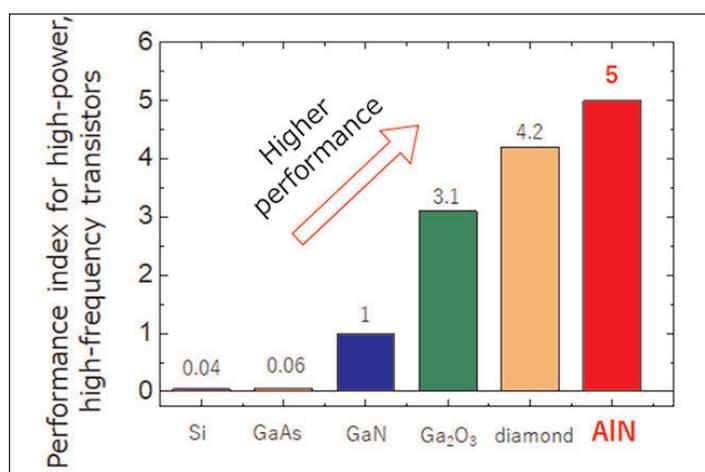


# Japan's NTT reports the first RF operation of AlGaN transistors with Al-content over 0.75

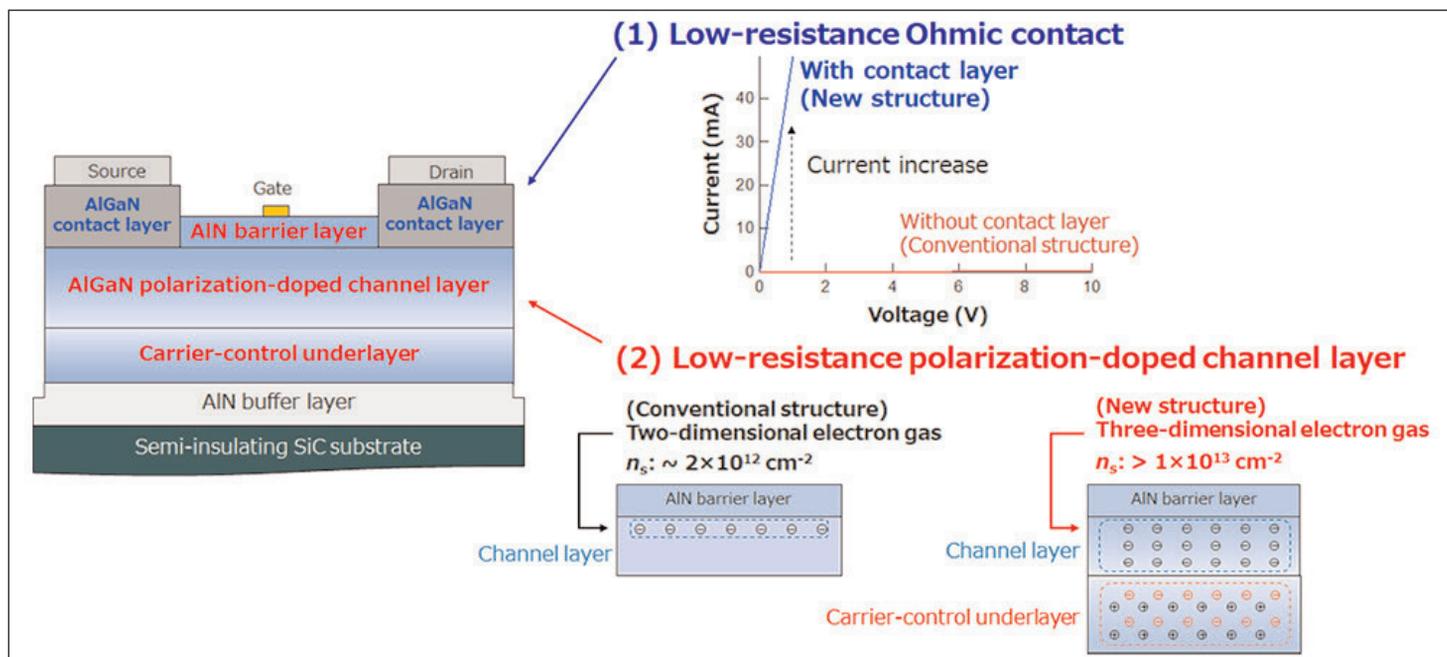
## Expanding applications of AlN from power conversion to post-5G wireless communications

**A**t the 71st IEEE International Electron Devices Meeting (IEDM 2025) in San Francisco on 10 December, Japan's NTT Inc of Tokyo, Japan presented what it claims is the first amplification of millimeter-wave high-frequency signals used in wireless communications in aluminium nitride (AlN)-based transistors (Kawasaki et al, 'First RF Operation of AlGaN-channel Polarization-Doped FETs with Average Al-content Over 0.75'). It has achieved this by designing a low-resistance structure.

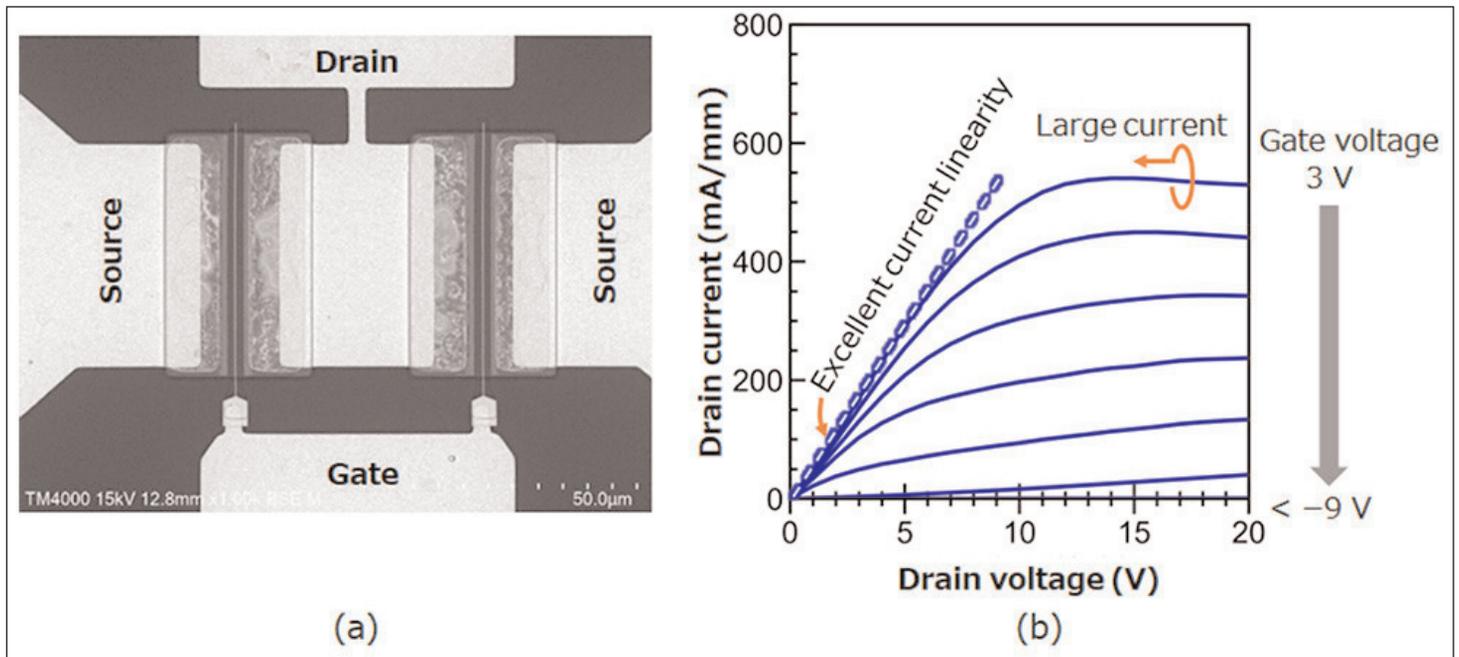
With further development toward higher output power, improvements in wireless communication services (such as expanded coverage areas and higher communication speeds) are expected in the post-5G era. NTT claims to have been first in the world to develop AlN as a semiconductor. Due to its excellent semiconductor properties, AlN is expected to be applied to power devices used in power conversion.



**Figure 1. Predicted high-power, high-frequency transistor-performance index of semiconductor materials based on material properties. Johnson's figure of merit (normalized to GaN).**



**Figure 2. Schematic of the AlN-based transistor and key technical features.**



**Figure 3. (a) Top-view scanning electron microscope image of the AlN-based transistor (Al composition: 85%), and (b) drain current–voltage characteristics as the gate voltage varied from +3V to –9V.**

However, issues that have hindered high-frequency signal amplification in AlN-based transistors include high contact resistance and high channel resistance. These problems have been overcome by NTT designing a contact layer that reduces the energy barrier at the electrode-semiconductor interface and a channel structure that generates a high electron concentration. High-frequency operation of AlN-based transistors for wireless communication has hence been demonstrated for the first time, indicating the potential for AlN to expand its range of applications, from not only power devices but also wireless-communication devices.

### Technology developments

To achieve high-frequency operation of AlN-based transistors, NTT developed the following two technologies (Figure 2).

#### (1) Low-resistance Ohmic contact using an AlGaIn contact layer

In conventional structures where electrodes are formed directly on the AlGaIn channel layer, increasing the Al composition raises the energy barrier between the electrode and semiconductor, making it difficult to obtain Ohmic contact and limiting the drain current. To reduce this energy barrier, NTT developed a technique to form an AlGaIn contact layer with graded Al composition between the electrode and channel layer. This enables the reduction in the Ohmic contact resistance.

#### (2) Low-resistance channel via polarization-doped structure

In conventional AlGaIn channel structures with uniform Al composition, the two-dimensional electron gas

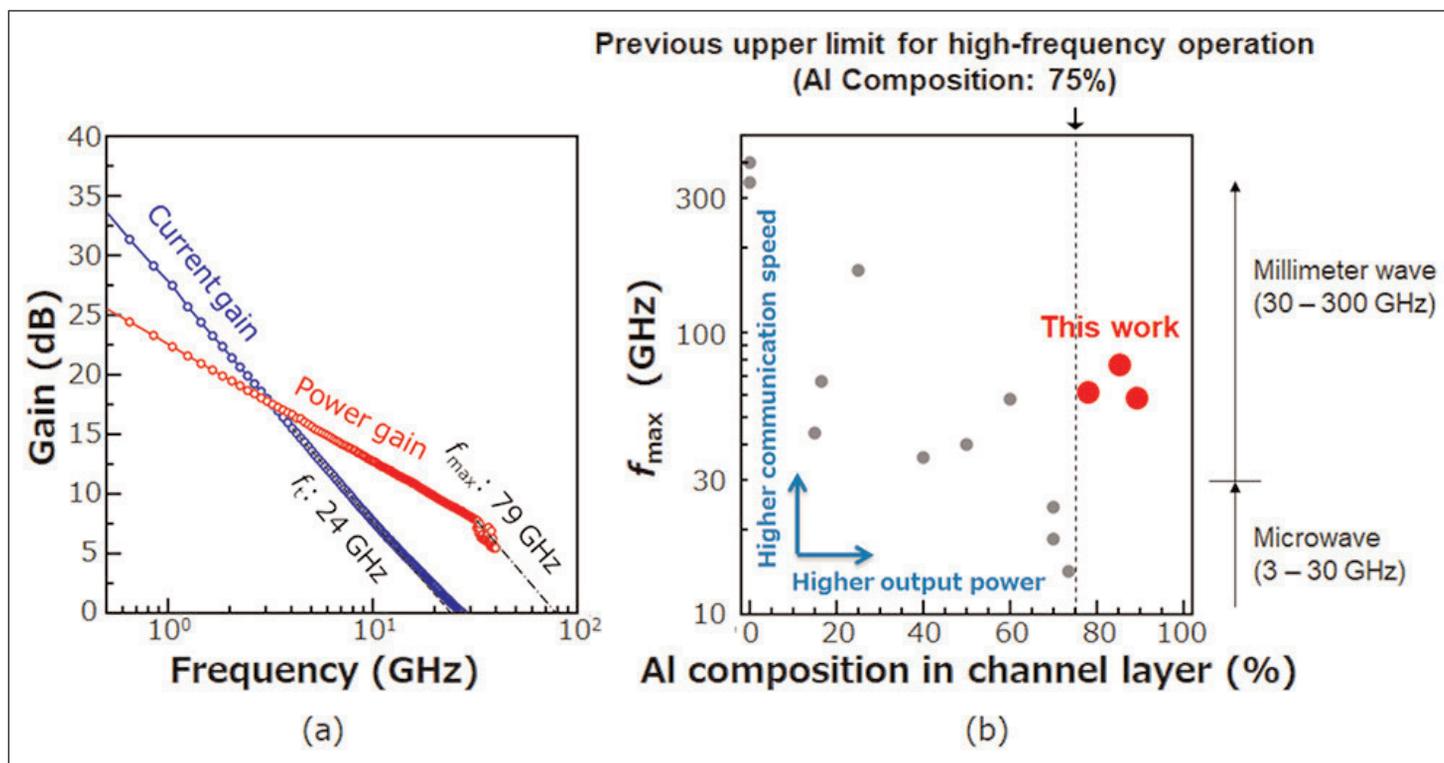
(2DEG) formed at the interface between the AlN barrier layer and AlGaIn channel layer is used as the current path. However, in high-Al-content AlGaIn, the reduction in 2DEG density leads to increased channel resistance and limited drain current. The energy barrier for confining the electron gas within the channel is also low, making it difficult to achieve a high on/off current ratio. NTT developed a polarization-doped channel structure in which an AlGaIn channel layer with graded Al composition is sandwiched between an AlN barrier layer and charge-control underlayer, enabling the formation of a high-density three-dimensional electron gas within the channel layer. This significantly reduces the channel resistance.

### Research results

Using these technologies to reduce Ohmic contact resistance and channel resistance, NTT fabricated AlN-based transistors in the high-Al-composition range (Al compositions of 78%, 85% and 89%). Even in the Al-composition region above 75%, where drain current had previously been severely limited, NTT confirmed large drain current and excellent current linearity in the linear region of the transistor.

As one example, the transistor with 85% Al composition exhibited a high drain current exceeding 500mA/mm and high on/off ratio exceeding  $10^9$  (Figure 3).

With these improvements in transistor performance, NTT succeeded, for the first time it is claimed, in achieving RF power amplification above 1GHz in AlN-based transistors with Al composition exceeding 75%. The transistor with 85% Al composition also achieved a maximum frequency of oscillation ( $f_{max}$ ) of 79GHz in the millimeter-wave band (30–300GHz) — the



**Figure 4. (a) High-frequency characteristics of the AlN-based transistor (Al composition: 85%), and (b) trend of  $f_{max}$  as a function of the Al composition in AlN-based transistors.**

highest among AlN-based transistors reported to date (Figure 4).

Since higher Al composition is advantageous for achieving higher output power in high-frequency transistors, the structure proposed provides a design guideline for achieving the intrinsic potential of AlN, representing an important advancement toward the application of AlN-based high-power, high-frequency transistors, NTT reckons.

### Future outlook

Going forward, NTT aims to design device structures capable of higher-current and high-voltage operation to demonstrate high power output of these high-frequency transistors and to continue R&D on the practical implementation of AlN-semiconductor technology from power conversion to wireless communications. ■

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