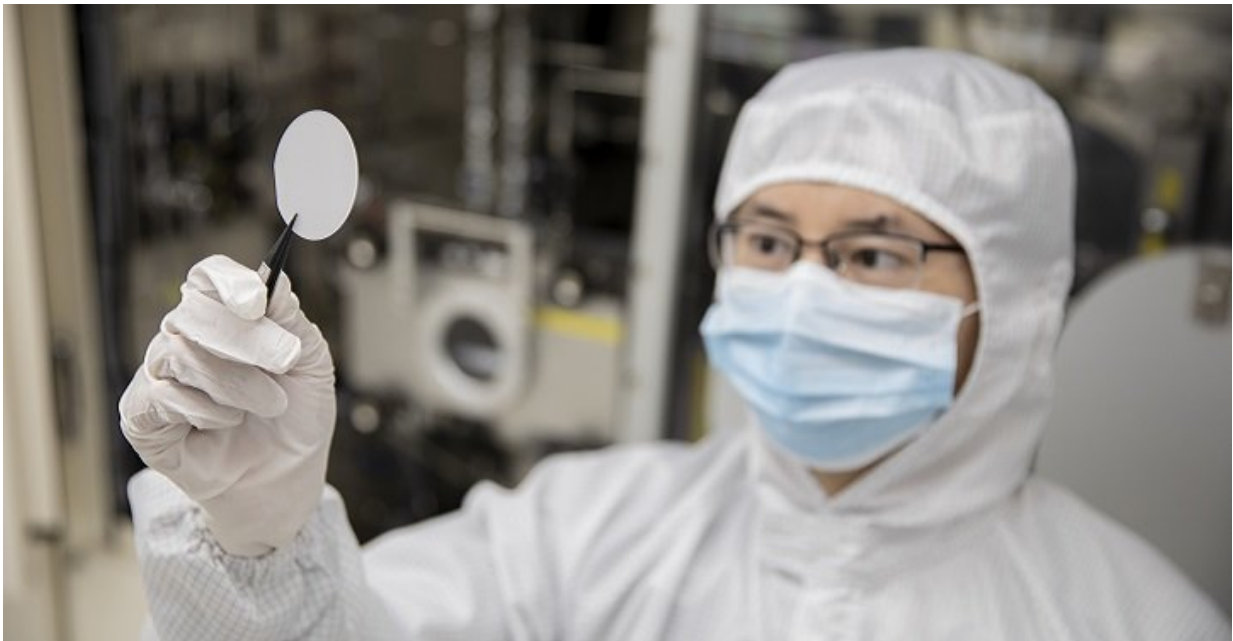


# Controlling the crystal structure of gallium oxide

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Working in a clean suit in the lab, Dr. Sun holds up a gallium-oxide template.  
Credit: KAUST

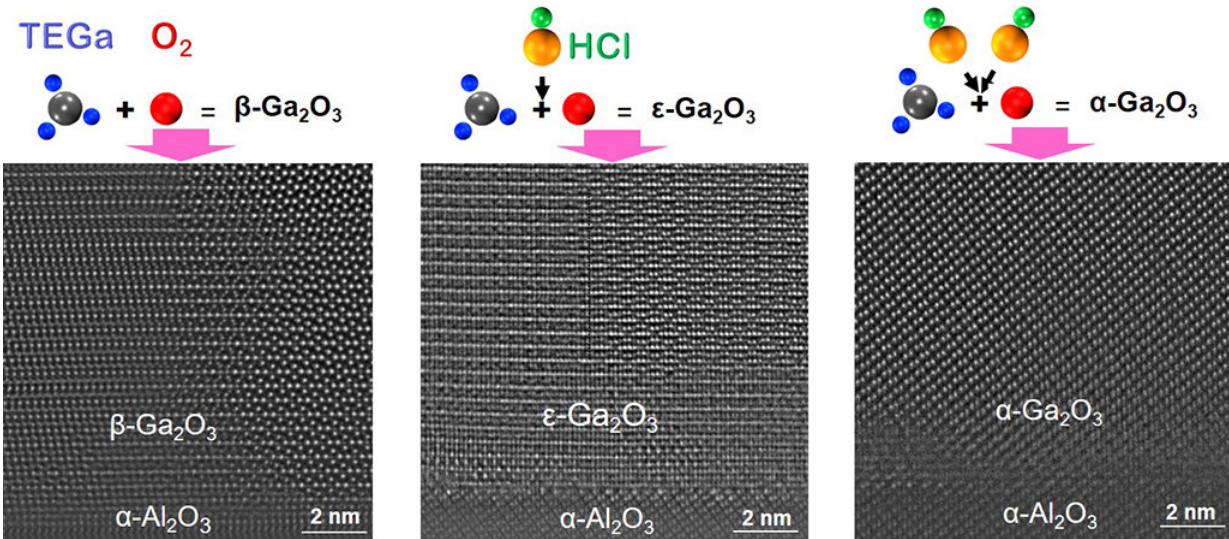
A simple method that uses hydrogen chloride can better control the crystal structure of a common semiconductor and shows promise for novel high-powered electronic applications.

The electronic components used in computers and mobile devices operate at relatively lower power. But high-power applications, such as

controlling electrical power grids, require alternative materials that can cope with much higher voltages. For example, an insulating material begins to conduct electricity when the field is high enough, an effect known as electrical breakdown. For this reason, [power electronics](#) often use nitride-based semiconductors, such as [gallium](#) nitride, which have a very high breakdown field and can be epitaxially grown to create multilayered semiconductors.

However, ever-increasing energy demands and the desire to make electricity distribution more efficient requires even more electrically robust materials. Gallium [oxide](#) ( $\text{Ga}_2\text{O}_3$ ) has a theoretical breakdown field more than twice that of gallium-nitride alloys and so has emerged as an exciting candidate for this function. The latest challenge however is a simple way to deposit high-quality gallium oxide on the substrates commonly used for power electronics, such as sapphire.

Haiding Sun, Xiaohang Li, and co-workers from KAUST worked with industry partners Structured Materials Industries, Inc. in the U.S. to demonstrate a relatively simple method to control the [crystal structure](#) of gallium oxides on a sapphire substrate using a technology known as metalorganic chemical vapor deposition (MOCVD). "We were able to control the growth by changing just one parameter: the flow rate of [hydrogen chloride](#) in the chamber," explains Sun. "This is the first time that hydrogen chloride has been used during oxide growth in an MOCVD reactor."



Different polymorphs of gallium oxide can be grown in a MOCVD chamber by controlling the flow of hydrogen chloride. Credit: American Chemical Society

The atoms in gallium oxide can be arranged in a number of different forms known as polymorphs.  $\beta$ - $\text{Ga}_2\text{O}_3$  is the most stable polymorph but is difficult to grow on substrates of other materials.  $\epsilon$ - $\text{Ga}_2\text{O}_3$  has been grown on sapphire but its growth rate has been difficult to control.

Led by Li, Sun and the team show that they can achieve precise control of the growth rate by adding hydrogen chloride gas to triethylgallium and oxygen in their MOCVD chamber. When they added the hydrogen chloride at a low flow rate,  $\beta$ - $\text{Ga}_2\text{O}_3$  formed on the sapphire substrate. But as they increased the [flow rate](#), they were able to create  $\epsilon$ - $\text{Ga}_2\text{O}_3$  and even  $\alpha$ - $\text{Ga}_2\text{O}_3$ .

"We are now using kinetic models to unveil the whole mechanism of the crystallization process when [hydrogen](#) chloride is used," says Sun, "while also working on fabricating transistors using the three phases of gallium

oxide films."

KAUST have begun a close collaboration with Semiconductor Manufacturing International Corporation, an integrated-circuit foundry that provides semiconductor technology services, to fulfill its mission to pursue [gallium-oxide](#) semiconductors for practical power-electronic applications.

**More information:** Haiding Sun et al. HCl Flow-Induced Phase Change of  $\alpha$ -,  $\beta$ -, and  $\epsilon$ -Ga<sub>2</sub>O<sub>3</sub> Films Grown by MOCVD, *Crystal Growth & Design* (2018). [DOI: 10.1021/acs.cgd.7b01791](https://doi.org/10.1021/acs.cgd.7b01791)

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