Sandia National Laboratories

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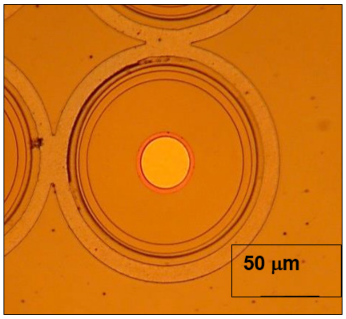
ULTRA-WIDE BANDGAP POWER ELECTRONICS

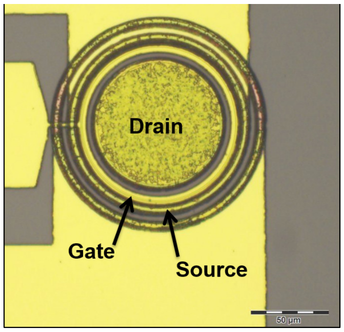
Patents Pending

Technology Readiness Level: 4-5

Basic technological components are integrated to establish that the pieces will work together

Power electronics used for routing, control, and conversion of electrical power traditionally utilize silicon semiconductors. These systems tend to be bulky, require active cooling, and are inadequate for applications demanding portable power conversion requirements (e.g., distributed power generation, vehicles, and satellites). Researchers at Sandia have grown ultra-wide bandgap (UWBG) AlGaN materials and from them fabricated an $Al_{0.3}Ga_{0.7}N$ PiN diode with a breakdown voltage > 1600 V and an $AlN/Al_{0.85}Ga_{0.15}N$ high electron mobility transistor (HEMT) with a breakdown voltage > 800 V. These are seminal, world-record devices that can be used as building blocks to make next-generation power electronics for transferring electrical power from a source to a load and converting voltages, currents, and frequencies.





$AlN/Al_{0.85}Ga_{0.7}N$ PiN diode (above), $AlN/Al_{0.85}Ga_{0.15}N$ HEMT (below)

The UWBG power semiconductor devices developed by our team will eventually miniaturize and vastly improve the performance and efficiency of power systems for electrical power grids, electric vehicles, computer power supplies, and motors. The device performance, defined by breakdown voltage and electrical conductivity, is ultimately determined by the bandgap of the material utilized. Compared with Si and even with commercial state-of-the-art wide-bandgap (WBG) materials, UWBG AlGaN materials (with bandgaps larger than SiC and GaN) have the potential to dramatically improve device performance and operate at even higher voltages, frequencies, and temperatures.

Different materials for power semiconductor devices are compared through a Figure of Merit (FOM) which quantifies the trade-off between electrical conductivity and breakdown voltage. The FOM scales with the seventh power of the bandgap. Thus, realizing devices in wide bandgap GaN rather than Si, improves FOM by 870X. Another factor of 37X is gained in FOM, by moving to ultra-wide bandgap AlN from wide bandgap GaN.

Because these power electronic devices could enable 10X faster switching speeds than the current state-of-the-art, passive components in the power circuits can be smaller, and thus virtually every electrical power conversion system can be miniaturized commensurately. At the same time, the devices can function at higher operating temperatures without active cooling and in high radiation environments such as outer space. Just as silicon integrated circuits put supercomputer capabilities into everyone's hands, UWBG devices can enable order-of-magnitude improvements in size, weight, and power for portable electrical power on demand.

TECHNOLOGICAL BENEFITS

- Improved size, weight, and power
- 10x faster switching speeds
- Improved efficiency
- Suitable for use in harsh environments (high radiation, high temperature)

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