Packaging Challenges and Solutions for Silicon Carbide Power Electronics

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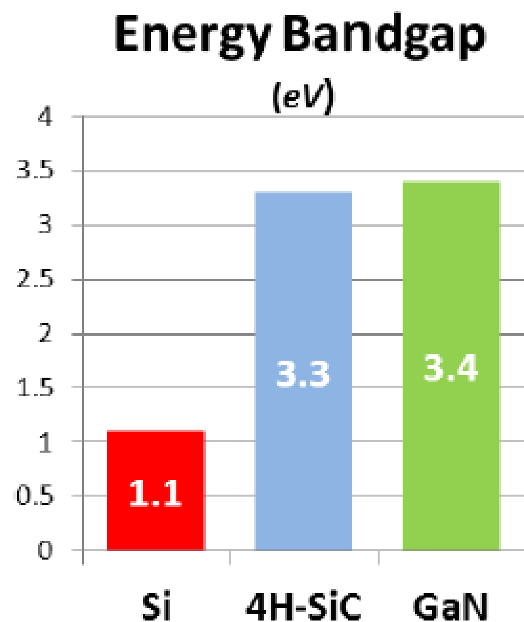
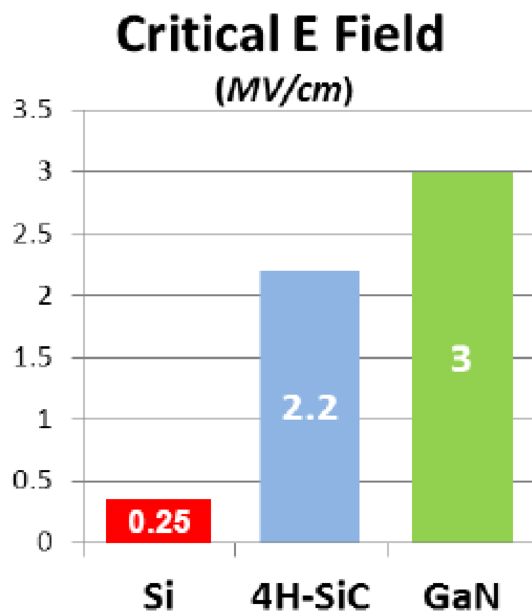
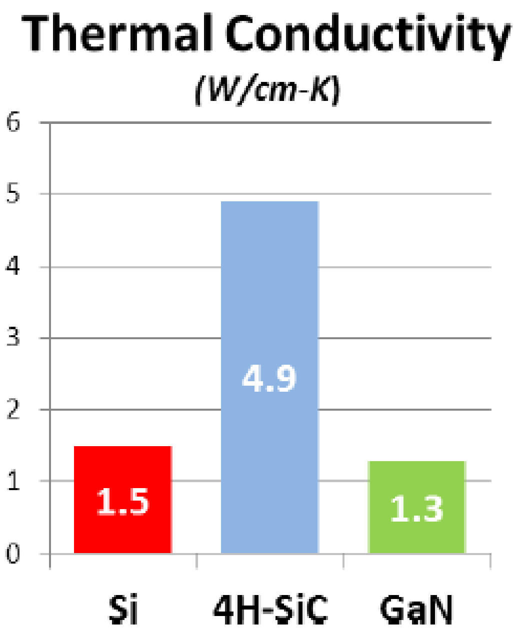
Electronic Components and Technology Conference

Semiconductor Materials for Power Electronic Devices







As Bandgap Increases

- ↓ Leakage Current
- ↑ Operating Temperature
- ↑ Radiation Hardness

Higher Critical E Field

- ↓ On-Resistance
- ↑ Blocking Voltage

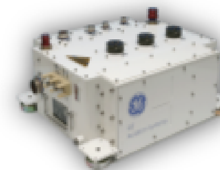
Higher Thermal Conductivity

- ↑ Heat Spreading
- ↑ Power Density

SiC Enables New Product Capabilities

GE SiC MOSFET

1/2	Space & weight, or
2x	Power Density
2x	Reliability
50ºC	Higher temperature capability

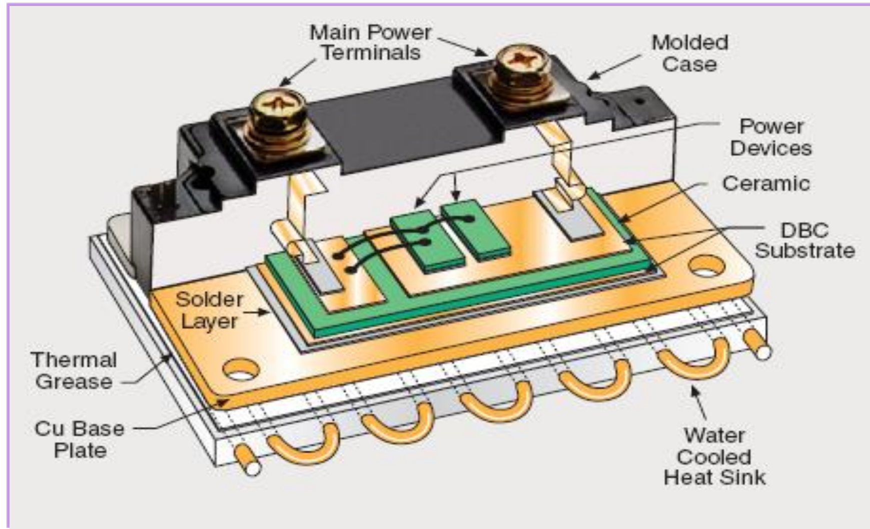

Generation

Conversion

Distribution

Air
Land
Marine

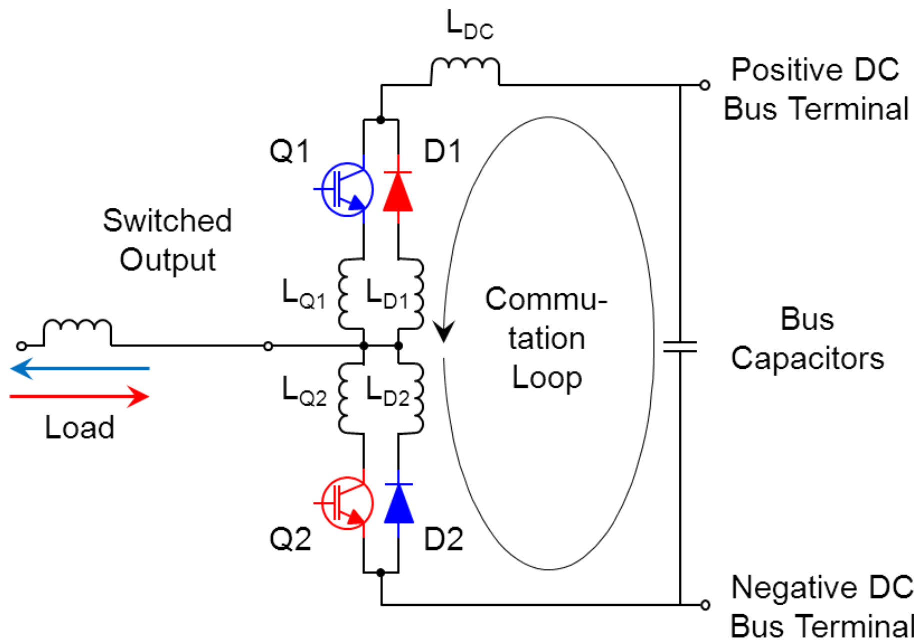
Limitations of Standard Power Module



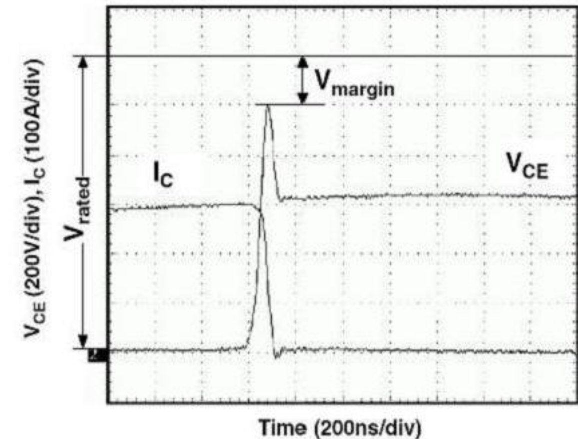
- Electrical limitations
  - Current sharing
  - Package inductance too high
  - Wirebond current handling
- Thermal limitations
  - Baseplate-to-heatsink thermal resistance
  - Low power density (including heatsink)
- SiC module power limitations
  - Yield and cost challenges associated with wirebonding many small SiC devices

Importance of Low Inductance

- Minimize voltage overshoot / derating
- Reduce switching losses, or increase frequency
- Minimize snubber requirements



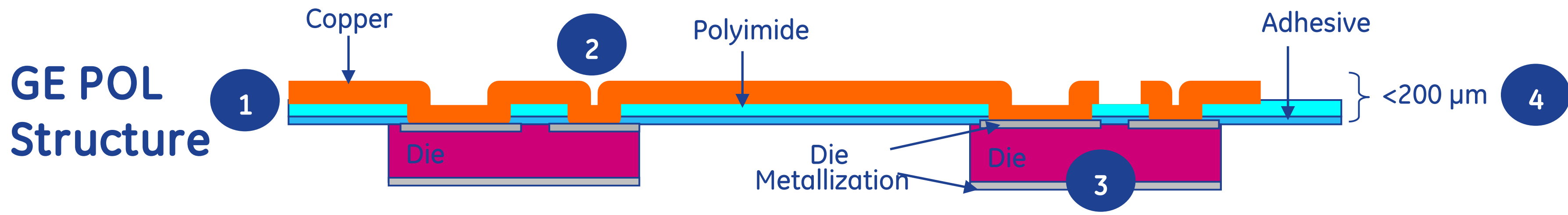
$$V_s = L_{loop} \cdot \frac{\Delta I}{\Delta t_{OFF}}$$



Power OverLay (POL) Interconnect

PWB-like planar interconnect for power packaging

GE POL Structure

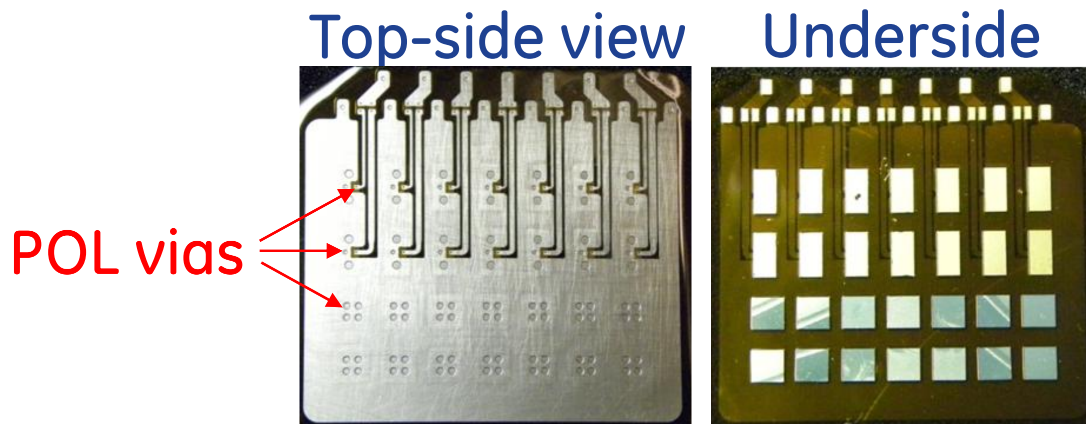


Wirebond Structure

1. **Low & matched parasitics** - Low Inductance, Low Resistance; High current capability : Power Efficiency
2. **Eliminate** wire-bonds and solder-bumps: Power Efficiency & Performance
3. Ability to **array** multiple die: System Cost
4. **Reducing size and weight** while maintaining performance: System Cost

PWB-like Manufacturing Processes

- Thick copper connections
- Litho defined layout
- Laser drilled vias
- Frame based
- Flexible film



Performance Differentiation

	Wirebond	POL	Flip-Chip
Resistance			
Inductance			
Manuf Costs			
HF characteristics			
System Cost			

SiC Power Module –Switching Test

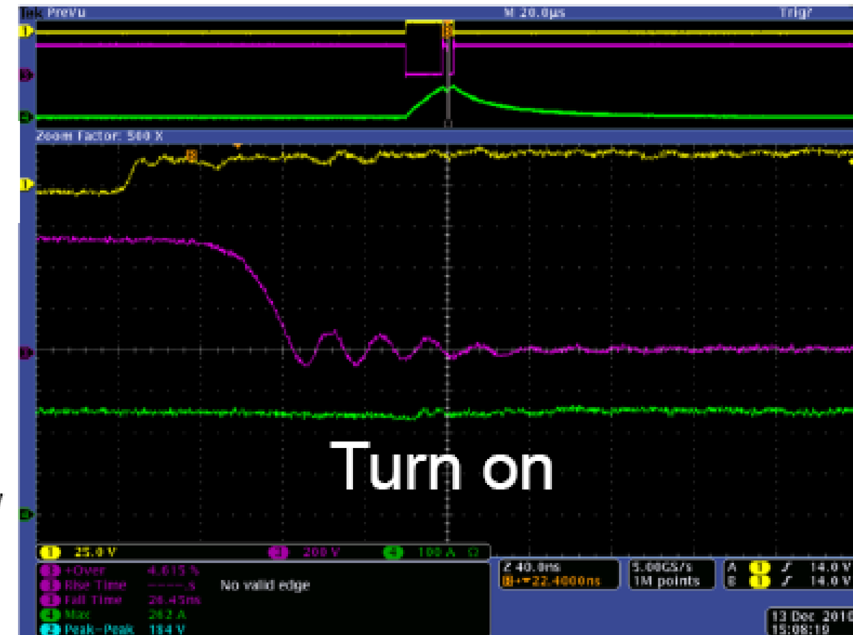
11ns inductive switching at: V_{DS} = 540V, I_D = 300A

Voltage Rise Time 11.2ns, Overshoot 28%

Vgate

Vds 200V/div

Inductor Current 100A/div



Voltage Fall Time 26.4ns

75kW SiC Inverter

Dual function: engine starter + ECS compressor drive

GE SiC MOSFET Modules

+/- 270V$_{DC}$

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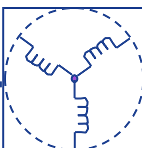
Liquid Cooling

Motor

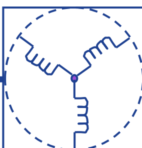


Environmental Control System (ECS)

Aircraft Cabin

Comp-ressor

Starter



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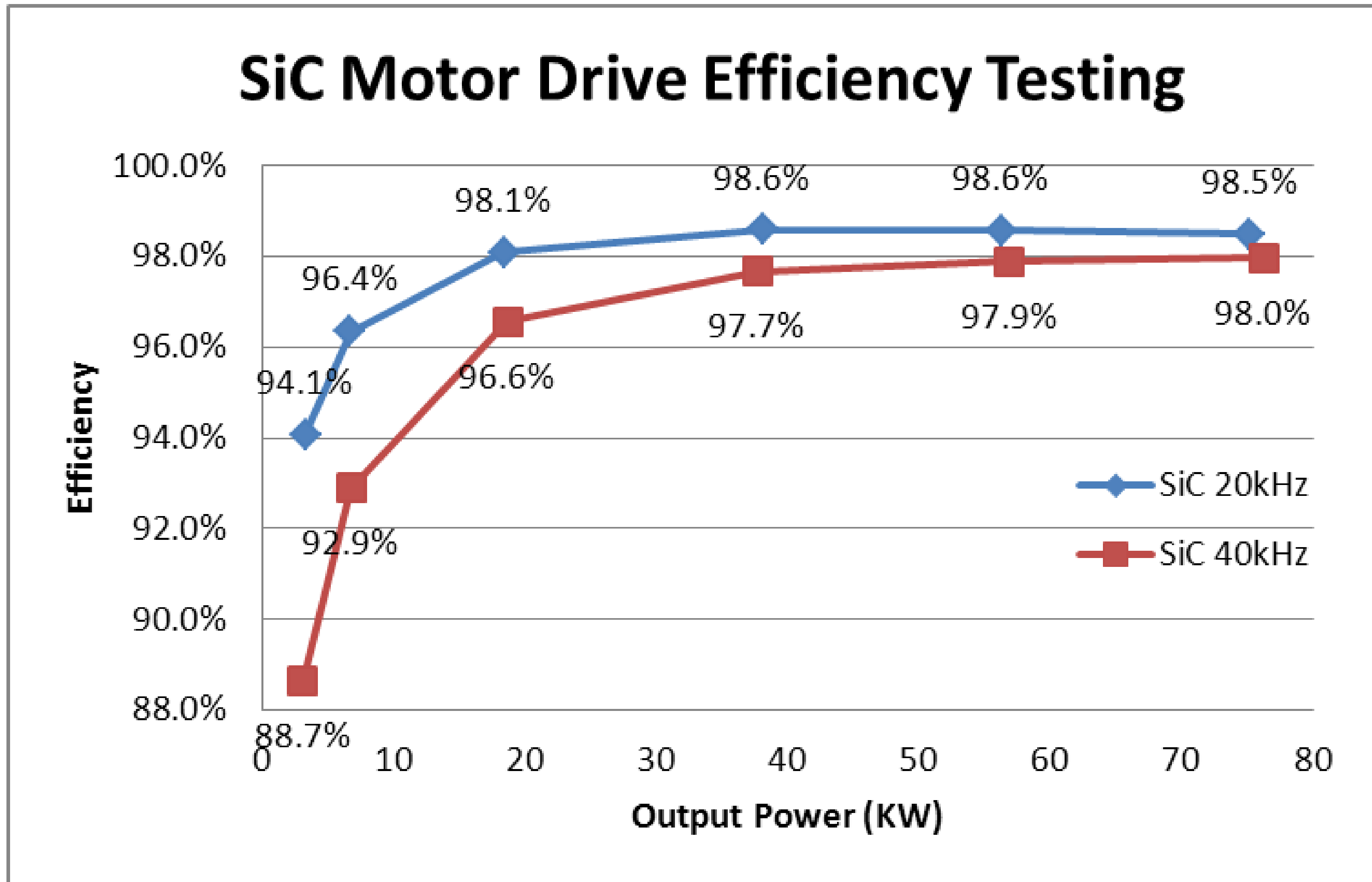
Air
Land
Marine

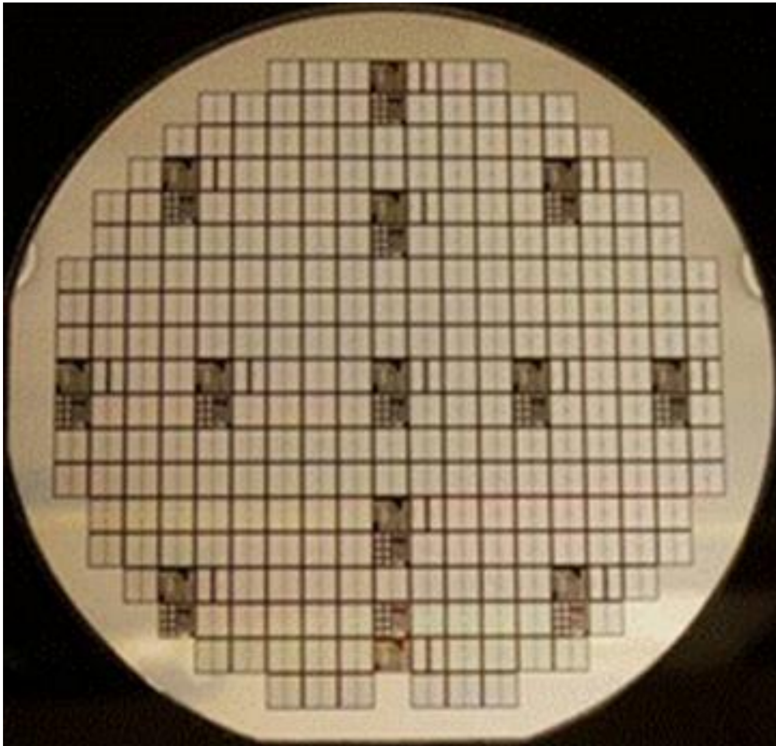
$V_{IN} = +/-270V_{DC}$, $V_{OUT} = 220V_{LN}$, $P_{OUT} = 75kW$, $F_{FUND_MAX} = 1.8kHz$

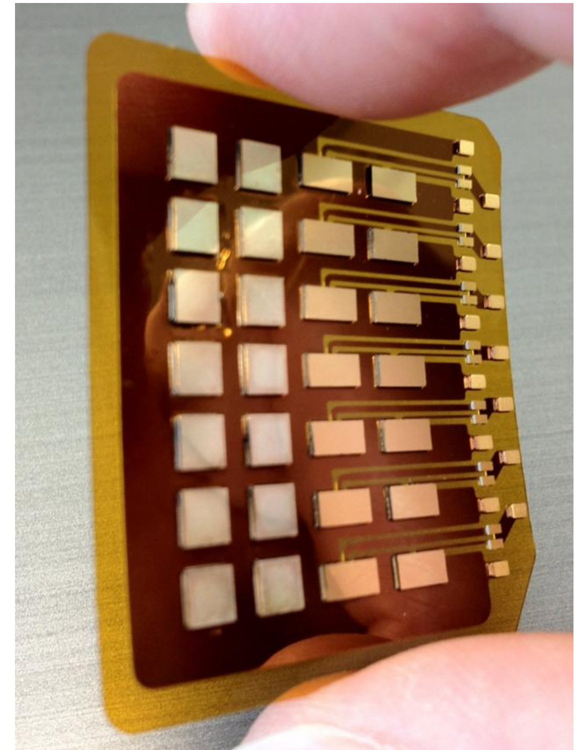
SiC MEA Inverter - Efficiency Results



Summary: GE SiC Development

Realizing the full benefit of SiC power electronics





imagination at work