

SKiN: Double side sintering technology for new packages

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- **Introduction**
- **SKiN Assembly Process**
- **Test Results**
- **Summary**

Industry



Drives: Lower Cost



Elevator: Reliability



Power Supply: Efficiency

Vehicles



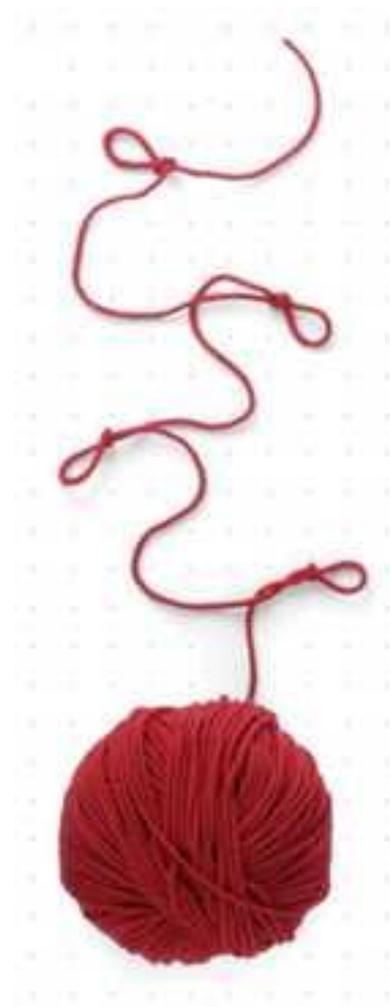
**Cost, Robustness,
Weight, Size**

Renewables

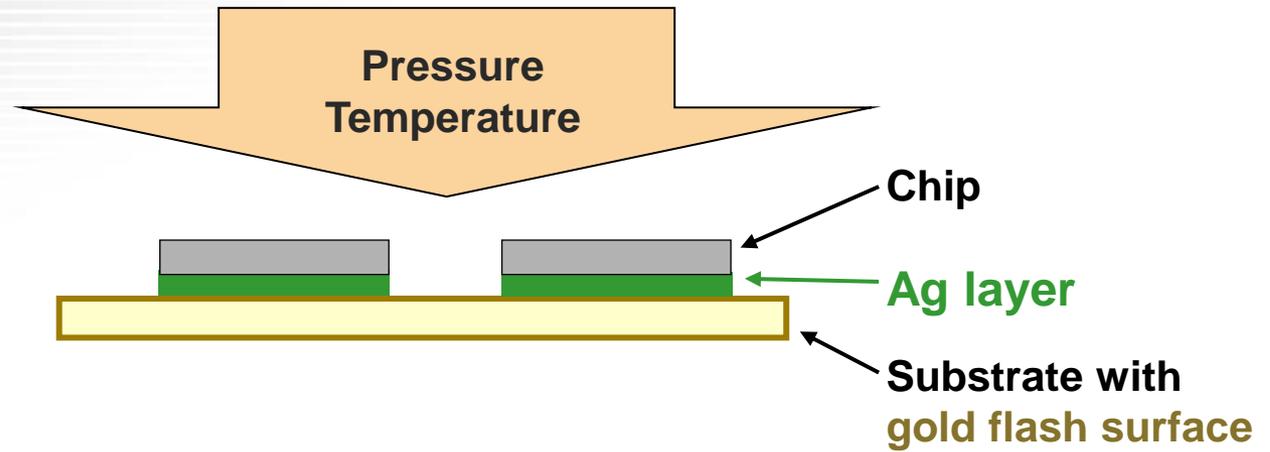


Size, Reliability

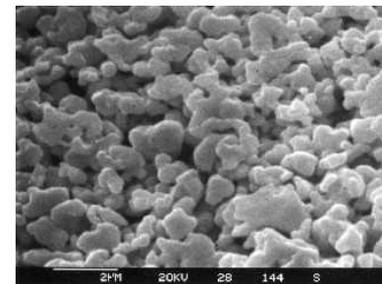
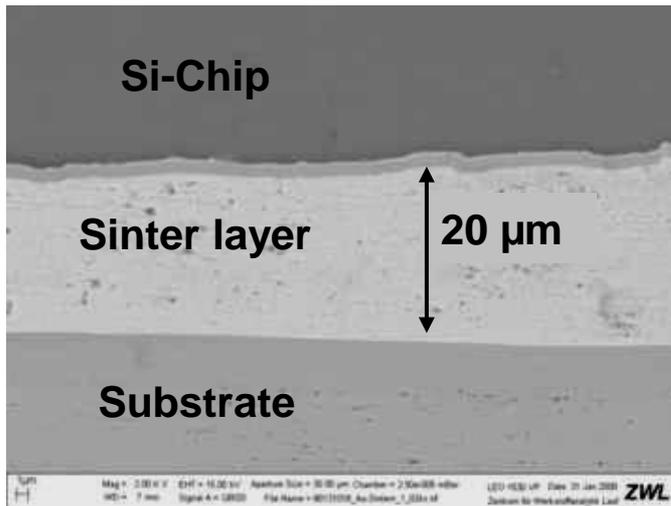
- ▷ Higher operating temperatures
 - ▷ Better cooling
 - ▷ New materials
- ▷ New Chip Technologies
 - ▷ Wide Bandgap Devices
 - ▷ RC IGBT
 - ▷ Next gen. IGBT
- ▷ Reliability
 - ▷ Bond wires
 - ▷ Solder fatigue
- ▷ Integration
 - ▷ Electronics inside



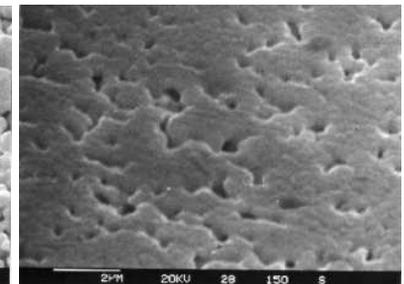
Replace Solder by Diffusion Sintering



Ag sinter layer between chip and substrate



Ag layer before



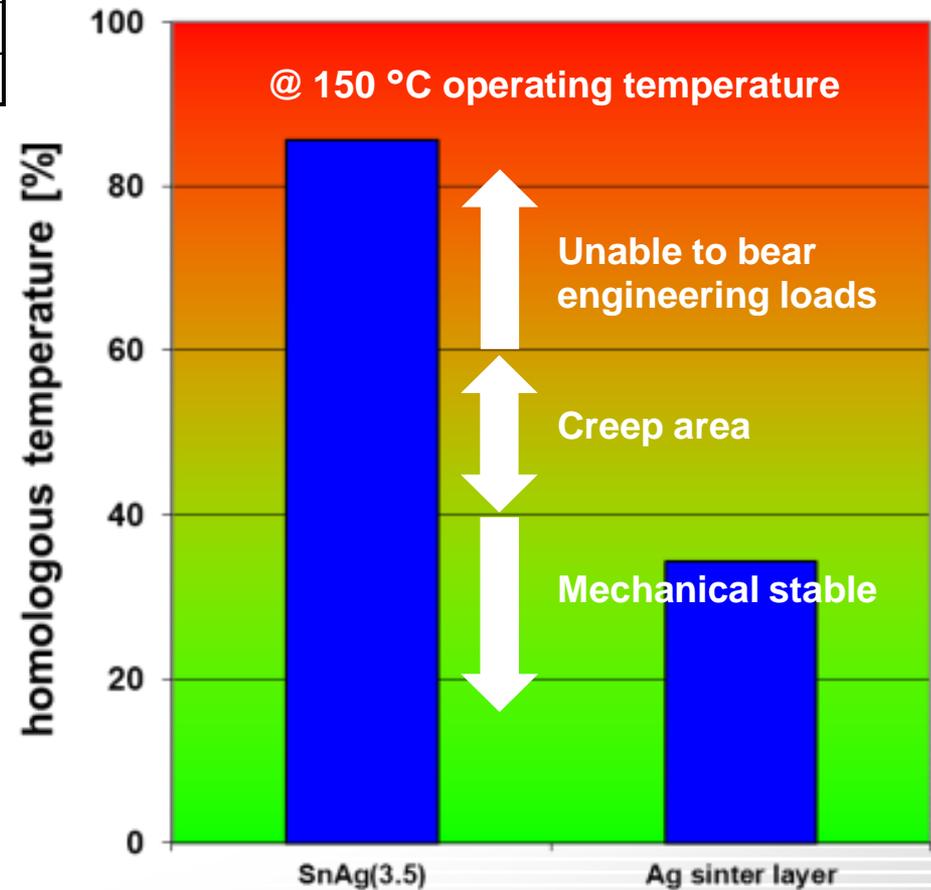
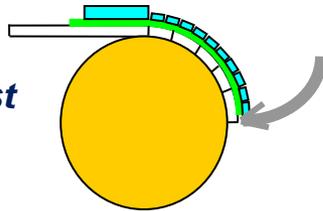
after sintering

Sinter Technology

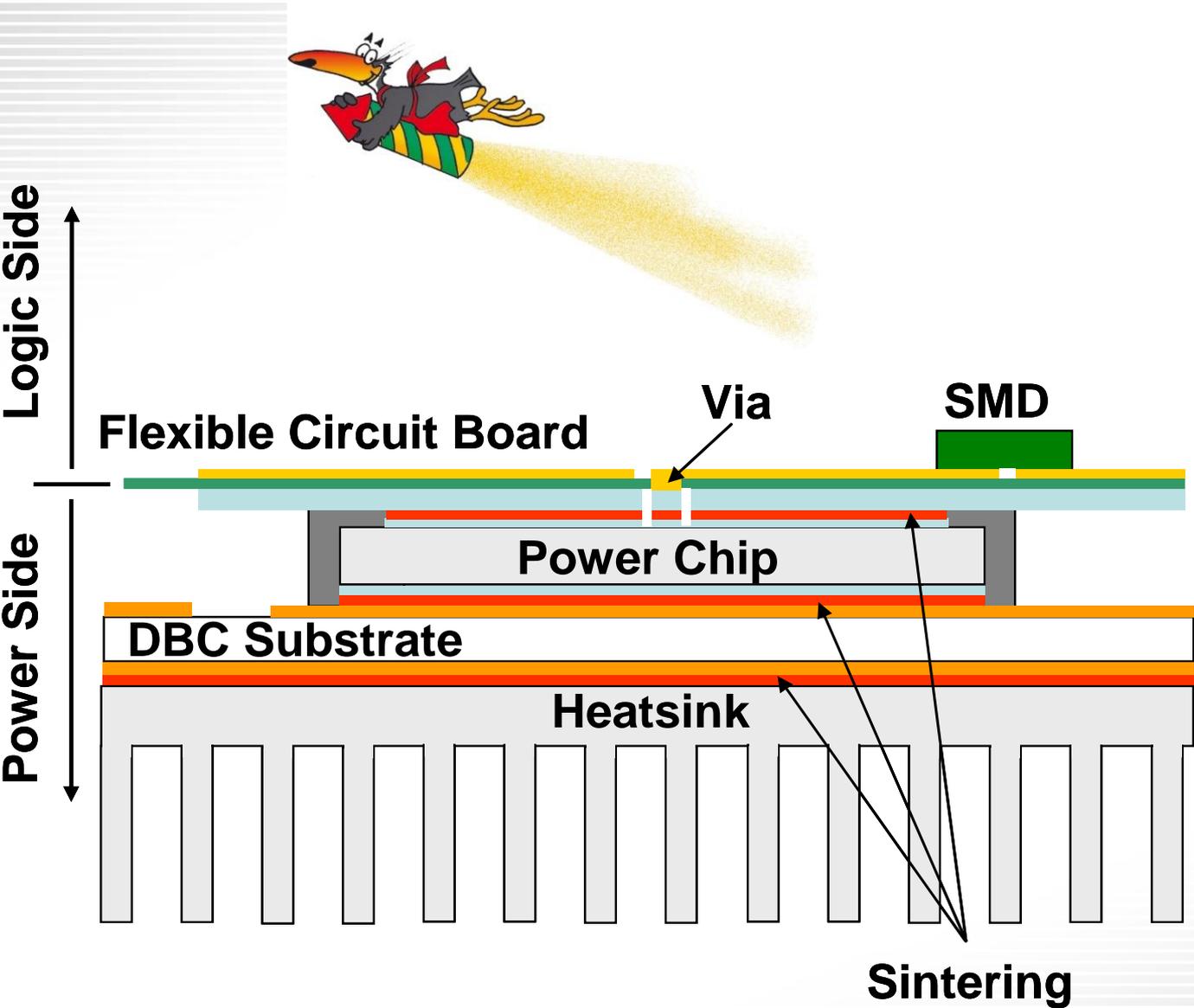
properties		solder layer SnAg(3)	Ag diffusion sinter layer
melting temperature	°C	221	962
thermal conductivity	W/mK	70	240
electrical conductivity	MS/m	8	41
layer thickness	µm	~90	~20
CTE	ppm/K	28	19
tensile strength	Mpa	30	55



Adhesion test

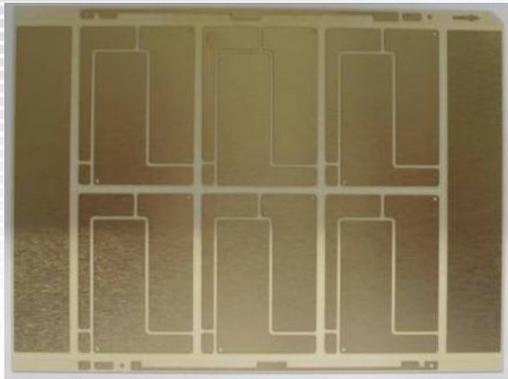


SKiN device cross section

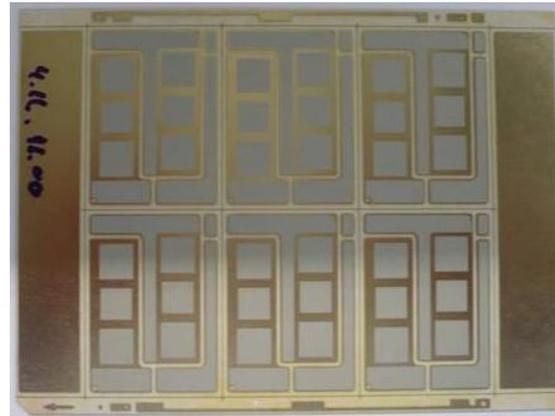


SKiN: Die sintering to substrate

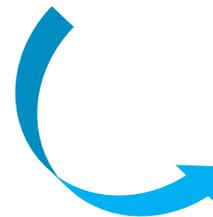
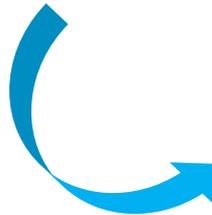
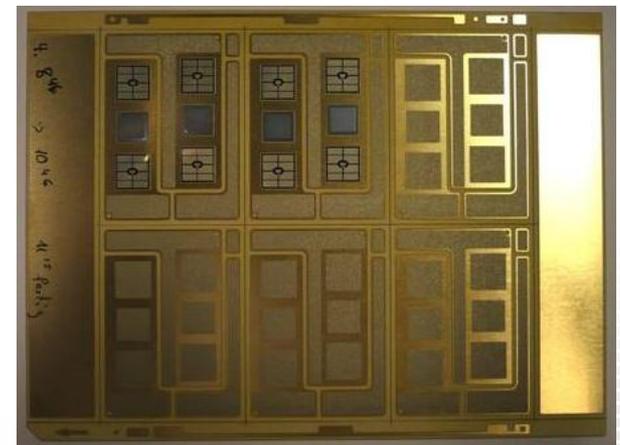
DBC, 5" x 7", plated



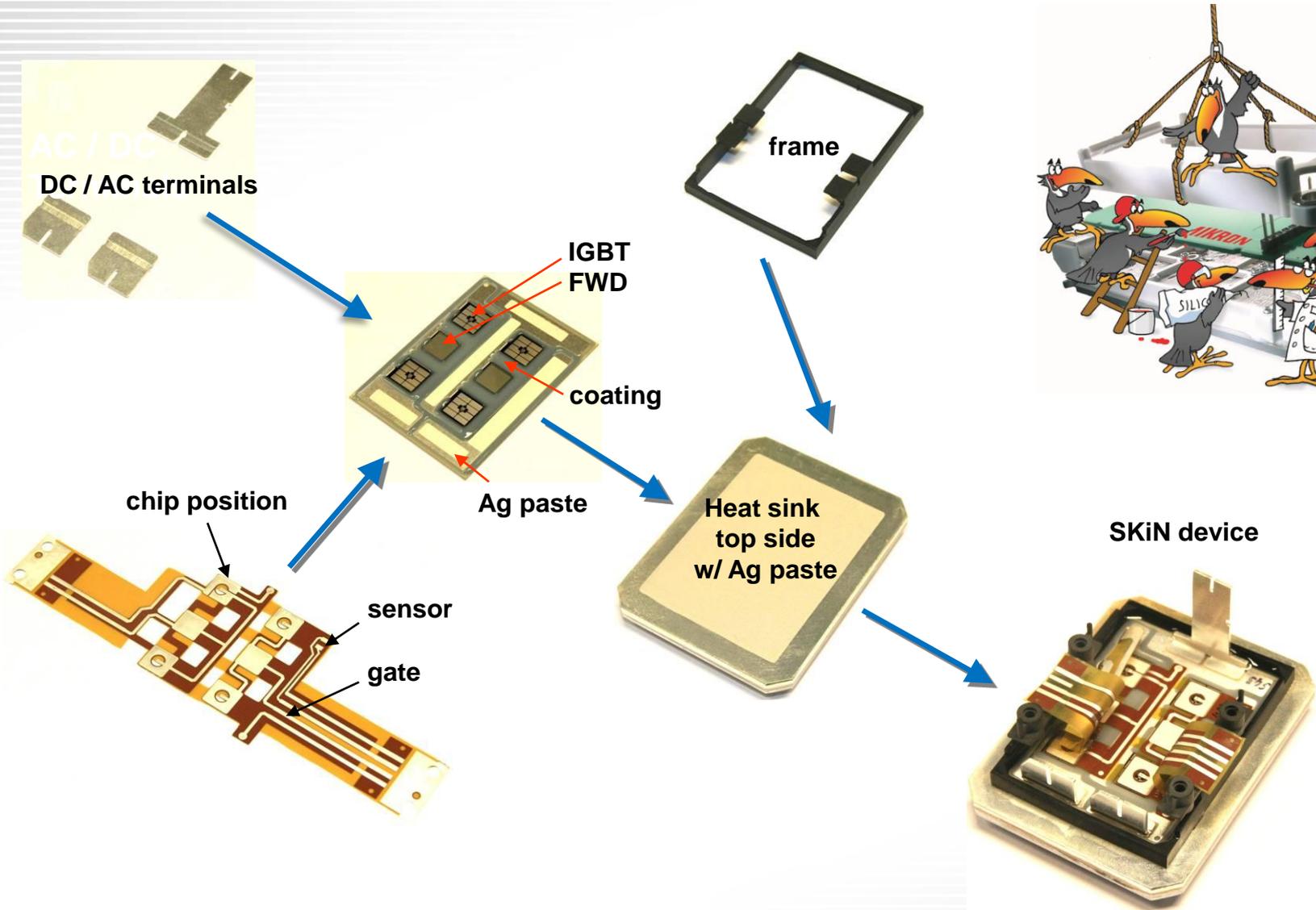
Ag paste, stencil printed



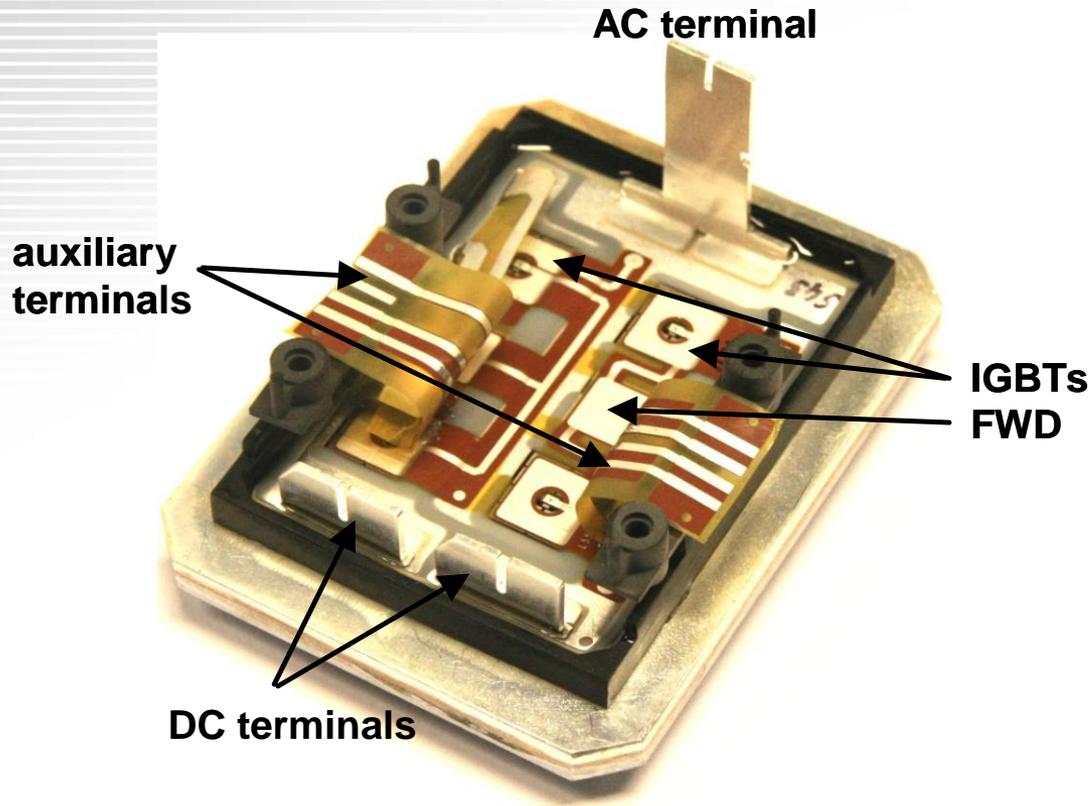
IGBTs & FWDs, sintered



SKiN device assembly



Assembled SKiN device

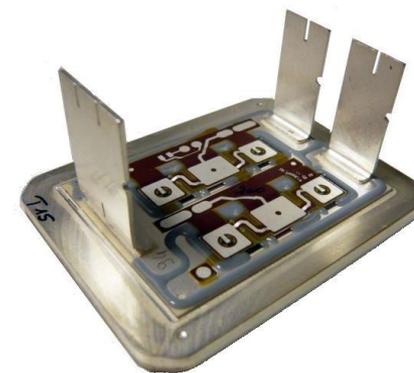
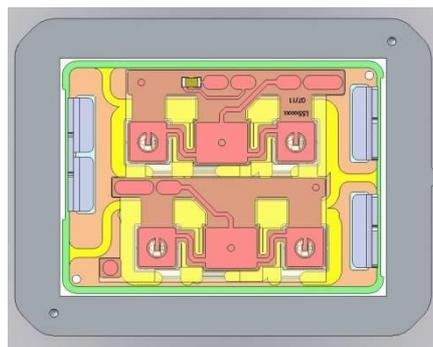
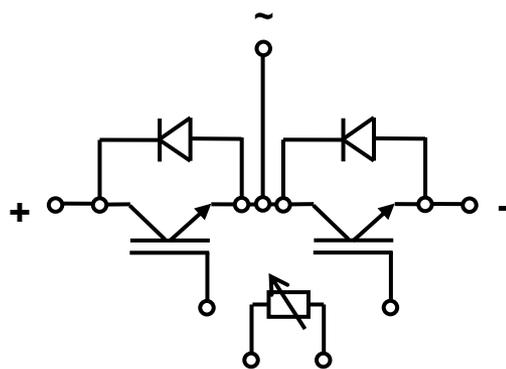


sintered SKiN on
pin-fin cooler



SKiN[®] Half Bridge Modules

	1700V	1200V	650V
IGBT voltage	1700V	1200V	650V
DC link voltage	1300V	900V	450V
Current Rating	180A	200A	400A
ISO test voltage	5.6KV DC	4.2KV DC	3.5KV DC
IGBT	2 x 100mm ²	2 x 100mm ²	2 x 100mm ²
Diode	1 x 120mm ²	1 x 120mm ²	1 x 120mm ²
Heatsink	74 mm x 56 mm	74 mm x 56 mm	74 mm x 56 mm

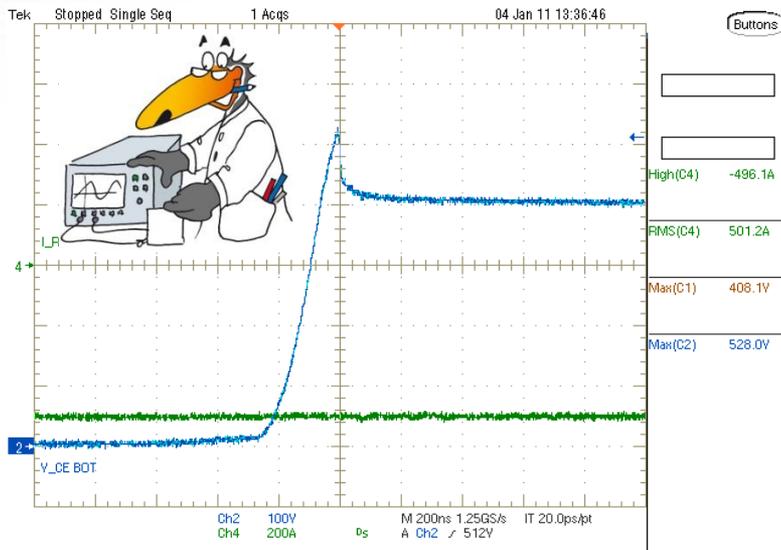


SKiN Process Line

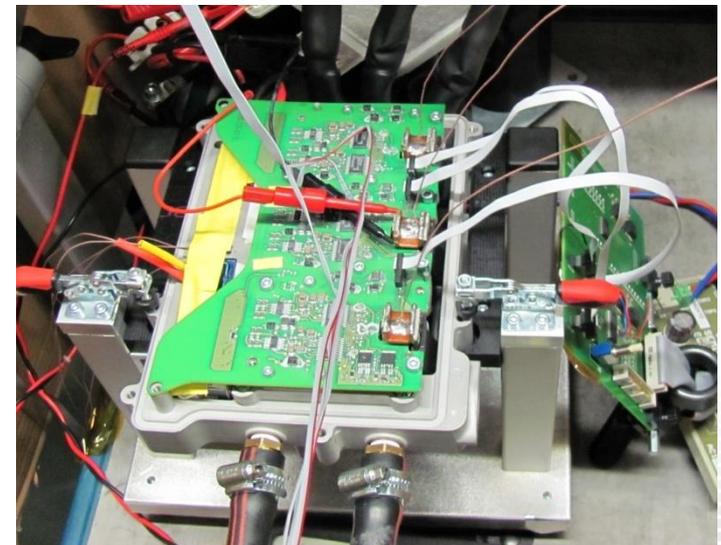
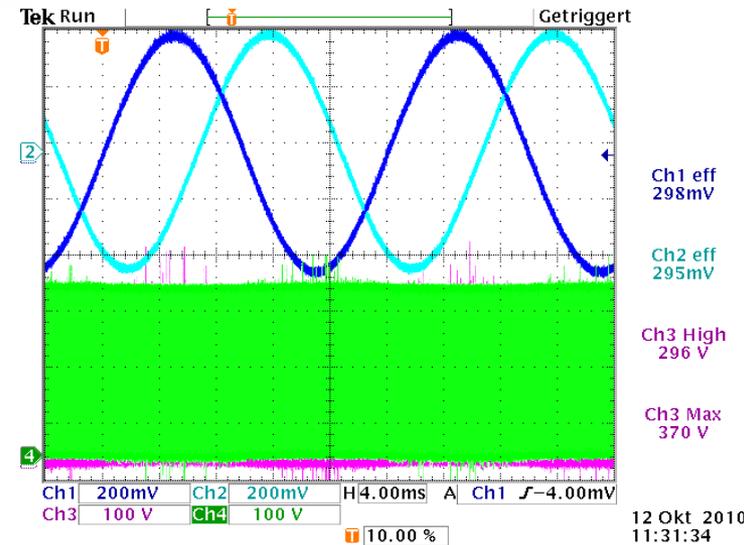


SKiN Development Status

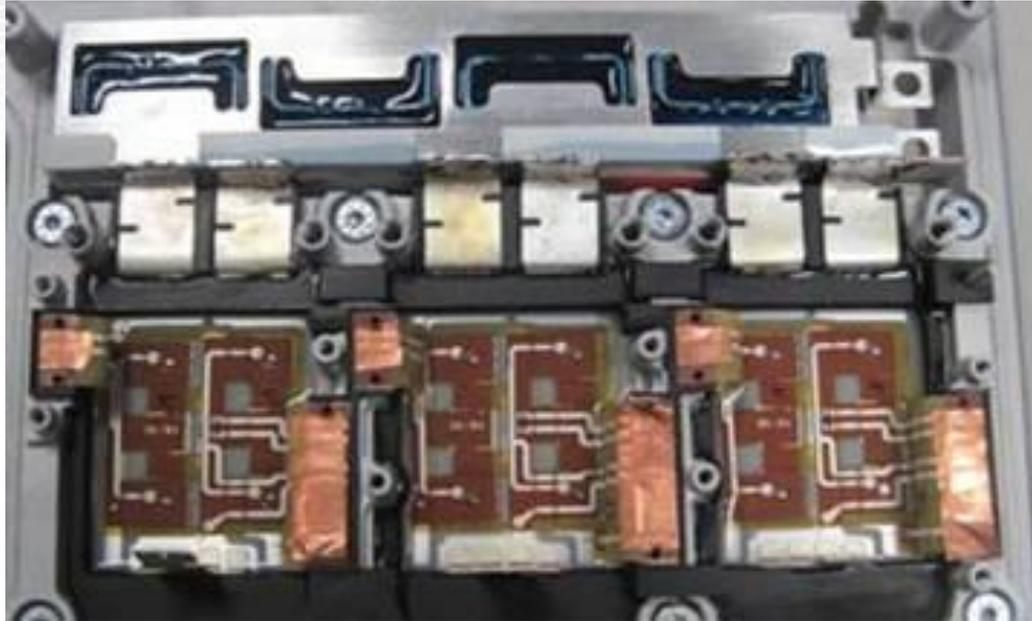
- ✘ Switching performance and inverter tests
- ✘ Inverters test @ 300V, 300A (110 kVA)
- ✘ Low stray inductance, no clamping, no snubber



Turn-off waveform of the BOT IGBT at 400V DC, 500 A. The peak voltage is 528 V

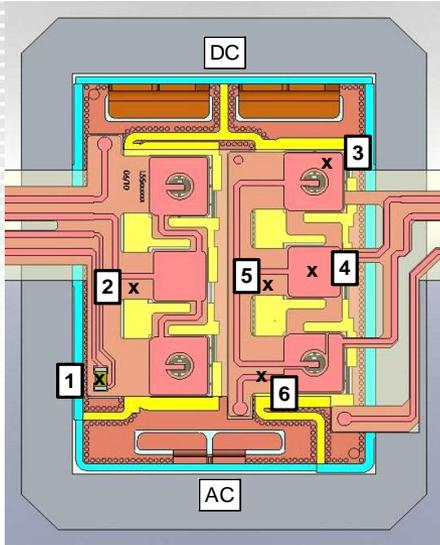


Measurement Setup



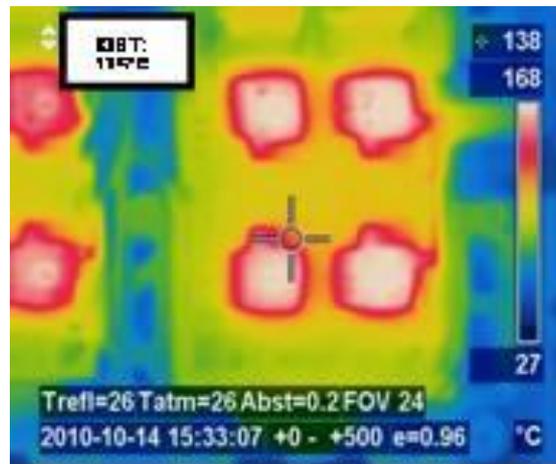
➤ **3-Phase Inverter, 20 kW/dm³ Power Density**

Schematic overview

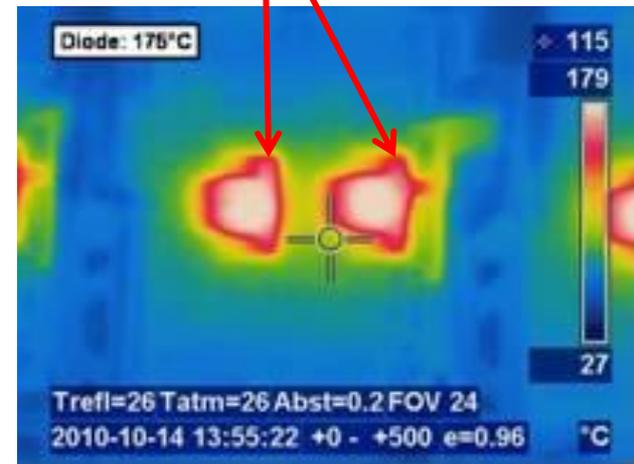


- ❖ Chips are thermally decoupled
- ❖ Homogenous temperature distribution
- ❖ $R_{thja} = 0.44 \text{ Kcm}^2/\text{W}$ (35% less than conv.)

Remove heat
flexible circuit board



IGBTs

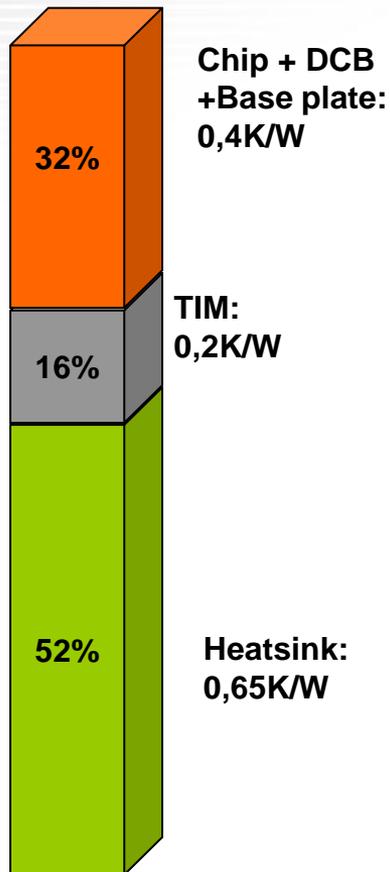


Diodes

$R_{th(j-a)}$ Comparison (81mm² diode)

SEMiX

$R_{th(j-a)}=1,25$ K/W

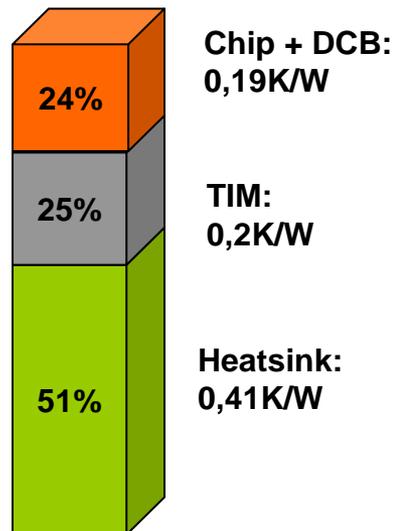


$P_v(\max)$ at
 $dT(j-a)=100K$:

80W
(1 W/mm²)

SKiM

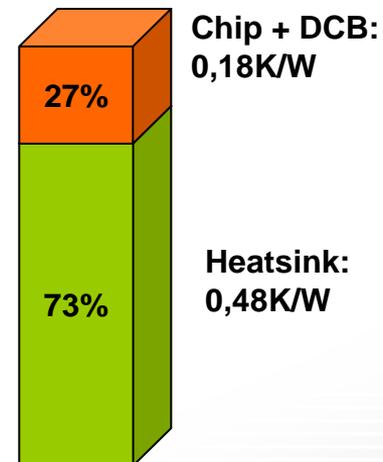
$R_{th(j-a)}=0,8$ K/W



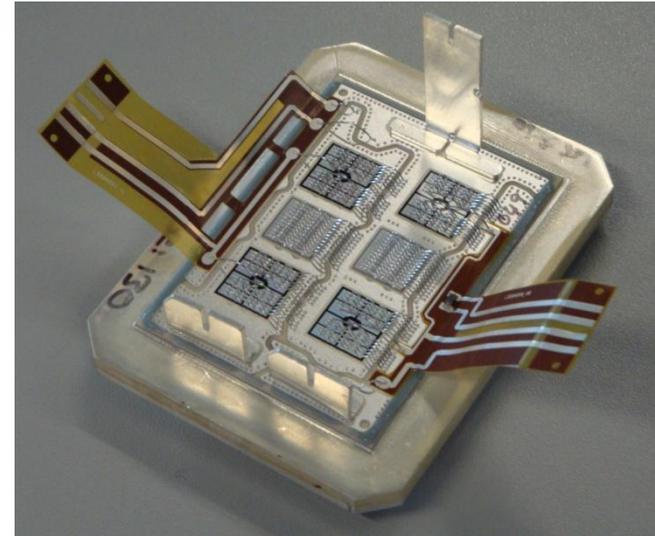
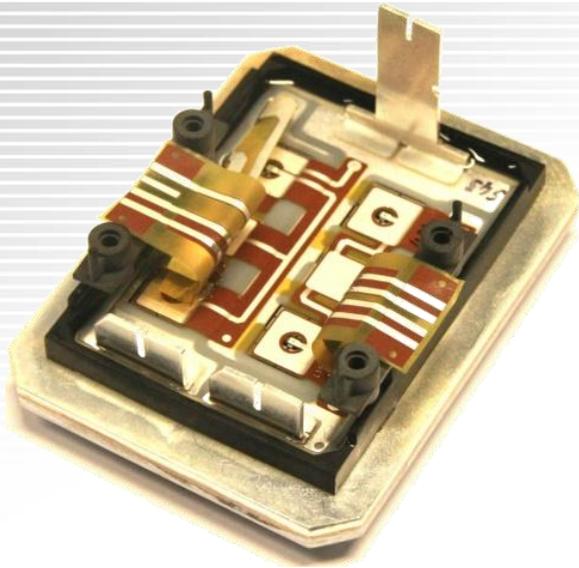
125W
(1,54W/mm²)

SKiN

$R_{th(j-a)}=0,66$ K/W



151W
(1,87W/mm²)



Benchmark samples have identical chips and dimensions

Only difference:

Chip Top side contact sintered to flex foil

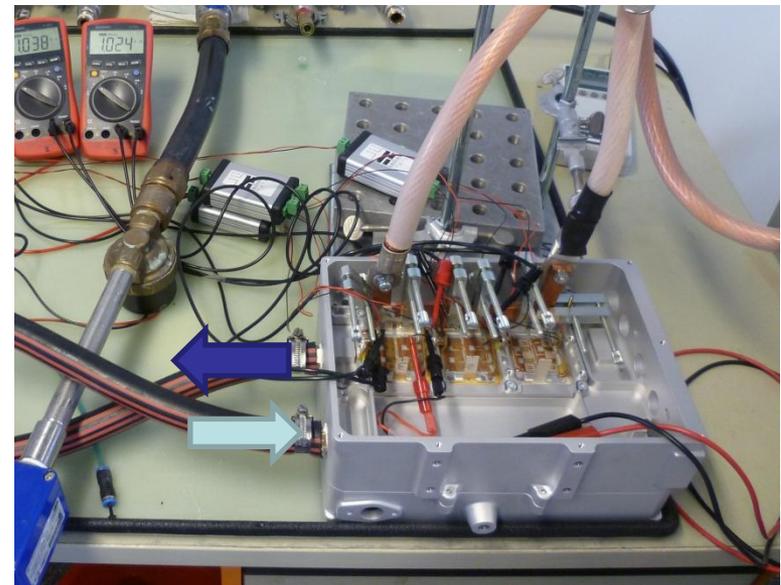
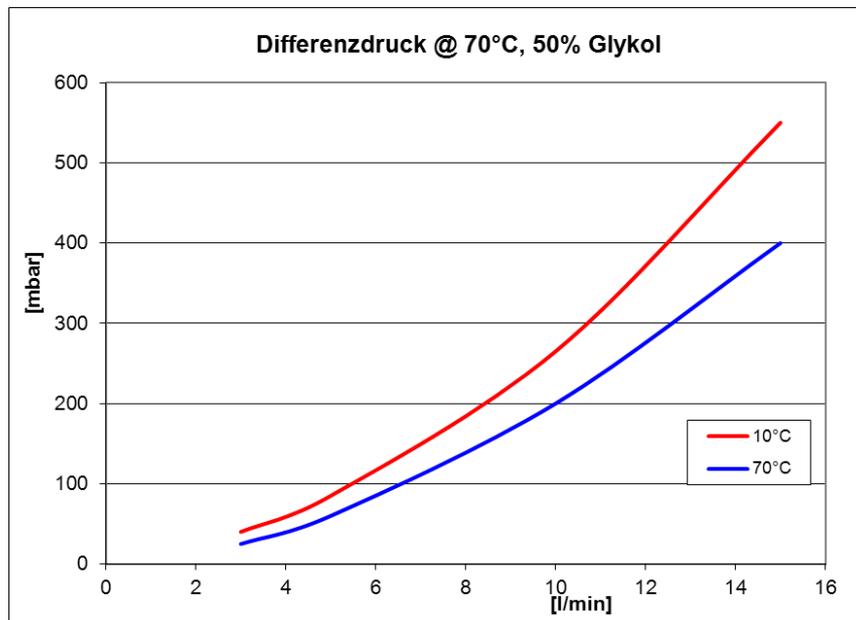
- ▶ Contact area IGBT ~50%
- ▶ Contact area Diode ~85%

Chip Top side contact with maximum amount of 300µm bond wires

- ▶ Contact area IGBT ~ 21%
- ▶ Contact area Diode ~ 21%

Thermal Resistance Measurement

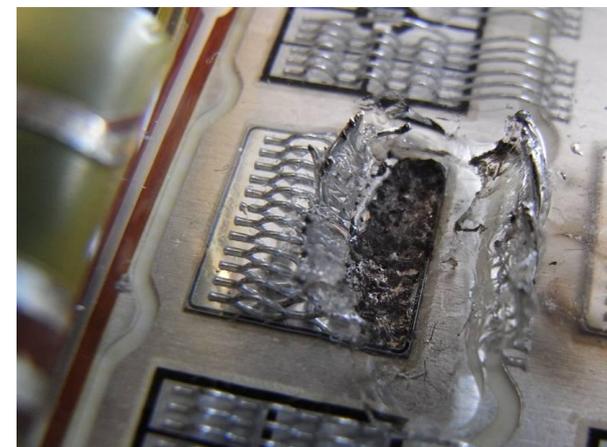
- Thermal measurements 400A module samples
 - ▶ 10l/min, 70°C coolant, 50% glycol
- Excellent thermal resistance: $R_{th(j-a)} = 0,177K/W$ @ 2cm² chip area
- 225 W/cm² chip area losses at 150°C junction and 70°C coolant



Measurement Setup

Diode Surge Forward Current Measurement

- Half sine wave current surge of 10ms duration at 25°C
- I_{FSM} rating of the flex layer module is 27% higher than the bond wire module
- Improvement possible due to the larger area top side contact and improved thermal spreading



Destroyed chip with bonds

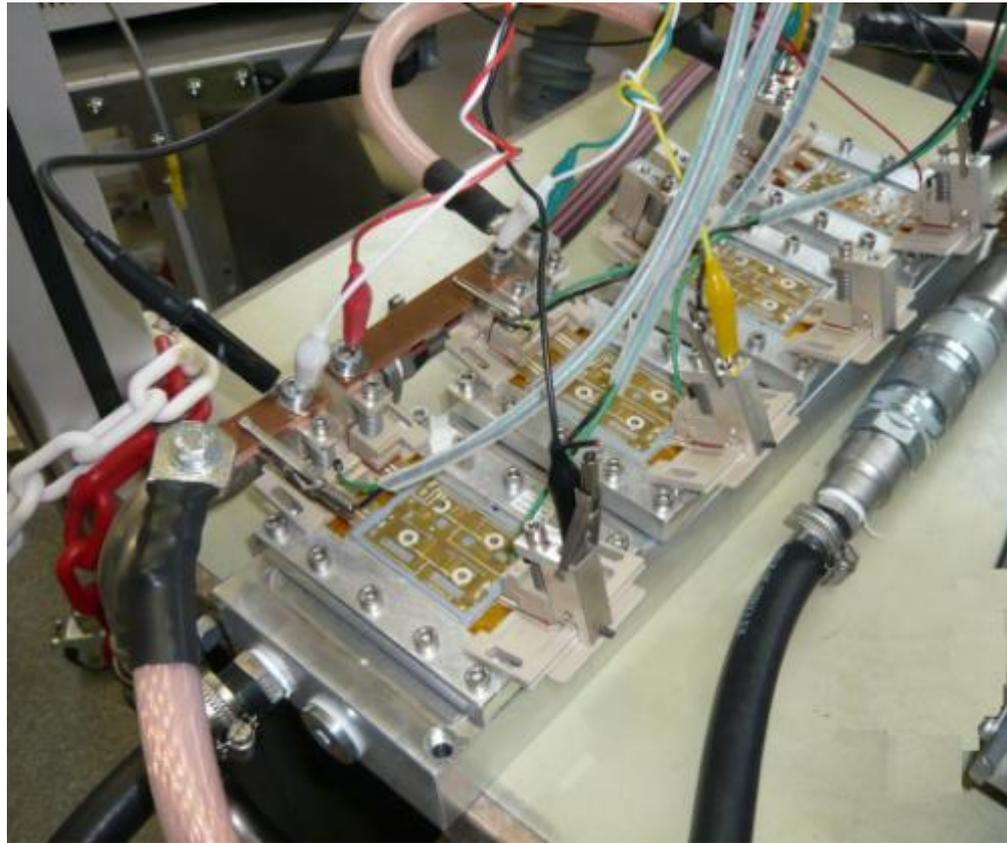
I_{FSM} comparison

	SKiN Module			Benchmark Module	
Sample		A	Sample		A
539	Top	2666	C641	Top	2092
	Bot	2690		Bot	2108
540	Top	2691	C652	Top	2105
	Bot	2662		Bot	2096
550	Top	2696			
	Bot	2662			
553	Top	2691			
	Bot	2656			
	min	2656		min	2092
	max	2696		max	2108
	mean	2677		mean	2100
Comparison		127%			100%



Destroyed chip with flex

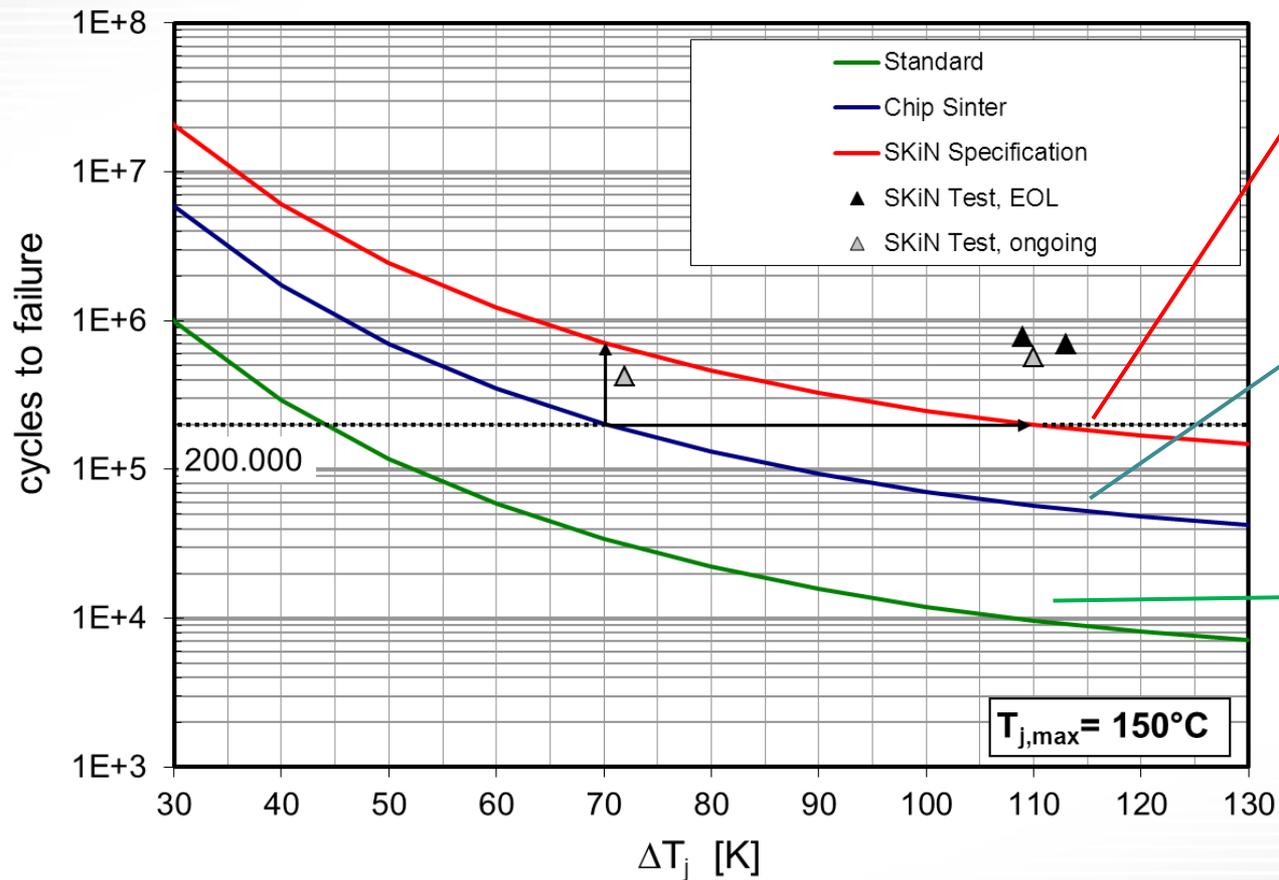
-  4 x 400Amp SKiN devices in parallel



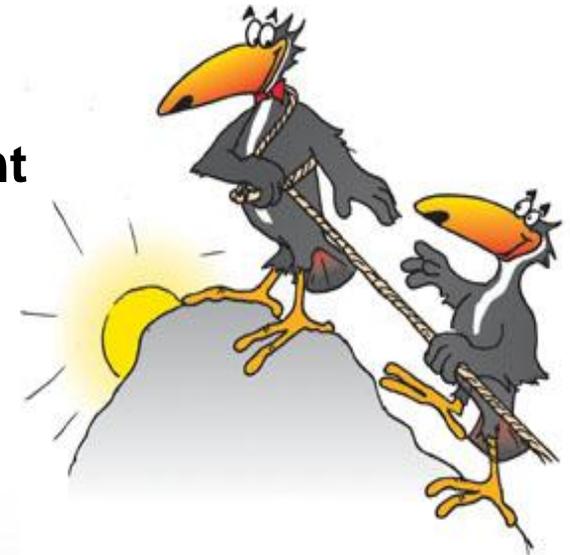
Power Cycling Results

Test under constant power:
700 kcycles @ $\Delta T=110\text{K}$
70 x improvement

Power cycling lifetime as a function of ΔT_j



- **A Flexible Circuit Board replaces Bond Wires**
- **Sintering replaces all Solder / Grease Layers**
- **Direct Sintering to cooler: low thermal resistance**
- **Significant chip shrink and/or higher current**
- **Power Cycling capacity improves 70 x**
- **SKiN technology is suited for 200 °C ambient**



Thank you

