- Up to 70% improvement in Zth
- Up to 30% improvement in Rth

Due to

- double sided IGBT cooling by solder contacting
- optimized heat spreading by thick Cu layer

Common Packages