Silicon Carbide (SiC) Power Electronics

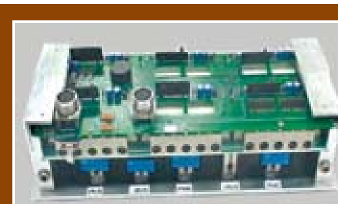
Provide the capability to manufacture affordable silicon carbide (SiC) high-temperature power devices/modules that will enable production of compact power electronics required for advanced mobility, survivability, and lethality systems for Brigade Combat Team platforms.

OBJECTIVE / SOLUTION

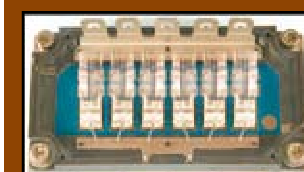
This program will develop manufacturing technology in parallel with material development for both SiC base material (wafers and epi layers) as well as SiC devices and modules. It is designed to: (1) increase SiC base material throughput by 3X and scale size to 4" diameter, and (2) increase device fabrication throughput for low-voltage (LV, 1.2-2 kV) diodes and switches and high-voltage (HV, 4-15 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 $.75/A for LV switches and HV diodes. Individual SiC die current ratings will range from 50-150A for LV diodes, 5-100A for LV switches, 25-100A for HV diodes, and 8-40kA for HV pulse switches. Base material production, device manufacturing, and packaging technology for high temperature, highpower modules are currently at MRL 3/4 and will be matured to MRL 6 or greater. SiC devices/modules are at TRL 5 for lower current applications and at TRL 4 for higher current applications.

ACHIEVEMENTS

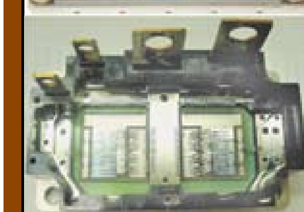
Defects in 100mm wafers have been drastically reduced: median micropipe density (MPD) from 50 to 5cm^{-2} and basal plane dislocations (BPD) from 100 to <30cm^{-2}. 1.2kV, 75A, and 100A LV, as well as 6kV, 50A and 75A HV power diode processes were baselined and devices delivered to the Army Research Laboratory (ARL) for inclusion in power circuits. Baseline of 1.2kV LV diodes projects FY07 cost as $0.45/A (2.7X reduction). Baseline of HV diodes projects FY07 cost at $0.60/A (7.9X reduction). 1.2kV, 400A and 600A (Si switch, SiC diode) power modules have been implemented using baselined devices. Initial evaluation of these hybrid modules at 90° indicates that use of SiC diodes (instead of Si) will reduce power loss by 33% for motor control applications. 1.2kV, 15A cascode static induction transistor (SIT), 50A bipolar junction transistors (BJT), and 20A MOSFET switches were also delivered to ARL for evaluation and inclusion in circuit demonstrations.



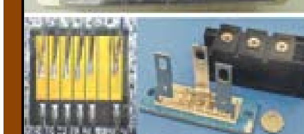
Power Electronics and Motors



900A Hybrid Module (Si Switch-SiC Diode 400kw Traction Drive)



400A Hybrid Module (Si Switch-SiC Diode 120kw DC-DC Converter)



100A All-SiC Module (SiC SIT-SiC 40kw Fan Drive)

BENEFITS

- Overall size and weight of vehicle electrical power systems will be reduced by 50 to 60%.
- Provides hybrid-electric vehicles (HEVs) with advanced mobility, survivability, and lethality systems to meet transportability requirements.

STATUS

- 100mm starting material was released for commercial sale in January 2006.
- Baseline of next-generation devices has begun: 1.2kV/150A and 6.1kV/100A diodes, 1.2kV/1.2kV/20A switches.
- Circuit demonstrations are planned for hybrid 250kW DC-AC inverter and high-power (pulse converter), and all-SiC (50kW DC-AC) power modules.

WEAPON SYSTEMS / SECONDARY ITEMS IMPACTED

- Combat vehicle mobility, survivability (electro-magnetic armor), and lethality (electro-thermal chemical gun, electro-magnetic gun, high power microwaves/directed energy) systems
- Power electronics for mobile electric power field generators and platform power conditioning

POTENTIAL COST AVOIDANCE

- Life cycle and logistics costs for Future Combat Systems (FCS) combat vehicle 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.

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