How to sustain the EV-Traction SiC Revolution: technology, manufacturing, supply chain and cost

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Agenda

- Wide-bandgap revolution and SiC impact on EV-Traction application
- onsemi's solid Technology Foundation in Traction
- EV-Traction Module Platform definition
- System Cost optimization / performance improvement

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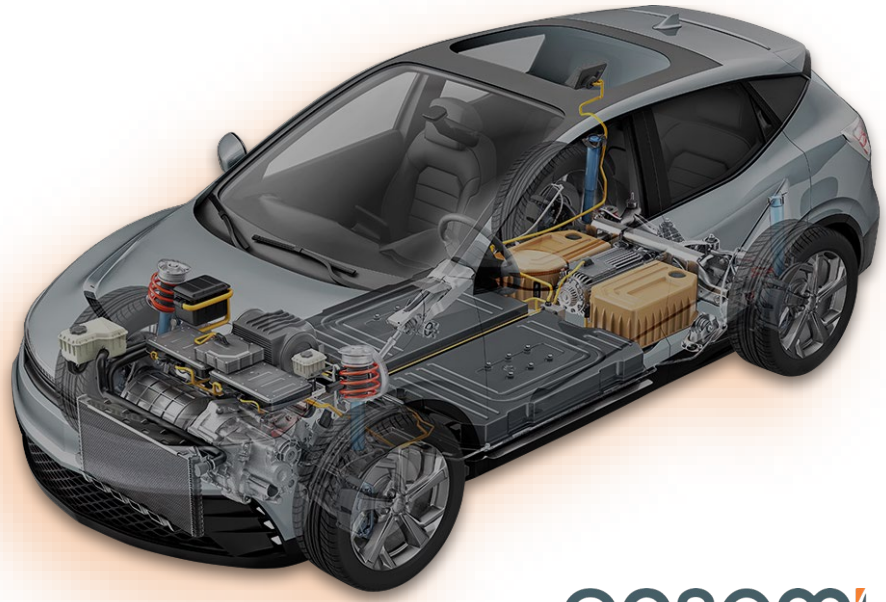
Automotive Solutions

Vehicle Electrification xEV

HEV / PHEV / BEV

- **Traction Inverter**



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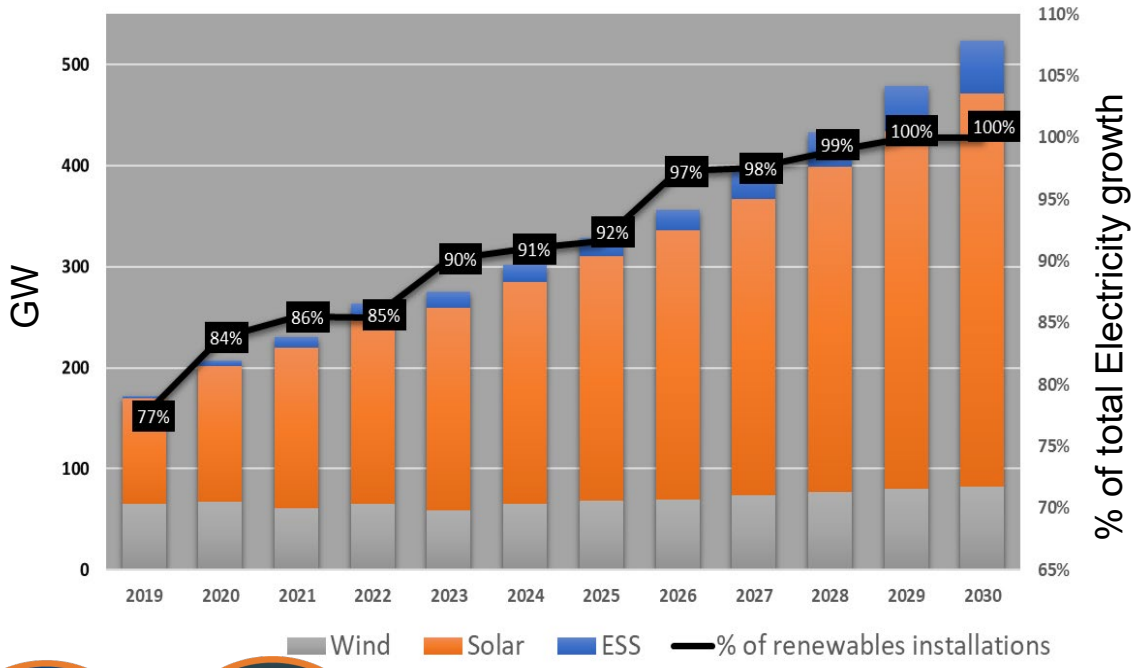
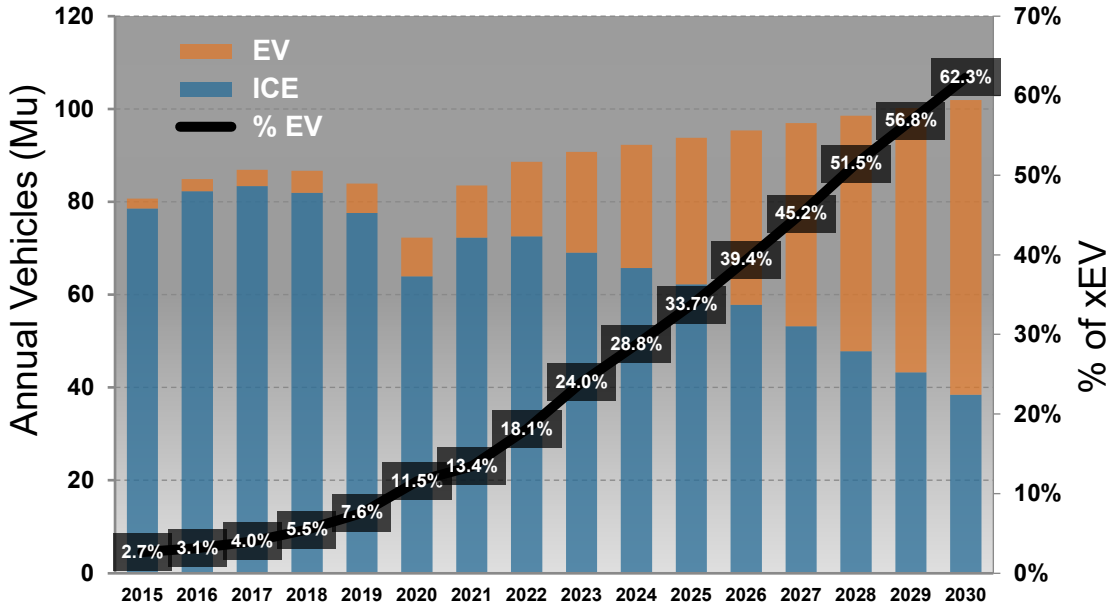
Wide-bandgap will drive the Energy Efficiency Revolution

Renewable Energy Infrastructure Growth



Source: IEA world energy outlook report 2021
IEA renewable energy market update 2021

xEV > 50% of Vehicle Sales in this Decade



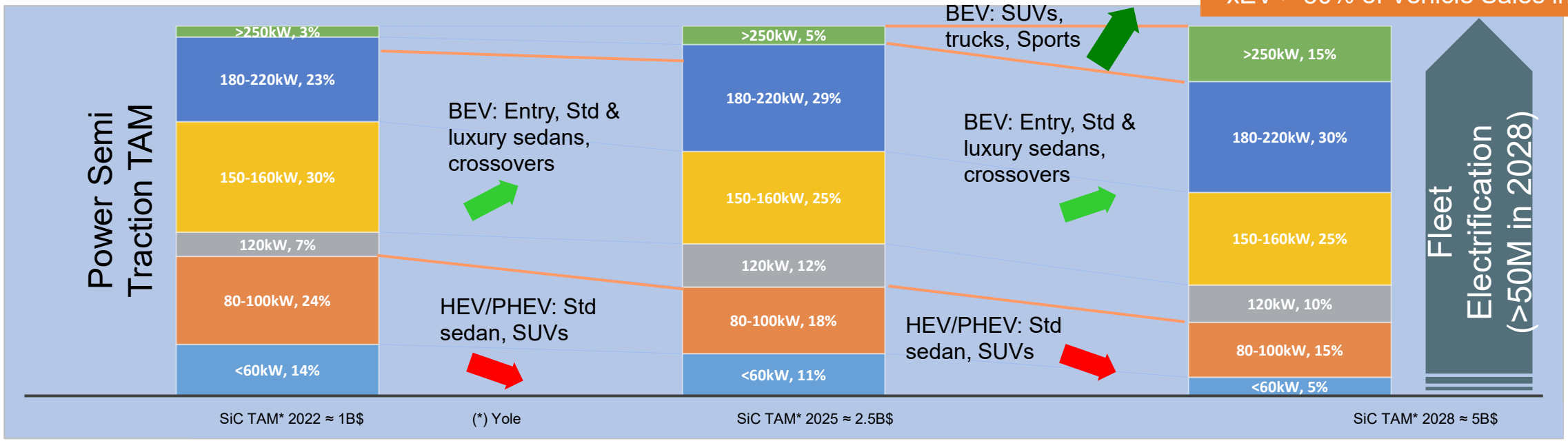
Source: EV/ IC breakdown: Credit Suisse – Mar 26 2021 – Global Semiconductor Sector – Automotive semis – Powering the EV megatrend – Report

Power semiconductors will build the energy network of the 21st century

Market Trend & Power Class Segmentation

- HEV & PHEV market will continue to shrink as OEMs take bolder direct move towards BEV
- Sedans & crossover BEVs will continue to grow & represent primary market
- SUVs, trucks & Sports will see major demand uptick beyond 2025, driving more demand for >250kW electric drives

xEV > 50% of Vehicle Sales in 2028



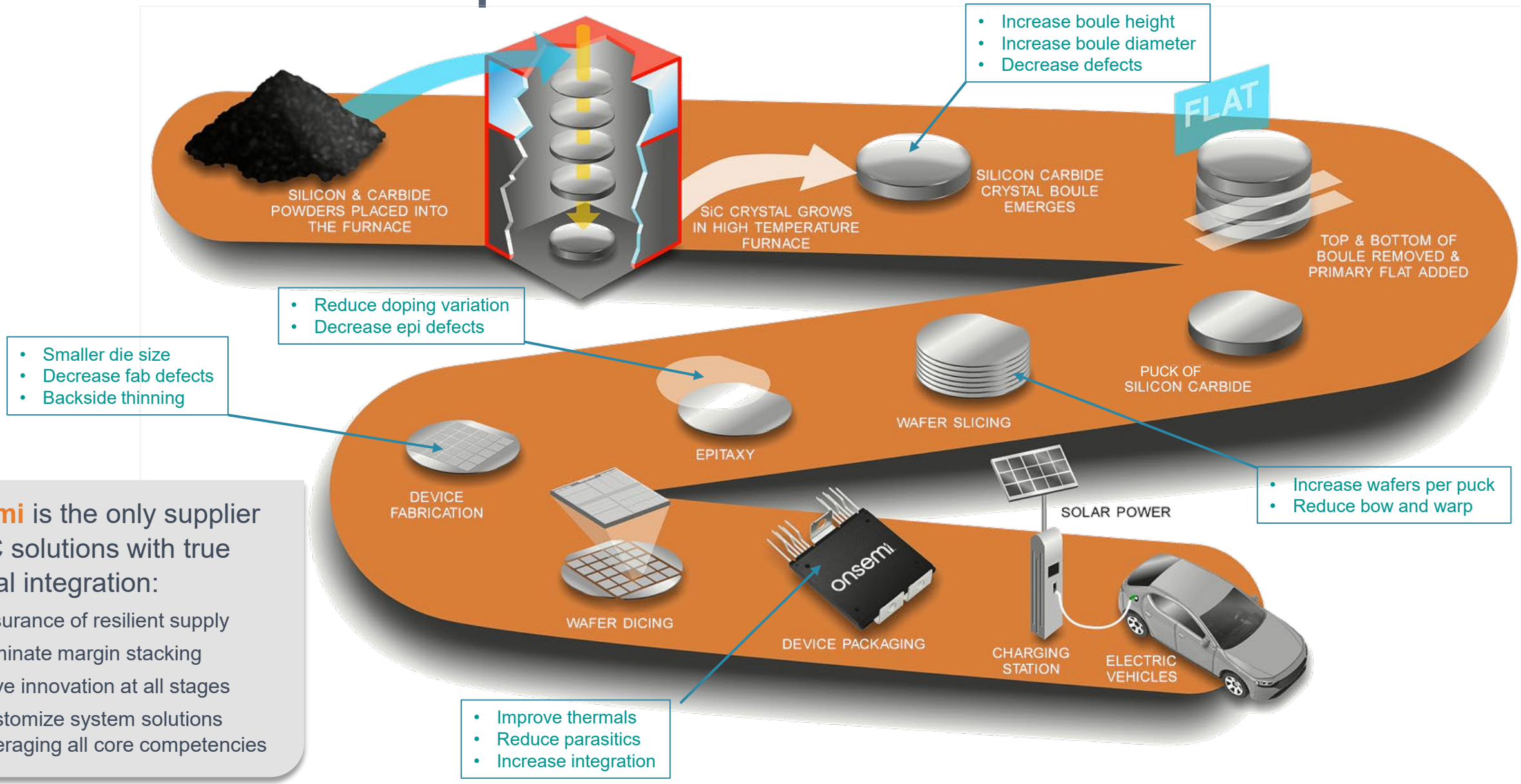
Inverter power	Dominant Vehicle Types (today)
<60kW	HEV & PHEV generators (IGBTs)
80-100kW	HEV & PHEV inverters (IGBTs, but **trending to SiC**)
120kW	**BEV Secondary axle + Small EV's + luxury PHEV (IGBT, but trending to SiC)**
150-160kW	Predominantly IGBTs in BEV today, but **SiC fast growing**
180-220kW	Predominantly SiC in BEV, IGBTs in secondary axle
>250kW	**Trucks, luxury and sport vehicles (SiC)**

- Adoption to SiC for Efficiency and ***longer Range***
- High Voltage Bus for ***fast charging and low distribution losses / smaller cables***
- ***High-reliability*** Packaging
- ***Scalable*** Power for range of vehicles (Roadmap/ASP trend)

onsemi **EliteSiC** Powertrain extends range by 8-12%

Source: EV/ IC breakdown: Credit Suisse – Mar 26 2021 – Global Semiconductor Sector – Automotive semis – Powering the EV megatrend – Report
Source: Yole YINTR22240_Power_SiC_2022_Report

onsemi SiC Leadership: from Powder to Power Modules

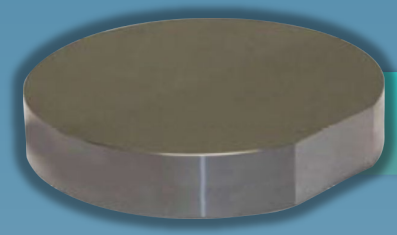


onsemi is the only supplier of SiC solutions with true vertical integration:

- Assurance of resilient supply
- Eliminate margin stacking
- Drive innovation at all stages
- Customize system solutions leveraging all core competencies

SiC Supply Assurance: From Substrate to Modules

SiC Substrates

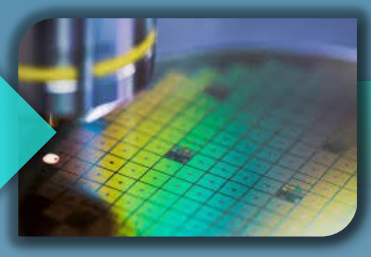


- 150/200mm SiC wafering internal

SiC Epi

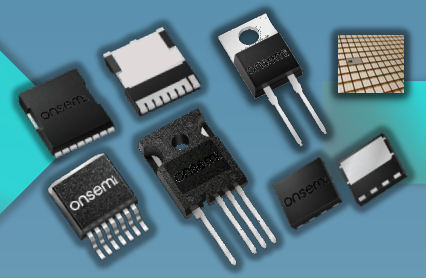
- 150/200mm SiC epi internal

SiC Fab



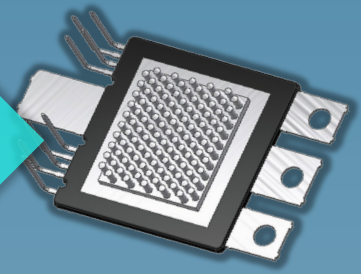
- Fabs ready today for 150mm→200mm migration

SiC Devices / Die



- Broad base of packages
- Die only & metal options
- Auto & Industrial devices

SiC Modules



- Case and transfer molded options
- Full portfolio of half & full bridge modules
- Single & dual cooling, direct & indirect

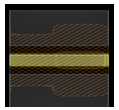
onsemi's end-to-end capabilities drive superior performance and quality

Driving Innovations

SiC Technology

Hex Cell

-16%

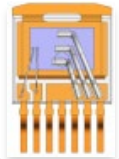


Strip Cell

-25%

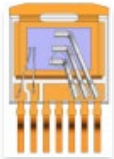
Trench Cell

Inter connect



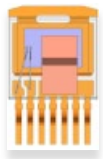
Solder Interconnect

-20%



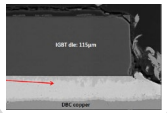
Sintered interconnect

-43%



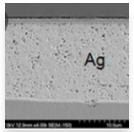
Sintered + Clip

High-Temperature Materials



Solder

-14%

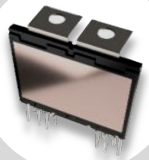


Ag sintering

-12%

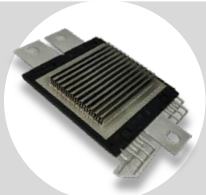
Cu Sintering /Embedding

Innovative Modules



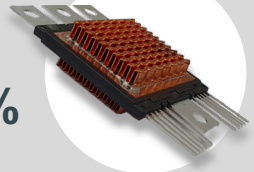
0.15(K/W)

▼ 13%



0.13(K/W)

▼ 15%



0.11(K/W)

Innovative cell and trench structure
→ High efficiency
→ Longer range

Efficient Interconnection
→ Less resistance
→ Lower power loss

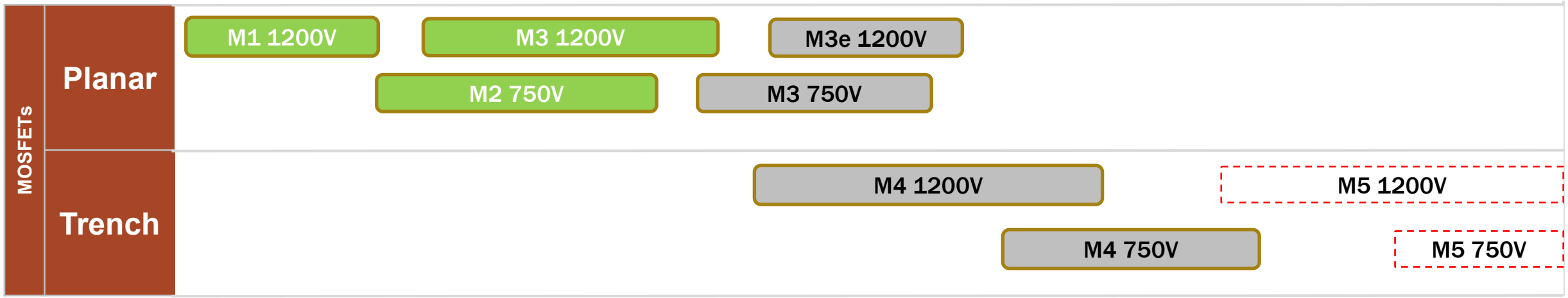
High Performance materials
→ Extended Operation
→ Longer life cycles
→ Higher power density

Scalable packaging and direct cooling
→ High power density
→ Less weight

EliteSiC Technology Roadmap (EV-Traction)

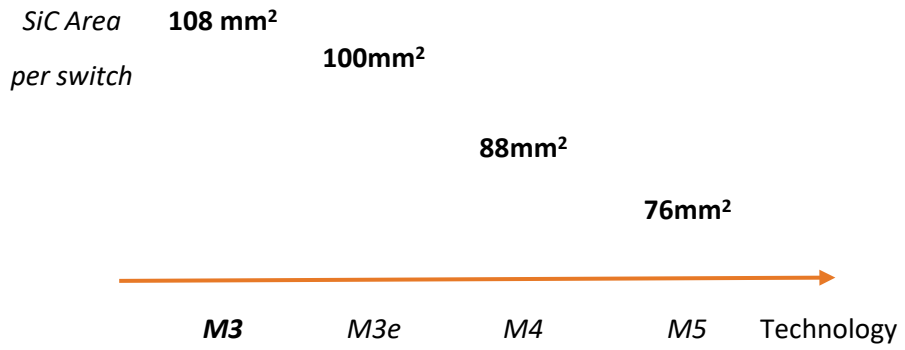
Released

Development



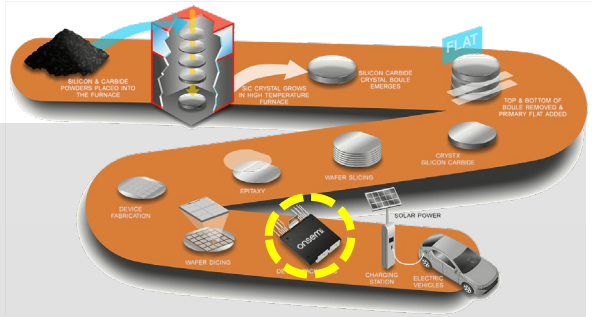
Technology	M3 1200V	M3e 1200V	M4 1200V
Structure	Planar stripe	Planar stripe	Trench stripe
Rsp mΩ*cm² @25C			
Rsp mΩ*cm² @175C			
Gate charge QG (nC/cm²)			
FOM: QG*RSP @25C			
Tsc typ (µs) Vge=18V, Tj=175C, V_{DS}=800V			
Avalanche capability			
Availability Technology			

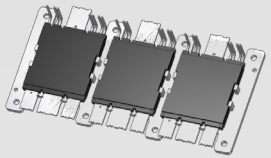
SiC Area reduction for same Irms (Power Module B2S in devlp)



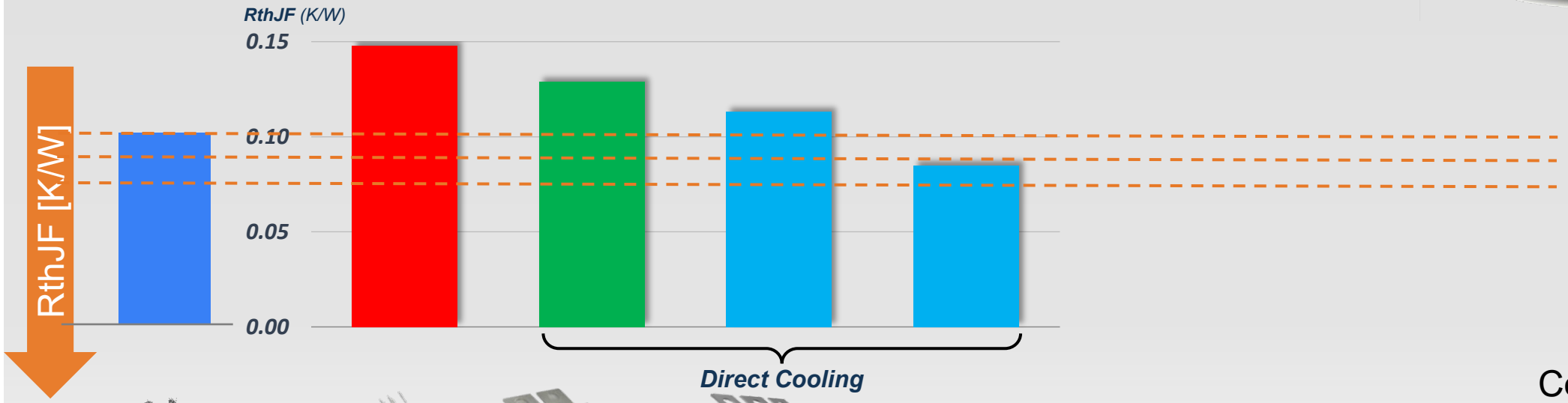
Rsp decreases about 20% with each technology cycle **(<3 years)**

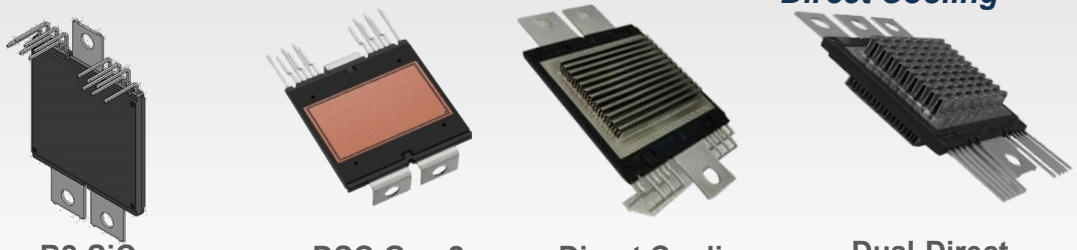
Module Packaging Roadmap (Rth)



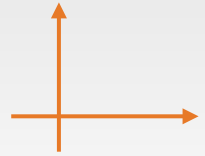


Thermal Resistance Figure of Merit





B2-SiC Indirect Cooling | DSC Gen 2 Indirect Cooling | Direct Cooling | Dual-Direct Cooling | Embedding



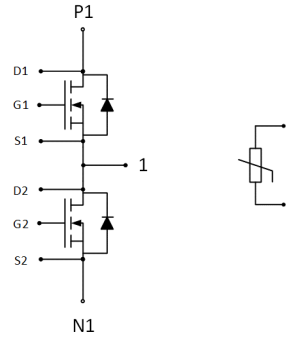
Module packaging innovation is key to deliver higher power

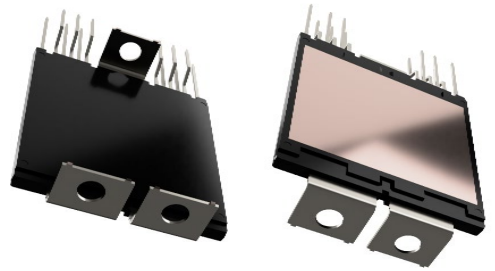
B2 SiC 1200V Product Configurations

Features

- *Low $R_{DS(ON)}$ and Low Switching losses*
- *AlN Substrate for Higher Thermal Performance and Ruggedness*
- *Ag Sintering for Die Attach and Clip to enhance thermal performance and current capability*
- *Ultra low thermal resistance up to $R_{thJ\text{-}F}$<0.11 k/W*
- *Low stray inductance < 7.5 nH*
- *T_{jmax} = 175 °C continuous operation and 200 ºC for 200 hrs operation over life time*

Block Diagram

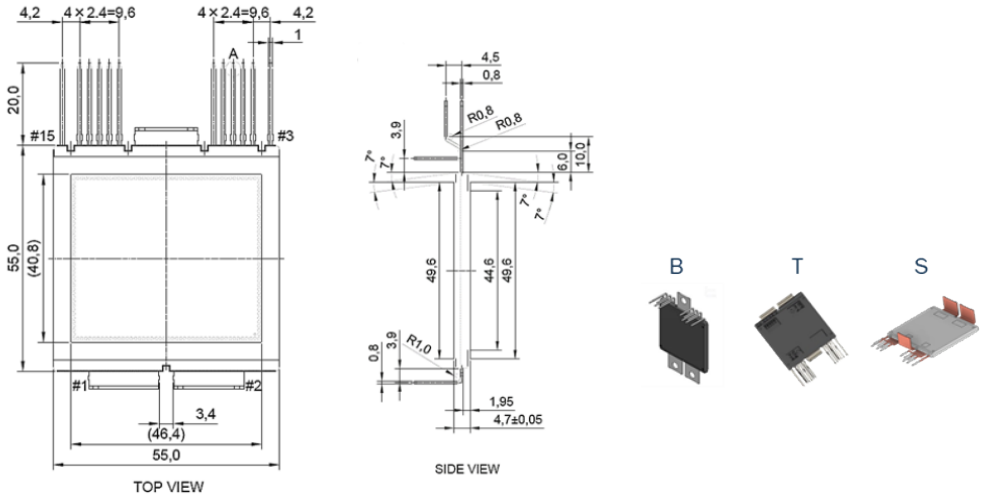




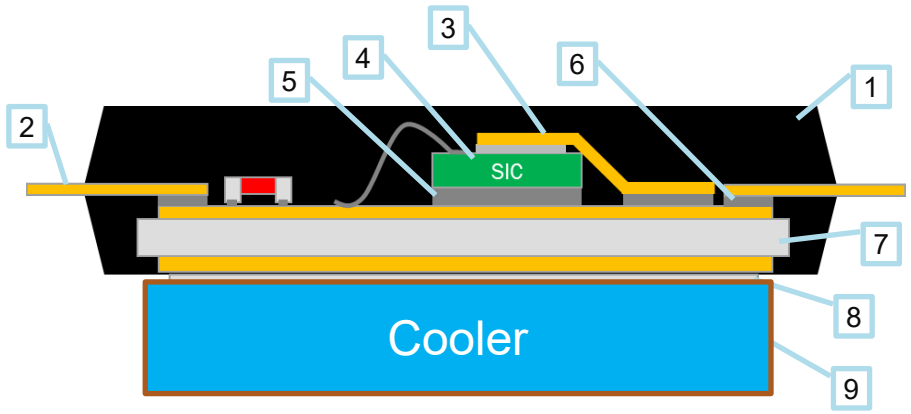
OPN	NVVR26A120M1SP
Inverter power	~250kW
Signal Pins	Standard pin or plated
Voltage Rating	1200 V
DBC Material	H-AlN
Die attach	Sintering technology
#Dies per switch	6 x 36 mm2
R_{DSon} (mOhm) @ 25 ºC	2.6
Terminals	Plated and Standard
Target RTM	Released

Package : 55 mm X 55 mm X 4.8 mm

Package Outline (Units in mm)



Thermal Stack B2-SiC Indirect package

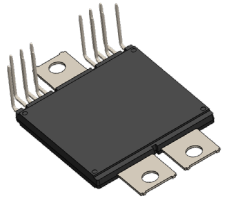


Nr,	Class		Material	Thickness	Thermal conductivity, (W/m°K)	Density, kg/m^3	Specific heat capacity, J/kg.k
1	EMC			NA	0.8	1700	1400
2	Lead Frame		copper	0.8 mm	391	8930	385
3	Clip		TAMAC4	0.5 mm	347.3	8940	381.5
4	Die (M1)		Silicon Carbide	0.2mm	360	3210	690
5	Die adhesive		Ag Sinter	0.025mm	100	3150	900
6	Solder internal		solder	> 0.050mm	67	7400	306
7	DBC	Top/ Bottom conductor	Bottom Cu	0.3mm	395	8933	397
			Top Cu	0.3mm			
		Insulator	Si3N4	0.32mm	80.0 @25°C, Temp. coefficient: -0.147W/mK^2	3300	790
			H-AlN (*)	**0.38mm**	**150@25°C, Temp. coefficient: -0.372W/mK^2**	**3290**	**860**
8	**TiM**		**PTM7000**	**0.05mm (fitting)**	**6.5**	**1700**	**1400**
9	Heatsink -FinPin		AL6061	Thickness 1.5 mm Pin 6 mm	180	2700	963

(*) currently implemented as “premium” approach, to reduce the Rth value. Future roadmap will be focused on Si3N4 standing supply chain and cost reasons

VE-Trac™ B2-SiC Platform Extension

Enhanced Thermals & low Inductance



+30%

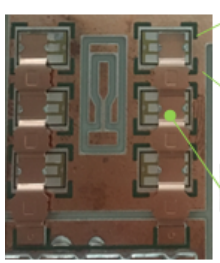
P_{out} & efficiency

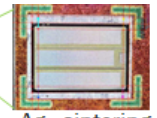
Indirect
Rω=0.13(K/W)
Ls = 7nH

Solderable / Sinterable
Rω<0.10(K/W)
Ls < 5nH

Development

Robust Interconnect Technology





Ag - sintering

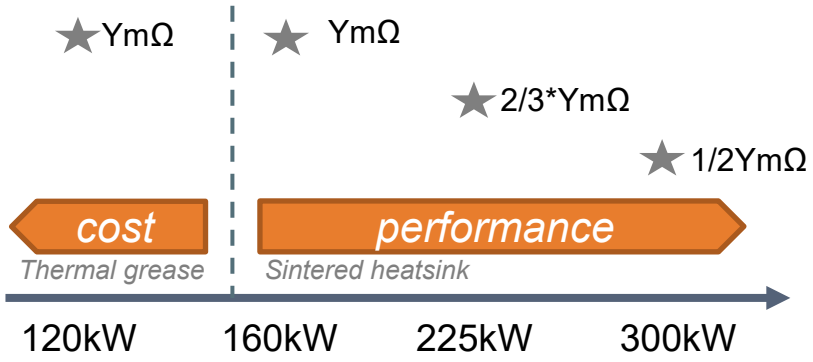
Clip attachment

Reflow oven

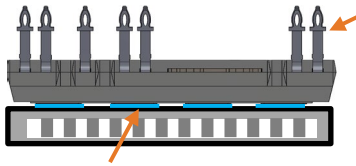
'Press' – pressure and Temperature

- Ag SiC sintering, Si_3N_4 DBC, copper clip for extended reliability with enhanced thermals

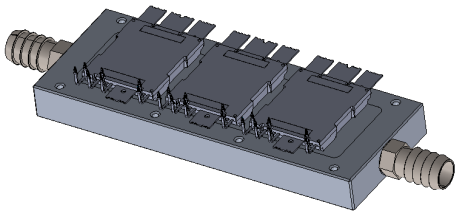
120 – 300kW Scalability



Versatile & Scalable Integration



- Press fit
- Soldering



Sintering = Performance
TIM = Cost
Soldering = Mid-solution

Key Takeaways

- The automotive market **Electrification revolution happening today is hungry of power and efficiency**, at the same time, to enable extra miles at lower cost.
- Onsemi **full vertical Integration of SiC supply chain** grants resilient supply, scalability and cost/quality control
- Technology, Material and packaging **investments for innovation** provide solutions for the most demanding needs of efficiency and performances
- **Wideband Semiconductor and innovative Packaging** need to converge to provide the most thermally enhanced performance to enable and possible cost optimization at system level.

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