Silicon Carbide (SiC) Power Electronics

Provide the capability to manufacture affordable silicon carbide (SiC) high-temperature power devices/modules that will enable production of compact power electronics required for advanced mobility, survivability, and lethality systems for Current-Force and Ground Combat Vehicles (GCV).

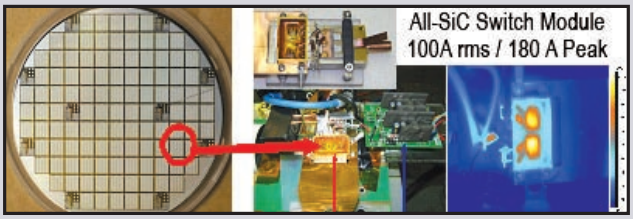
Traction Drive Motor

OBJECTIVE / SOLUTION

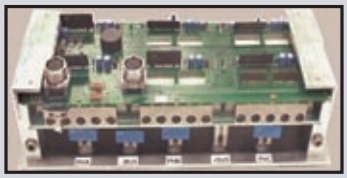
Develop manufacturing technology in parallel with material development for both SiC base material (wafers and epi-layers) as well as SiC devices and modules. It is designed to: (1) increase SiC base material throughput by 3X and scale size to 4" diameter, and (2) increase device fabrication throughput for low-voltage (LV, 1.2kV) diodes and switches and high-voltage (HV, 6 kV) diodes by 3X over baseline. Cost reduction goals from current baseline for final production of SiC devices are from $1.20/A to $0.30/A for LV diodes, and from $5.00/A to $2.50/A for LV switches and from $5.00/A to $1.50/A for HV diodes. Individual SiC die current ratings will range from 50-100A for LV diodes, 5-70A for LV switches, and 25-50A for HV diodes. Base material production, device manufacturing, and packaging technology for high temperature, high power modules are currently at MRL 3/4 and will be matured to MRL 6 or greater. Through coordinated 6.2/6.3 programs, SiC devices/modules will be matured to TRL 5/6 for higher current applications by program end.

ACHIEVEMENTS

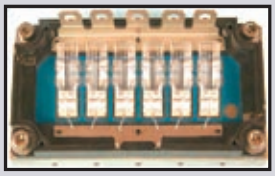
Defects in 100mm wafers have been drastically reduced: median micro-pipe density (MPD) from 50 to <0.8cm-2 and basal plane dislocations (BPD) from 100 to <2cm-2; with an increase in boule length of 1.75 X. 75A and 100A LV and 50A HV power diode as well as 50A LV switch processes were baselined and devices delivered to the Army Research Laboratory (ARL) for inclusion in power circuits. Baselined processes project end-of-program costs to be: $0.40/A (3X reduction) for LV diodes, $2.50/A (2X reduction) for LV switches, and $0.60/A (8X reduction) for HV diodes. 1.2kV/400A, 600A, and 1200A hybrid (Si switch, SiC diode) and 1.2kV/400A and 800A all-SiC (SiC switch, SiC diode) power modules have been implemented using baselined devices. Evaluation of these power modules for high-temperature high-efficiency operation indicates (when performance is compared to all-Si power module operation at 80°C heat sink) power loss for motor control applications can be reduced by: 20-25% with the use of hybrid power modules at 80°C heat sink temperature and 70% with the use of all-SiC power modules at heat sink temperatures up to 100°C.



67A DMOSFET Wafer Chip: 8mm x 7mm Active area: 0.406cm^2



Power Electronics



1200A Single Switch Hybrid Traction Drive Module

BENEFITS

- The use of SiC power electronics will reduce losses and size in power systems by up to 50%; and provide for reliable higher-temperature operation and thermal management systems that are smaller and require less power
- Provides Current-Force and Future combat vehicles with advanced mobility, survivability, and lethality systems. Provides increased thermal margin for 'limp home' capability following battle damage
- Life cycle and logistics costs for vehicle platforms and mobile electric power field generators expected to be significantly reduced via increased conversion energy density and reliability for systems using high-temperature SiC power electronics

STATUS

- 100mm starting material was released for commercial sale in January 2006 and transitioned to commercial diode process in March 2007 and commercial DMOSFET process by end of 2009
- Baseline of next-generation devices has been completed: 1.2kV/100A diodes and 1.2kV/50A switches; current focus is on 1.2 kV switch efficiency/reliability
- Circuit demonstrations are in progress for all-SiC 150kW DC-DC converter and 100-250 kW inverter power modules (including 400 and 800 A dual switch modules) and will be completed by end of the fiscal year

WEAPON SYSTEMS / SECONDARY ITEMS IMPACTED

- Combat vehicle mobility and other power systems
- Power electronics for mobile electric power field generators and platform power conditioning

POTENTIAL COST AVOIDANCE

- Based on Ground Combat Vehicle modernization, the Return on Investment is projected at 5.8:1 with a cost benefit of $134M