Fujitsu triples output power of gallium nitride HEMTs

Radar observation range could be extended by 2.3 times.

At the International Symposium on Growth of III–Nitrides (ISGN-7) in Warsaw, Poland (5–10 August), Tokyo-based Fujitsu Ltd and Fujitsu Laboratories Ltd have announced that they have developed a crystal structure that increases both current and voltage in gallium nitride (GaN) high-electron-mobility transistors (HEMT), effectively tripling the output power of transistors used for transmitters in the microwave band.

The GaN HEMT technology can serve as a power amplifier for equipment such as weather radar — by applying the new technology to this area, it is expected that the observation range of the radar will be expanded by 2.3 times, enabling early detection of cumulo-nimbus clouds that can develop into torrential rainstorms.

To expand the observation range of equipment like radar, it is essential to increase the output power of the transistors used in power amplifiers. With conventional technology, however, applying a high voltage could easily damage the crystals that compose a transistor. So, it was technically difficult to increase current and voltage simultaneously, which is required for realizing high-output-power GaN HEMTs.

Fujitsu and Fujitsu Laboratories have now developed a crystal structure that improves operating voltage by dispersing the applied voltage to the transistor, preventing crystal damage (patent pending). This technology has enabled Fujitsu to achieve record power density of 19.9 watts per millimeter of gate width for a GaN HEMT using an indium aluminium gallium nitride (InAlGaN) barrier layer.

Development background

In addition to having been widely used in recent years in high-frequency power amplifiers in long-distance radio wave applications (such as radars and wireless communications), GaN HEMTs are also expected to be used for weather radars to accurately observe localized torrential rainfall, as well as in millimeter-waveband wireless communications for fifth-generation mobile communications (5G). The spread of microwaves from the microwave and millimeter-wave bands used for radar and wireless communications can be extended by increasing the output power of the high-frequency GaN HEMT power amplifiers used for the transmitter. This allows expanded radar observation range as well as longer-distance and higher-capacity communications.

Fujitsu Laboratories has been conducting research on GaN HEMTs since the early 2000s, and currently provides aluminium gallium nitride (AlGaN) HEMTs used in a variety of areas. Recently, it has been conducting research on indium aluminium gallium nitride (InAlGaN) HEMTs as a new-generation GaN HEMT technology, which enables high-current operation as high-density electrons become available. Accordingly, Fujitsu and Fujitsu Laboratories have developed a

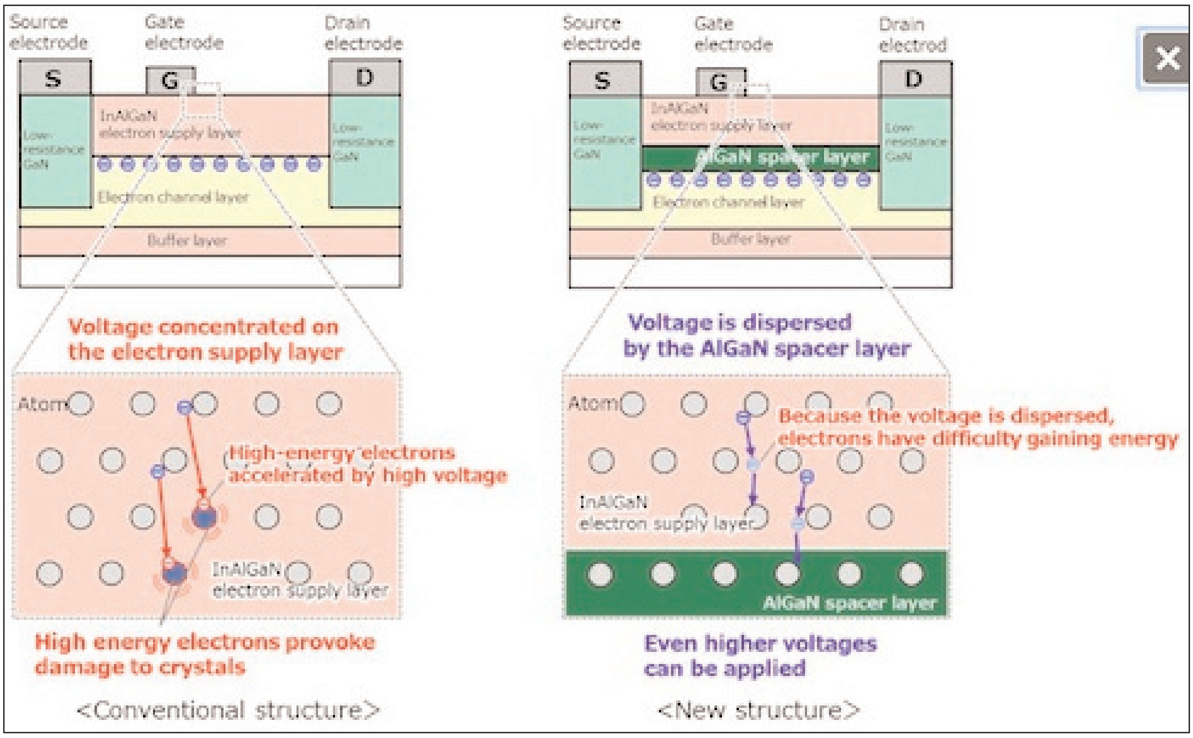

Figure 1: Mechanism for crystal damage and the new crystal structure.

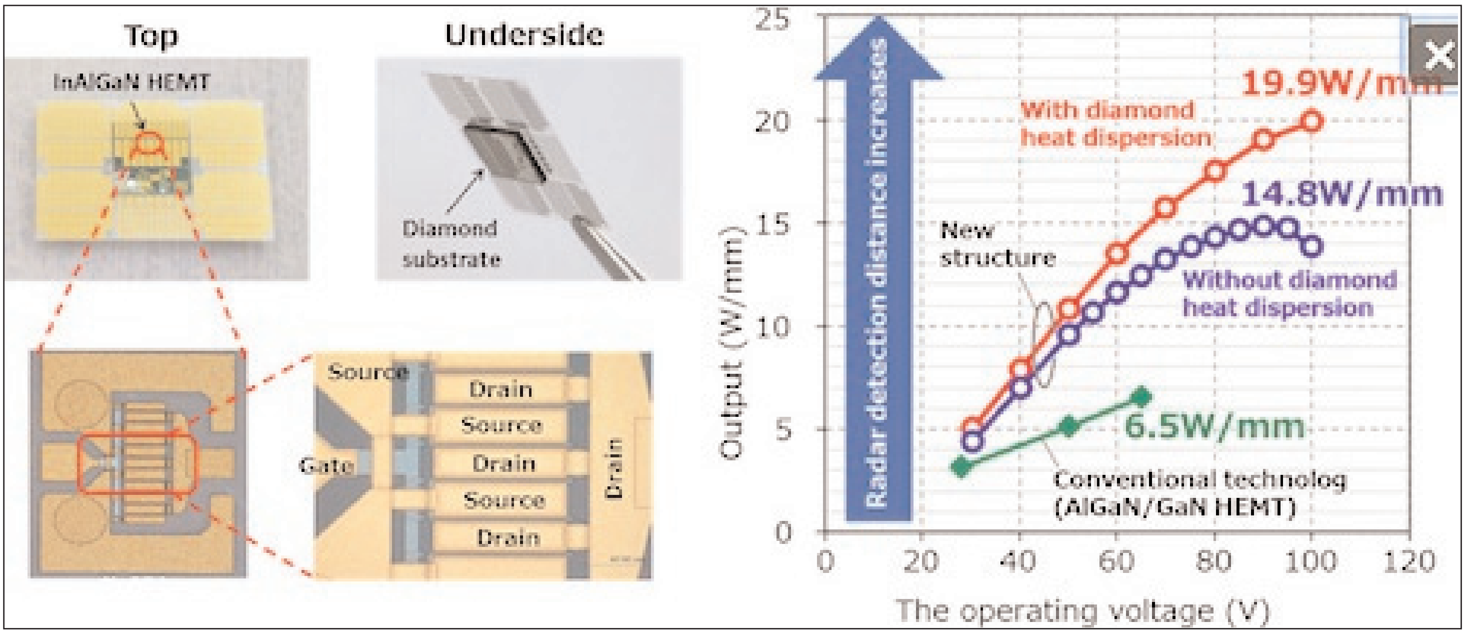

Figure 2: New GaN HEMT transistor structure and comparison of output power versus conventional technology.

crystal structure that achieves both high current and high voltage simultaneously.

Issues

To improve the output power of a transistor, it is necessary to realize both high-current and high-voltage operation. Research is ongoing on InAlGaN HEMTs for next-generation GaN HEMTs that would contribute to increased current, as InAlGaN HEMTs can increase electron density within the transistor. When a high voltage is applied, however, an excessive amount of voltage becomes concentrated on part of the electron supply layer, damaging the crystal within transistors. Consequently, these transistors had a serious issue where their operating voltage could not be increased (Figure 1).

The newly developed technology

Fujitsu and Fujitsu Laboratories have developed a transistor that can provide both high current and high voltage by inserting a high-resistance AlGaN spacer layer between the electron supply layer and the electron channel layer.

For conventional InAlGaN HEMTs, all of the applied voltage between the gate and drain electrodes are applied to the electron supply layer, and many electrons with high kinetic energy are generated in the electron supply layer. These subsequently violently strike the atoms comprising the crystal structure, causing damage. As a result of this phenomenon, there was a limit to the maximum operating voltage of the transistor.

By inserting the newly developed high-resistance AlGaN spacer layer, the voltage within the transistor can be dispersed across both the electron supply layer and the AlGaN spacer layer. By mitigating the concentration of voltage, the increase in the electrons' kinetic energy within the crystal is suppressed and damage to the electron supply layer can be prevented, leading to an improved operating voltage of up to 100V. This would correspond to over 300,000V if the distance between the source electrode and gate electrode were 1cm.

Effects

As well as Fujitsu and Fujitsu Laboratories inserting this new AlGaN spacer layer into InAlGaN HEMTs to achieve both high current and high voltage operation, by applying the single-crystal diamond substrate bonding technology that Fujitsu developed in 2017, the heat generation within the transistor can be efficiently dissipated through the diamond substrate, enabling stable operations. When GaN HEMTs with this crystal structure were measured in actual tests, they achieved the record output power of 19.9W/mm gate width (three times higher than the output power of conventional AlGaN/GaN HEMTs).

Future plans

Fujitsu and Fujitsu Laboratories will conduct an evaluation of the heat resistance and output performance of GaN HEMT power amplifiers using this technology, with the goal of commercializing high-output-power, high-frequency GaN HEMT power amplifiers for applications such as radar systems (including weather radar) and 5G wireless communication systems by fiscal 2020.

The research was partially supported by the Innovative Science and Technology Initiative for Security, established by the Japanese Ministry of Defense's Acquisition, Technology & Logistics Agency (ATLA). ■

www.fujitsu.com/jp/group/labs/en