SAND2026-18792M

MARKET SHEET

Hafnia Gate Dielectrics for Energy Conversion

Sandia National Laboratories

Hafnia gate dielectrics for energy conversion offer a novel solution for enhanced performance in wide bandgap semiconductor device applications today and beyond

Patent pending

Technology Readiness Level (TRL) 5

Business Problem

The electrical grid is facing increasing pressure due to the rapid growth of artificial intelligence and data centers. Additionally, there is a growing global demand for efficient energy technologies. Traditional semiconductor materials struggle to meet the high-performance requirements of power devices, leading to energy losses and inefficiencies. As industries seek to enhance energy management and conversion, there is a critical need for advanced materials that can operate effectively in high-current and high-voltage applications.

Customer Need

With over $2 trillion of electricity processed annually through the U.S. grid, there is a need for advanced power semiconductor technologies to enhance energy management and conversion. Even a one percent reduction in transmission and distribution losses could save between $500 million and $1 billion each year. Industries require reliable and efficient power semiconductor devices to manage energy effectively, particularly in demanding environments such as transportation, data centers, and the electrical grid. Customers are actively seeking solutions that not only improve performance but also ensure long-term reliability, addressing the critical challenges posed by increasing energy demands.

Sandia Approach

Researchers at Sandia National Laboratories have developed the first commercially available hafnia (HfO_2) gate dielectric specifically designed for wide bandgap (WBG) semiconductors. This material has a high permittivity of approximately 22. It is produced using a novel atomic-layer deposition (ALD) process that effectively eliminates interfacial oxide impurities. This ensures compatibility with WBG power devices, enhancing their operational efficiency and paving the way for advancements in energy management technologies. By addressing the limitations of traditional materials, this hafnia gate dielectric innovation represents a significant step forward in the development of reliable and efficient power semiconductor solutions.

Competitive Advantage

Hafnia gate dielectrics offer significant advantages over traditional silicon dioxide (SiO_2) gate dielectrics by serving as a direct replacement that operates under the same conditions while delivering superior performance. This compatibility allows manufacturers to adopt advanced materials without extensive redesign, facilitating a seamless transition to hafnia technology. As the first commercially available hafnia gate dielectric for WBG semiconductors, this innovative solution is ready for immediate manufacturing. Its introduction is expected to redefine industry standards and accelerate the shift toward more efficient and reliable energy solutions, unlocking new application areas and driving innovation in energy systems.

Technical Benefits

- **High Permittivity:** This innovation enhances capacitance for faster switching speeds and improved signal integrity.
- **Improved Performance:** HfO_2 can boost device performance by 50%, increasing dies per wafer and reducing costs.
- **Enhanced Reliability:** Hafnia offers greater lifetime and robustness with lower stress than SiO_2, ensuring stability.
- **Increased Mobility:** The atomic-layer deposition process enhances channel mobility tenfold, improving efficiency.
- **Lower Resistance:** High permittivity and improved mobility reduce channel resistance by a factor of 25, lowering power consumption.
- **Cost Efficiency:** Performance improvements can double yield and cut manufacturing costs by 50%.
- **Compatibility:** Functions under the same conditions as SiO_2, enabling a smooth transition for manufacturers.

Industries & Applications

- **Transportation**
- **Electrical Grid**
- **Data Centers**
- **Satellite Technology**

Awards and Recognition

This innovation won an R&D 100 Award in 2025, which honors the year's 100 most innovative technologies and products.

Next Steps

Sandia is seeking partners to develop and commercialize this technology. For more information, please contact Sandia National Laboratories' Licensing and Technology Transfer office.

Contact Us

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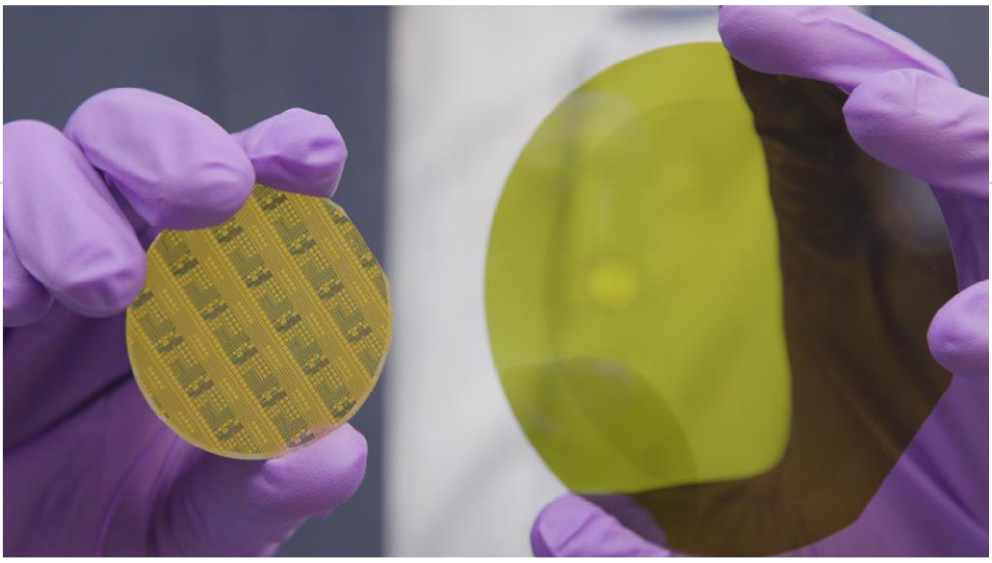
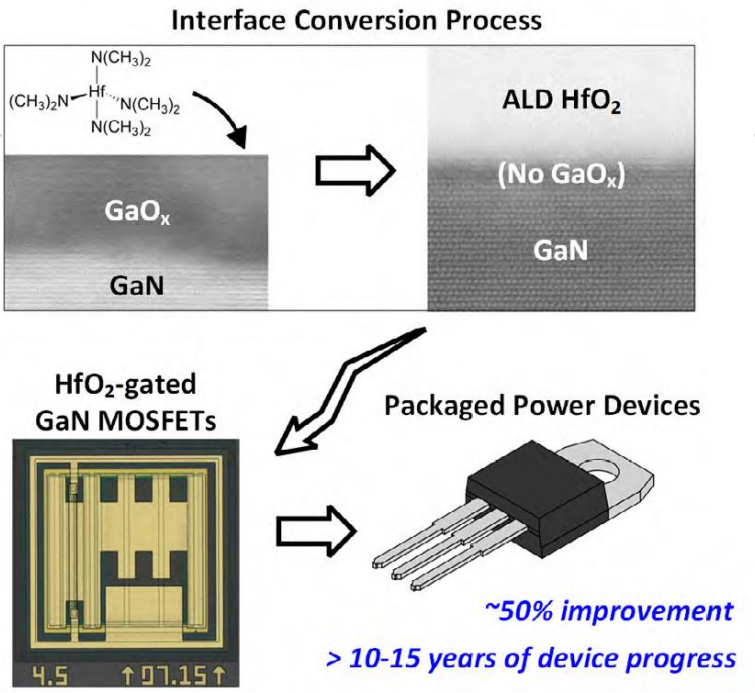
Technical Figures



Product demonstrator [left] showing record setting hafnia-gated MOSFETs on a 2" gallium nitride substrate and a sample film of hafnia on 4" silicon carbide [right].



Interface conversion process for $Hf O_2$ gate dielectrics and integration into power devices.

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