Gallium Nitride-based 100-Mrad Electronics Technology for Advanced Nuclear Reactor Wireless Communications

PI: M. Nance Ericson – Oak Ridge Natl. Lab.

Collaborators: Siddharth Rajan[1], L. Raymond Cao[1], Kyle Reed[2], Dianne Bull Ezell[2]

[1] The Ohio State University

[2] Oak Ridge National Laboratory

Program: Nuclear Energy Enabling Technologies (NEET) Crosscutting Technology Development (CTD).

NEET- 2. *Wireless Technology for Nuclear Instrumentation and Control Systems.*

ABSTRACT:

The proposed effort will develop, fabricate, and demonstrate a gallium nitride (GaN) HEMT-based radiation hardened wireless sensor communication link for advanced nuclear reactor monitoring. Use of a GaN integrated circuit process will enable both high temperature (>400°C) and total ionizing dose (TID) and neutron fluence (>100 Mrad (GaN); >10^{15} n/cm^2) electronics for advanced reactors. A demonstration system will be designed and fabricated for wireless interfacing with two GaN-based dual sensor transmitters with a viable path forward to increasing the number of sensors per transmitter and transmitters per centralized receiver. Two different wireless communications architectures will be explored – analog frequency modulation and digital modulation with linear block error correction encoding. Irradiation studies will be carried out for gamma (>100 Mrad (GaN)), neutrons (>10^{15} n/cm^2), mixed gamma/neutrons, and elevated temperatures up to 400°C. The sensor platform will wirelessly link to a software defined radio (SDR) receiver for data collection, processing, and networking.

Tasks include GaN FET fabrication, analog and digital circuit blocks design, fabrication and testing, and simulation model refinement. Both analog and digital dual sensor interfacing and transmitting circuit architectures will be designed and simulated using GaN device models. Individual GaN devices and circuit blocks will then be tested then integrated to implement a complete dual sensor interface and wireless communications module. Radiation and temperature tests will be performed at the device and circuit block level and then again following full system integration. A commercial-of-the-shelf software defined radio (SDR) receiver (non rad-hard) will be used for receiving, processing, and networking data from multiple harsh environment wireless dual sensor transmitters. Shielding of critical system components will be investigated for further hardening, and a comparative analysis will be performed on the pre and post temperature and irradiation test data, which will be used for further model optimization.

The expected outcomes of this research are GaN-based sensor and electronics technologies which extend beyond the thermal and radiation limits of Si-based systems to enable sensing and wireless communications electronics systems suitable for integration into reactor facilities (in-vessel and/or near-vessel) that has been advanced to a ≥TRL-4 status.

Deliverables/Outcomes:

The following major deliverables associated with advanced reactors will be provided upon completion of the project:

1. GaN-based device, cell, and circuit fabrication and component SPICE modeling (OSU)
2. Wireless dual sensor transmitter circuit and SDR architectural design and simulation (ORNL)
3. Radiation and temperature evaluation and modeling of the sensors and GaN devices (ORNL, OSU)
4. Analysis of radiation hardening of the system components (sensors, electronics) via shielding (OSU)
5. A fabricated and tested GaN-based dual sensor interface and wireless electronics system (ORNL)
6. Radiation dose and temp. testing of the combined sensing/communications system (ORNL, OSU)
7. Comparative analysis of pre and post irradiation and temperature data to show effects on GaN (ORNL, OSU).