The electronic transistor you've been waiting for

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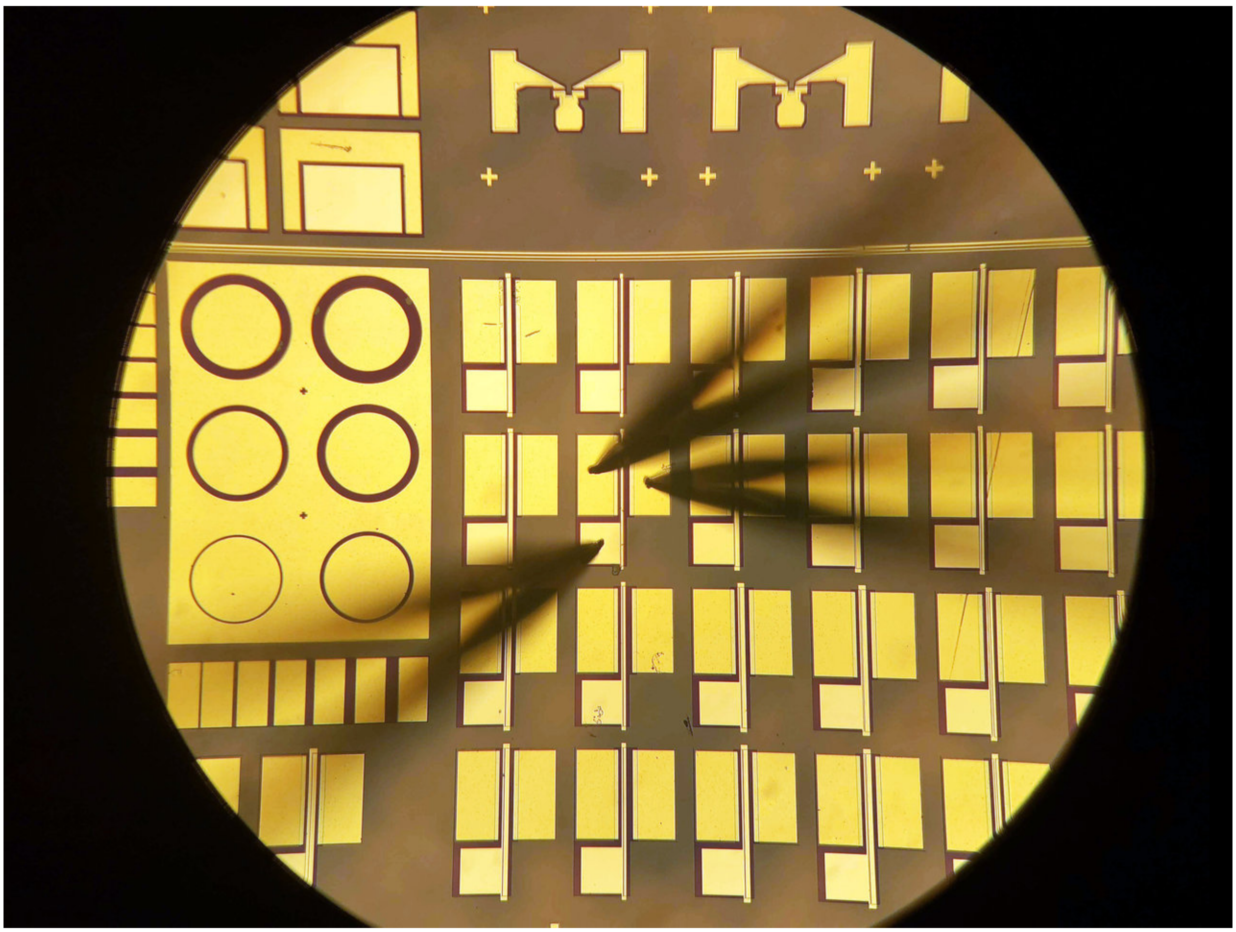

Credit: University at Buffalo An optical microscope image of an array of the transistor. The three dark arrows are the needle probes contacting the terminals of the transistor for electrical measurement. Credit: Ke Zeng, University at Buffalo

How do you pack more power into an electric car?

The answer may be electronic transistors made of gallium oxide, which could enable automakers to boost energy output while keeping vehicles lightweight and streamlined in design.

A recent advancement—reported in the September issue of the journal *IEEE Electron Device Letters*—illustrates how this evolving technology could play a key role improving electric vehicles, solar power and other forms of renewable energy.

"To advance these technologies, we need new electrical components with greater and more efficient power-handling capabilities," says the study's lead author Uttam Singisetti, Ph.D., associate professor of electrical engineering in UB's School of Engineering and Applied Sciences. "Gallium oxide opens new possibilities that we cannot achieve with existing semiconductors."

The most widely used semiconducting material is silicon. For years, scientists have relied upon it to manipulate greater amounts of power in electronic devices. But scientists are running out of ways to maximize silicon as semiconductor, which is why they're exploring other materials such as silicon carbide, gallium nitride and gallium oxide.

While gallium oxide has poor thermal conductivity, its bandgap (about 4.8 electron volts) exceeds that of silicon carbide (about 3.4 electron volts), gallium nitride (about 3.3 electron volts) and silicon (1.1 electron volts).

Bandgap measures how much energy is required to jolt an electron into a conducting state. Systems made with high-bandgap material can be thinner, lighter and handle more power than systems consisting of materials with lower bandgaps. Also, high bandgap makes it possible to operate these systems at higher temperatures, reducing the need for bulky cooling systems.

Singisetti and his students (Ke Zeng and Abhishek Vaidya) fabricated a metal-oxide-semiconductor field-effect transistor (MOSFET) made of gallium oxide that's 5 micrometers wide. A sheet of paper is about 100 micrometers wide.

The transistor has a breakdown voltage of 1,850 volts, which more than doubles the record for a gallium oxide semiconductor, the researchers say. Breakdown voltage is the amount of electricity required to transform a material (in this case, gallium oxide) from an insulator to a conductor. The higher the breakdown voltage, the more power the device can handle.

Because of the transistor's relatively large size, it's not ideal for smartphones and other small gadgets, Singisetti says. But it could be useful for regulating energy flow in large-scale operations such as power plants that harvest solar and wind energy, as well as electric vehicles including cars, trains and aircraft.

"We've been boosting the power-handling capabilities of transistors by adding more silicon. Unfortunately, that adds more weight, which decreases the efficiency of these devices," Singisetti says. "Gallium oxide may allow us to reach, and eventually exceed, silicon-based devices while using less materials. That could lead to lighter and more fuel-efficient electric vehicles."

For that to happen, however, a few challenges must be addressed, he says. In particular, gallium oxide-based systems must be designed in ways to overcome the materials' low thermal conductivity.

More information: Ke Zeng et al. 1.85 kV Breakdown Voltage in

Lateral Field-Plated Ga2O3 MOSFETs, *IEEE Electron Device Letters* (2018). DOI: 10.1109/LED.2018.2859049

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