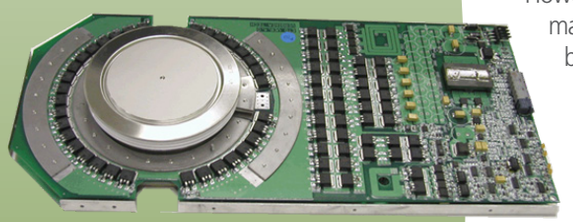
Sandia National Laboratories

Energy, Climate & Infrastructure Security

Deploy Clean Energy

Wide-Bandgap Power Electronics

Gaining an understanding of the degradation mechanisms of SiC and GaN is critical due to the high cost of these emerging devices compared to Si devices, especially in cost-sensitive applications such as renewable energy generation and energy storage.



Wide-bandgap semiconductor materials such as SiC and GaN have the potential to revolutionize the field of power electronics and Sandia National Laboratories is well-suited to understand both the performance and reliability in wide-bandgap power electronics.

Understanding Material Properties

SiC and GaN have material properties that make them well suited for demanding power environments where switching devices are subjected to high voltage, current, and temperature. These properties, such as their wide bandgaps, high breakdown voltage, and high thermal conductivity suggest they could be used to fabricate devices that would be competitive with well-established Si technology. However, the long-term reliability of these materials must be studied before that becomes a reality.

Assessing Performance and Reliability

Sandia National Laboratories is well-suited to understand both performance and reliability in wide-bandgap power electronics. Sandia's Microsystems Engineering and Sciences Applications (MESA) facility houses experts in both Si and compound semiconductor growth and processing, as well as experts in material and device characterization and reliability. A well-established solid-state lighting program has studied the epitaxial growth of GaN by MOCVD for nearly a decade, and associated electrical and optical characterization labs exist to ascertain the physics of the materials and devices. Additionally, Sandia possesses highly regarded reliability and failure analysis capabilities that have long supported Sandia's CMOS process. Sandia's uniquely broad expertise, ranging from materials science all the way up to grid-level power systems, ensures that the fundamental understanding gained is utilized to improve power distribution for the benefit of the nation.

Understanding Defects

In order to deploy robust next-generation power conversion systems, it is necessary to understand the fundamental physical factors limiting semiconductor switch performance and reliability, since these switches are the heart of the power conversion system. In collaboration with industry and university partners, Sandia is studying the properties of both bulk and interface defects in SiC that could affect the properties of both field-effect and bipolar devices based on this material. In field-effect devices such as power MOSFETs, bulk and interface defects associated with the gate oxide of the transistor may lead to shifts in its current-voltage characteristics, which can ultimately lead to reduced system efficiency or even catastrophic failure.

Sandia is also studying the properties of defects in GaN High-Electron Mobility Transistors (HEMTs). Combining expertise in areas including electrical device characterization, numerical modeling, optical spectroscopy, and atomic-force microscopy, the properties of surface and bulk defects in high-voltage HEMTs are being elucidated. Stress factors such as gate and drain voltage, which would be experienced by the HEMT in a working circuit, have been demonstrated to result in reduced performance and hence reduced system efficiency. The knowledge gained during performance and reliability characterization is utilized to improve the material growth and device fabrication processes.

Commercialization Path

Sandia looks forward to contracting with companies and research institutions to assist them with testing their ideas for new novel technologies. Sandia may utilize its broad expertise to assist industry in solving fundamental science questions related to the performance and reliability of emerging power electronics devices. In addition, Sandia seeks partnerships to jointly explore new technologies by making proposals to DOE or other funding agencies.

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U.S. DEPARTMENT OF ENERGY

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