A Semiconductor Particle Detector Based on Work Function Modulation

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A small, inexpensive, scalable new mechanism for robust and reliable radiation detection

Inventors at Georgia Tech have developed a semiconductor work function reference circuit for radiation detection. This detector features circuitry formed by a modified bandgap reference circuit, where the original bandgap reference circuit is designed such that its temperature-independent output is the bandgap energy of the semiconductor used in the circuit itself. Gallium nitride (chosen for its semiconducting and piezoelectric behaviors) is layered with aluminum gallium nitride (GaN/AlGaN) to form GaN high electron mobility transistor (HEMT) devices that are configured to behave as Schottky diodes as the detecting components.

Unlike traditional solid-state particle detectors (SSDs) that measure energy of incident particles through the creation of electron-hole pairs, Georgia Tech's device detects particles by recording transient fluctuations in the Schottky barrier height—dependent on the work function—of the detecting components that occur due to particle interactions in the material. Notably, the device's capability to measure transient fluctuations and use those transient signatures as a mechanism of particle detection offers the potential for more robust radiation detection that is not available in silicon or germanium SSDs.

In particular, the mechanism should result in higher efficiencies and the ability to detect particles of lower energy than is typically possible in other SSDs. In addition, whereas typical semiconductor device behavior is heavily temperature dependent, the circuit used here produces a fixed output voltage independent of temperature variations, supply variations, and loading. This lends confidence that transient fluctuations observed are not due to temperature variations, thus leading to more trusted radiation detection.

Summary Bullets

- **Small:** Can be used as a portable radiation detector
- **Versatile:** Can be implemented in current particle detectors for accuracy testing and experimental verification
- **Scalable:** Offers the potential to be used in creating an array of devices for implementation in larger research experiments

Solution Advantages

- **Small:** Can be used as a portable radiation detector

- **Versatile:** Can be implemented in current particle detectors for accuracy testing and experimental verification
- **Scalable:** Offers the potential to be used in creating an array of devices for implementation in larger research experiments
- **Economical:** Features inexpensive and discrete components, avoiding long integrated circuit fabrication processes
- **Streamlined:** Uses gallium nitride or III-nitride materials, thereby eliminating the need for an absorption layer
- **Robust:** Monitors in-situ transient response, discriminates between different particle types and angles of incidence, detects particles of lower energy than other SSDs, and could provide source location discrimination when used in an array

Potential Commercial Applications

- Small modular reactors for nuclear power to monitor for safety concerns
- Dosimeters for protection of radiation workers
- Urban radiation detection networks
- Complementary/Parallel use with optical radiation detectors
- Nuclear nonproliferation treaty verification (in conjunction with other detectors)
- Nuclear medicine to monitor radiation doses during treatment

Background and More Information

Broad uses for nuclear power make overcoming the historically conspicuous safety issues surrounding its use a priority. Not only is it an economically viable option for the U.S. power grid, but it also has the potential to play an important role in a low-carbon future. In 2014, the United Nations Intergovernmental Panel on Climate Change reported that nuclear power has the lowest life-cycle carbon dioxide emissions of any electric-generating technology with the exception of wind power.

However, one of the primary impediments to building nuclear energy capacity in the U.S. is the large capital costs associated with large-scale nuclear power plant construction. Small modular reactors (SMRs) represent a less capital-intensive approach to increasing the nuclear portion of our low-carbon energy output. The instrumentation and control (I&C) that supports SMRs is critical to improving and optimizing their performance, thus increasing their efficiency and profitability. I&C is also important to the operational safety of the reactor. SSDs aim to enhance the I&C of SMRs so that the chance of accidents, such as Fukushima, Three Mile Island, or Chernobyl, is dramatically diminished. Unfortunately current SSDs are hampered by size and the need for multiple stages, so development of a particle detector like Georgia Tech’s device that can measure energy and momentum is a significant contribution to particle physics.

Inventors

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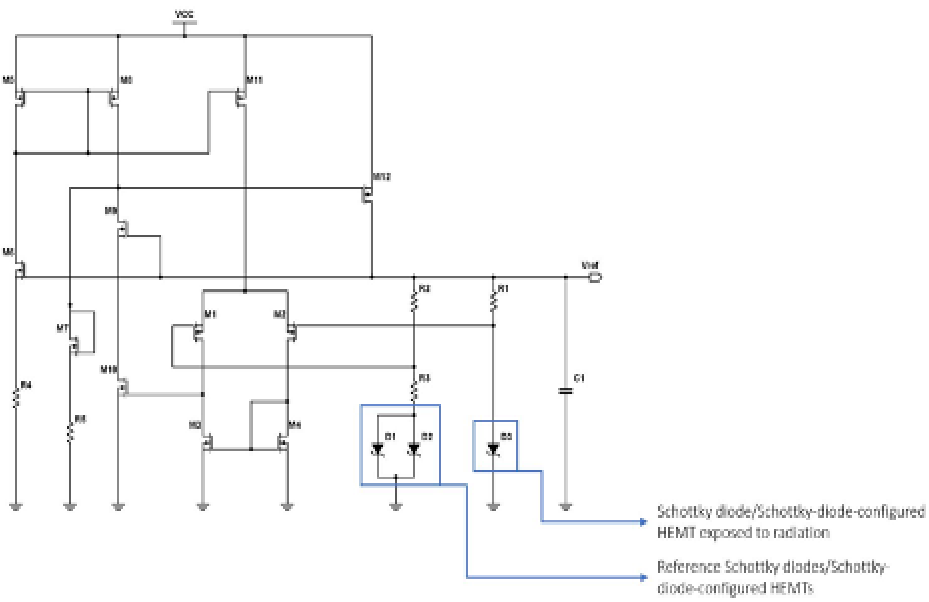
IP Status

<p>Patent application has been filed</p>: US62/984505

Publications

Semiconductor Particle Detector Based on Work Function Modulation, American Physical Society March 2020 Meeting G10: Detectors, Sensors, and Transducers - Presented March 3, 2020

Images



This figure represents the bandgap reference circuit for Georgia Tech’s semiconductor particle detector.

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