Extreme-Environment Silicon-Carbide (SiC) Wireless Sensor Suite

For real-time monitoring of nuclear thermal propulsion (NTP) engines

A number of critical telemetry measurements must be monitored under continuous field operation, including temperature data across the reactor chamber and the nozzle, pressure data, neutron flux density, and flow rate of the propellant. Real-time monitoring of these data in nuclear thermal engines would greatly improve operational safety and performance, reduce operational costs, and significantly impact maintenance costs and reliability. Even though some extreme-environment sensors have become available recently, it is still impossible to directly and accurately measure the critical operational parameters of NTP engines due to the lack of extreme-environment electronics for those sensors. Data from extreme-environment sensors is delivered via wire-line to an external actively cooled electronics box, where it is processed. This approach presents significant drawbacks, such as the need for complex shielded wiring harnesses that not only are heavy but also limit sensor location and signal quality (i.e., signal-to-noise ratio). Additionally, these systems suffer from reliability issues due to wiring connections.

In this Phase II project, Arkansas Power Electronics International (APEI), Inc., delivered a set of SiC-based integrated wireless sensor-transmitter suites for extreme-temperature operation (450 °C) in NTP engines. These sensor suites allow for real-time monitoring of critical engine components, reducing the risk of catastrophic failure and decreasing the inherent risk associated with NTP operation. The final wireless sensor systems are fully integrated into an autonomous drop-in solution for advanced sensing systems, including wireless energy harvesting.

Applications

NASA

- Health monitoring systems of NASA space exploration vehicles:
  - Spacecraft
  - Rockets
  - Aircraft

Commercial

- Health monitoring of turbine engines for both military and commercial aircraft:
  - This technology enables nearly continuous onboard situational awareness of the vehicle health state for use by the flight crew, ground crew, and maintenance depot.
- Power generation, including both nuclear power generation and gas turbine power generation:
  - By introducing high-temperature sensors and wireless transmitters into the gas turbine units (specifically within the blades where temperatures range from 450 to 1,200 °C), very accurate turbine conditions can be determined in real time.


NASA photo

Phase II Objectives

- Develop an integrated SiC wireless sensor suite capable of *in situ* measurements of critical characteristics of NTP engine
- Compose SiC wireless sensor suite of:
  - Extreme-environment sensors
  - Dedicated high-temperature (450 °C) SiC electronics that provide power and signal conditioning capabilities as well as radio frequency modulation and wireless data transmission capabilities
  - An onboard energy harvesting system as a power source

Benefits

- Allows for real-time monitoring of critical engine components
- Reduces the risk of catastrophic failure
- Decreases risk associated with NTP operation
- Eliminates (or reduces) the need for thermal shielding and active cooling systems, reducing the size, weight, and the complexity of control systems

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