IMaSS
Institute of Materials and Systems for Sustainability

# New Approaches for next generation III-Nitirde devices

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We explore new approaches to develop the next-generation devices of III-Nitrides, after Silicon the second most important semiconductor. It is most widely used in light-emitting diodes (LEDs) and recently also replaces silicon in power electronics like phone and laptop power supplies.

## µLED (Micro-LEDs)

µLEDs are light emitting diodes than are less than 20µm across. Such small µLEDS are sought after for virtual reality displays, where million of pixels are needed with high brightness and high efficiency to project 3D images into your eyes.

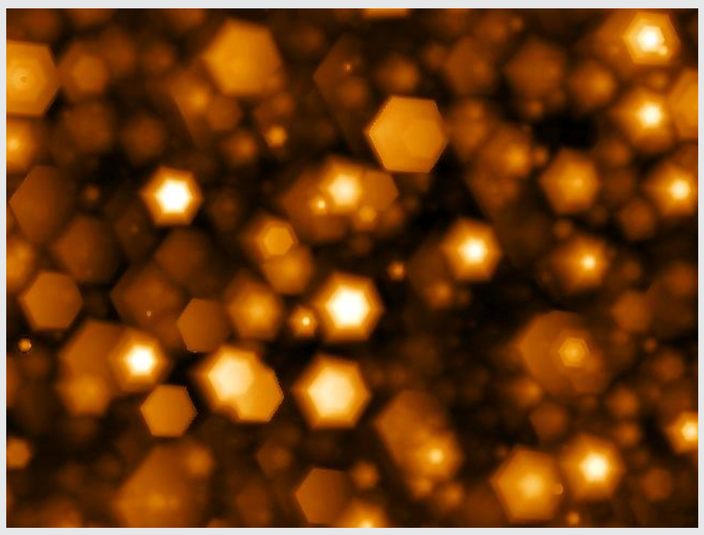
However, as the dimension shrink, the efficiency reduces as well. The main suspect is surface recombination at the sidewalls.

The project looks at the fundamental properties of the LED emission process, and tries from that to understand the physical mechanism and devise ways to reduce this effect.

One possible pathway could be a controlled roughening, another the use of unconventional crystal orientations (so-called “semi-polar” planes). These and other approaches are currently under investigation.

## N-polar III-Nitrides

A GaN wafer looks like a disc of clear glass. However, the top and bottom of the GaN crystal are fundamentally different. GaN grows normally in Ga-polar orientation, i.e. one side is strongly preferred. If done correctly, one can invert the orientation and with it the internal electric field. N-polar GaN and AlN enable better high-speed transistors, operating at higher voltages as well as deep ultra-violet light sensors.

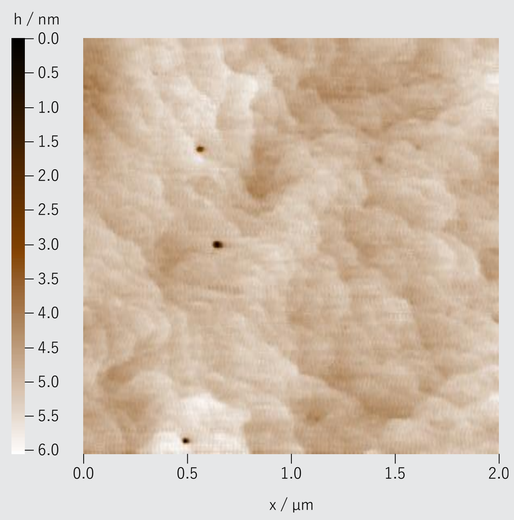


N-polar GaN growth showing large hexagonal crystallites unless specially optimised conditions are used.

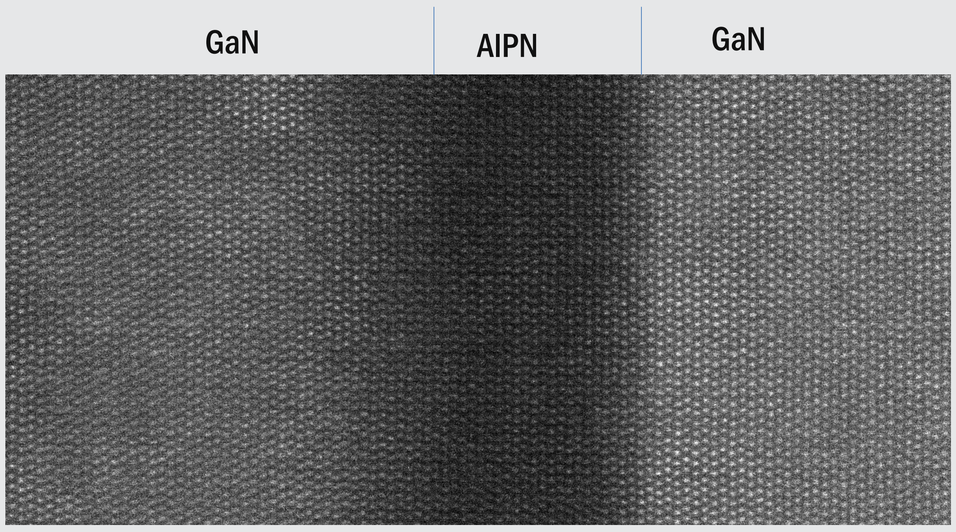
## AlPN: A new semiconductor, born at Nagoya University

AlPN is a new III-Nitride semiconductor, combining Al with a mixture of phosphorous and nitrogen. It was first realised worldwide in our group in 2020. The material can enable high-speed transistors for the next generation (6G) mobile networks or direct satellite uplink. Using a similar structure this new material could also reduce the resistivity of high-power transistors, which find their use in power conversion like for roof-top solar cells or in electric cars. Or just in your pockets, since AlGaN-based transistors enabled recently shrinking laptop power supplies in size and weight by 40% while increasing their conversion efficiency.

To realize this, we work together with other groups at Nagoya University and outside. There is a large joint project together with Berlin, Germany.




Atomic height steps seen on top of an AlPN layer




Columns of atoms of a layer of AlPN in a transmission electron microcopy