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Gallium oxide on silicon for power electronics

Ultra-wide-bandgap gallium oxide, grown on standard silicon wafers: a low-cost, scalable route to the high-voltage power devices that AI data centres and spacecraft now need.

An ultra-wide-bandgap silicon-compatible semiconductor material for companies building high-voltage power conversion hardware, above all for AI data centres and spacecraft.

Gallium oxide offers the best high-voltage performance of any manufacturable power semiconductor, but until now it could only be grown on small, costly specialist substrates. This technology grows it on standard silicon wafers, so it can be made at scale, at low cost, on existing foundry equipment in the semiconductor industry.

Background

By 2030, more than 80% of the world's electricity will pass through power electronics, and around a tenth of it is lost as heat on the way. AI is making this acute. A high-end AI server rack drew about 100 kW in 2024 and is now heading beyond 1 MW, which is pushing the industry to move rack power distribution to 800 V and above.

This forces a shift away from conventional silicon devices for AI power, which are at their physical limit at these voltages. Silicon carbide and gallium nitride perform well and are in volume production, but are already maturing toward their own physical limitations.

Gallium oxide is the next step. Its ultra-wide bandgap gives it a theoretical power figure of merit roughly ten times that of silicon carbide, meaning leaner devices, lower resistance and less waste heat. To date its problem has been

Reference number: DIX-12318-25

crystal growth in making the devices, which has been constrained to industry non-standard wafer materials which are small, expensive, and poor at conducting heat away from the device.

Researchers in the Department of Materials Science and Metallurgy at the University of Cambridge have developed a proprietary process for growing device-quality gallium oxide semiconductor material directly onto standard silicon wafers, removing the substrate barrier that has limited the material to date and rapidly accelerating the time-to-market for this revolutionary material.

Technology overview

A proprietary process produces device-quality, single-phase gallium oxide crystal layers on industry-standard commodity silicon wafers. Putting these two materials together has previously failed on three fronts at once, thermal, chemical and mechanical, and this approach answers all three. Heat is carried away where on other substrates it was trapped.

The process carefully controls chemical mixing of the silicon and gallium oxide layers to produce sharp, best-in-class layer interface control. And the finished wafers handle like ordinary silicon.

The resulting material shows electron mobility and high-voltage breakdown among the best in class. The process has been demonstrated on 100 mm silicon wafers using industry-standard semiconductor equipment, and working vertical diode devices have been made.

Everything downstream of the growth step, the wafers, the tools and the processing, is standard industry kit. This is a materials epitaxy technology, ready to be integrated into a vertical process flow from raw material through to finished products. Patent pending.

Benefits

- Low cost and scalable: standard silicon wafers in place of small, expensive specialist substrates, processed on standard semiconductor tooling, demonstrated at 100 mm with a clear route to larger wafers
- Best in class: electron mobility and high-voltage breakdown among the best reported for gallium oxide
- Efficient at high voltage: an ultra-wide bandgap blocks more volts per micron, giving thinner, lower-resistance, lower-loss devices with simplified cooling requirements
- Runs cooler: heat dissipation addressable through silicon compatibility
- Ready to integrate: processing that drops into a standard device process flow, on wafers that handle like ordinary silicon in existing fabs and packaging lines

- Robust: high radiation tolerance and wide temperature stability, opening up new markets for power electronics

Applications

- AI data centre power, including the move to 800 V rack distribution and beyond for fast-growing compute loads
- Space and satellite power, where radiation tolerance, temperature stability and low mass are essential
- Transport electrification, including high-power vehicle charging and rail traction
- Renewable energy, grid infrastructure and offshore wind transmission
- High-voltage power conversion generally, wherever silicon devices are now the efficiency bottleneck

Opportunity

The inventors are keen to speak with potential partners, licensees and investors.