Scientists see defects in potential new semiconductor

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A research team has reported seeing, for the first time, atomic scale defects that dictate the properties of a new and powerful semiconductor.

The study, published earlier this month in the journal *Physical Review X*, shows a fundamental aspect of how the semiconductor, beta gallium oxide, controls electricity.

"Our job is to try to identify why this material, called beta gallium oxide, acts the way it acts at the fundamental level," said Jared Johnson, lead author of the study and a graduate research associate at The Ohio State University Center for Electron Microscopy and Analysis. "It is important to know why this material has the properties it has, and how it acts as a semiconductor, and we wanted to look at it at the atomic level—to see what we could learn."

Scientists have known about beta gallium oxide for about 50 years, but only in the last several years has it become an intriguing option for engineers looking to build more reliable, more efficient high-powered technologies. The material is especially well-suited for devices used in extreme conditions, such as in the defense industry. The team has been studying beta gallium oxide for its potential to provide high-density power.

For this study, the CEMAS team, overseen by Jinwoo Hwang, assistant professor of materials science and engineering, examined beta gallium oxide under a powerful electron microscope, to see the way the material's atoms interacted. What they saw confirmed a theory first hypothesized about a decade ago by theorists: Beta gallium oxide has a form of imperfection in its structure, something the team refers to as "point defects," which are unlike any defects previously seen in other materials.

Those defects matter: For example, they could be places where electricity could be lost in transit among electrons. With proper manipulation, the defects can also provide opportunities for unprecedented control of the material's properties. But understanding the defects must come before we learn how to control them.

"It is very meaningful that we could actually directly observe these point defects, these abnormalities within the crystal lattice," Johnson said. "And these point defects, these oddballs within the lattice structure, lower the energy stability of the structure."

A lower energy stability means that the material might have some flaws that need addressing in order to conduct electricity efficiently, Johnson said, but they don't mean beta gallium oxide would not necessarily be a good semiconductor. The defects can in fact behave favorably to conduct electricity—if scientists can control them.

"This material has very good properties for those high-powered technologies," he said. "But it is important that we're seeing this on the fundamental level—we're almost understanding the science behind this material and how it works, because this defect, these abnormalities, could affect the way it functions as a semiconductor."

More information: Jared M. Johnson et al. Unusual Formation of Point-Defect Complexes in the Ultrawide-Band-Gap Semiconductor β−Ga2O3, *Physical Review X* (2019). DOI: 10.1103/PhysRevX.9.041027

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