# Fraunhofer IAF uses MOCVD to fabricate aluminum yttrium nitride

**Alternative to magnetron sputtering of AlYN opens up commercial applications of AlYN/GaN heterostructures.**

Fraunhofer Institute for Applied Solid State Physics (IAF) of Freiburg, Germany has used metal-organic chemical vapor deposition (MOCVD) to fabricate and characterize aluminum yttrium nitride (AlYN), enabling the development of new, diverse applications.

AlYN has attracted the interest of many research groups worldwide due to its material properties and adaptability to gallium nitride (GaN), enabling potential use in energy-efficient high-frequency and high-performance electronics for information and communications technology. However, growth of the material has been a major challenge. Until now, AlYN could only be deposited by magnetron sputtering.

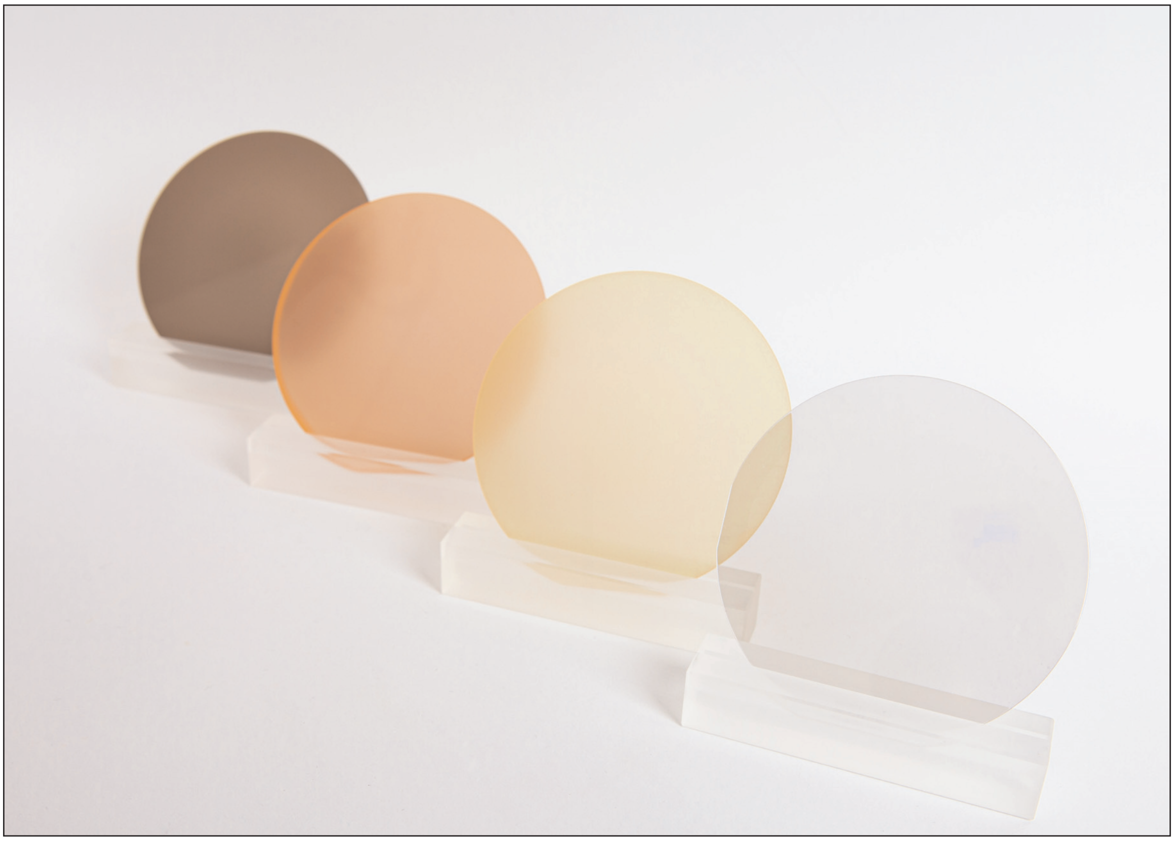
"AlYN is a material that enables increased performance while minimizing energy consumption, paving the way for innovations in electronics," says epitaxy scientist Dr Stefano Leone.

Recent research had already demonstrated the material properties of AlYN, such as ferroelectricity. In developing the new compound semiconductor material, the researchers at Fraunhofer IAF focused primarily on its adaptability to GaN. The lattice structure of AlYN can be optimally adapted to GaN, and the AlYN/GaN heterostructure promises significant advantages for the development of future-oriented electronics.

## From layer to heterostructure

In 2023, the Fraunhofer IAF research group deposited a 600nm-thick AlYN layer for the first time. The layer with wurtzite structure contained an unprecedented yttrium concentration of more than 30%. Now the group has fabricated AlYN/GaN heterostructures with precisely adjustable yttrium concentration that are characterized by excellent structural quality and electrical properties. The heterostructures have an yttrium concentration of up to 16%. The structural analysis group, led by Dr Lutz Kirste, continues to perform detailed analyses to further the understanding of the structural and chemical properties of AlYN.

The Fraunhofer researchers have already measured promising electrical properties of AlYN that are of interest for use in electronic components. "We were able to



**The different color nuances of the AlYN/GaN wafers result from different yttrium concentrations and growth conditions. © Fraunhofer IAF.**

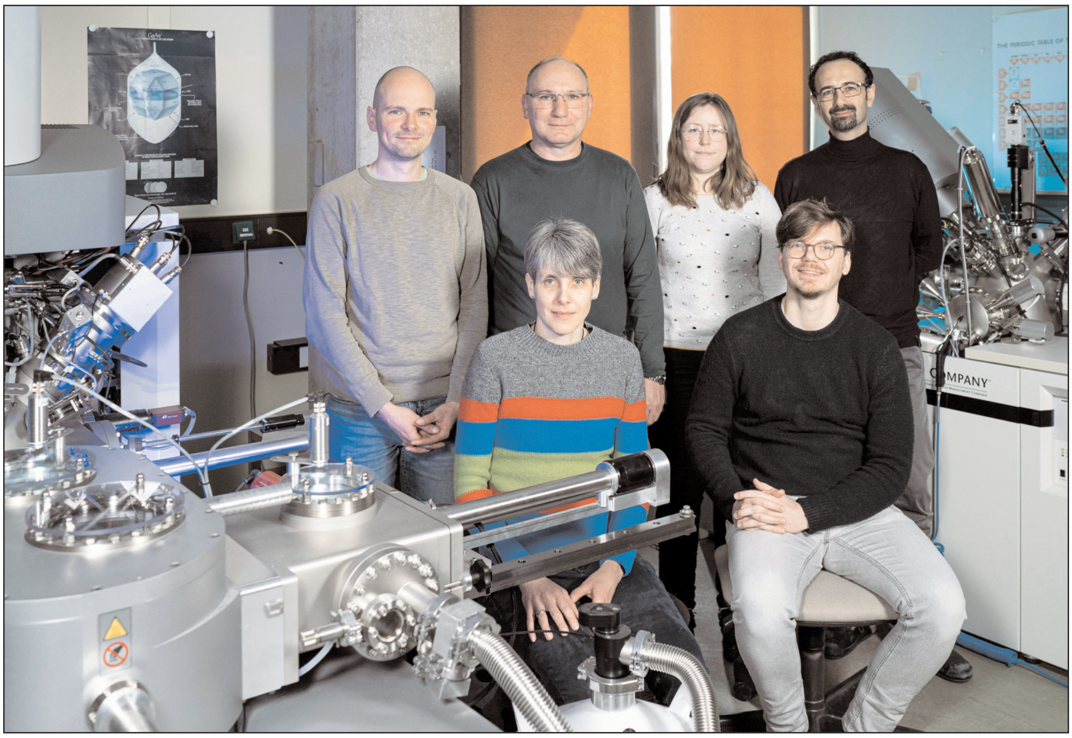
observe impressive values for sheet resistance, electron density and electron mobility," says Leone. "These results showed us the potential of AlYN for high-frequency and high-performance electronics."

## AlYN/GaN heterostructures for high-frequency applications

Due to its wurtzite crystal structure, AlYN can be adapted very well to the wurtzite structure of gallium nitride with a suitable composition. An AlYN/GaN heterostructure promises to enable the development of semiconductor components with improved performance and reliability. In addition, AlYN has the ability to induce a two-dimensional electron gas (2DEG) in heterostructures. Recent research results from Fraunhofer IAF show optimal 2DEG properties in AlYN/GaN heterostructures at an yttrium concentration of about 8%.

The material characterization results also show that AlYN can be used in high-electron-mobility transistors (HEMTs). The researchers observed a significant increase in electron mobility at low temperatures (more than 3000cm$^2$/Vs at 7K). The team has already made significant progress in demonstrating the epitaxial heterostructure required for fabrication, and continues to explore the new material for the development of HEMTs.

The researchers are also optimistic about industrial applications. Using AlYN/GaN heterostructures grown on 4-inch silicon carbide (SiC) substrates, they demonstrated the scalability and structural uniformity of the heterostructures. The creation of AlYN layers in a commercial MOCVD reactor enables scaling up to larger substrates in larger MOCVD reactors, underlining the potential of AlYN for the mass production of semiconductor devices.



The Fraunhofer IAF team that worked on the epitaxy and characterization of AlYN/GaN heterostructures. © Fraunhofer IAF.

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## Development of non-volatile memories

Due to its ferroelectric properties, AlYN is highly suitable for the development of non-volatile memory. Another advantage is that the material has no limitation on layer thickness. Therefore, the research team at Fraunhofer IAF encourages further research into the properties of AlYN layers for non-volatile memories, as AlYN-based memories can drive sustainable and energy-efficient data storage solutions. This is particularly relevant for data centers, which have to cope with the exponential growth in computing capacity for artificial intelligence and have significantly higher energy consumption.

## The challenge of oxidation

A major obstacle to the industrial use of AlYN is its susceptibility to oxidation, which affects its suitability for certain electronic applications. "In the future, it will be important to explore strategies to reduce or overcome oxidation. The development of high-purity precursors, the use of protective coatings, or innovative manufacturing techniques could contribute to this. The susceptibility of AlYN to oxidation is a major research challenge to ensure that research efforts are focused on areas with the greatest chance of success," concludes Leone. ■

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