Feb 23, 2018

Panasonic Develops Insulated-Gate GaN Power Transistor Capable of Continuous Stable Operation

Its low-loss and high-speed switching accelerates the miniaturization of equipment, and expands the GaN power transistor market

Osaka, Japan - Panasonic Corporation today announced that it has developed an insulated-gate (MIS [1]) gallium nitride (GaN) power transistor capable of continuous stable operation with no variation in its threshold voltage [2]. This technology makes it possible to further increase the speed of GaN power transistors, enabling the miniaturization of various electronic equipment.

Metal Insulator Semiconductor (MIS) type GaN power transistor is anticipated for practical uses as the next-generation power devices. Meanwhile, Panasonic has been continuing its research on MIS gate structure as a future technology to further increase its operation speed. However, hysteresis occurs in conventional MIS type GaN power transistors, and high-speed switching operations with a high current and a high voltage had not yet been confirmed.

For the first time, the company was able to confirm the continuous stable operation of MIS type GaN power transistors—which are required for future ultrafast GaN power devices—at a current of 20 A. With a significant increase in switching frequency, the miniaturization of peripheral passive components becomes possible. Highly efficient operation and miniaturization of various power conversion circuits, such as power supplies for servers and base stations, can be achieved with this technology. Enabling the operation at higher frequencies leading to further miniaturization of equipment, the new transistor is expected to expand the GaN power transistor market.

Panasonic's newly developed GaN power transistors have the following features:

1. Continuous stable operation: Maximum gate voltage of +10 V.
2. High current and high voltage operation: Drain current of 20 A and breakdown voltage of 730 V.
3. High-speed switching: OFF operation time of 1.9 ns and ON operation time of 4.1 ns.

The new transistor was developed using the following technologies:

1. Use of AlON [3] gate insulator
   The novel AlON gate insulator suppresses the hysteresis phenomenon [4] in gate voltage versus drain current characteristics, leading to continuous stable operation with a gate voltage up to +10 V for high-speed switching purpose.
2. Introduction of damage-free recessed gate structure [5]
   A crystal growth technique enables the formation of the recessed gate structure without processing damages, making it possible to achieve a high drain current while maintaining a normally-off operation [6].
3. Advanced GaN on Si technologies
   A high current and a high breakdown voltage were achieved by applying Panasonic's proprietary technologies featuring process uniformity over large areas, which have been acquired through the mass production of GaN power devices.

This achievement is the result of collaborative research with Assistant Professor Takuji Hosoi and Professor Heiji Watanabe of Osaka University, and Professor Tamotsu Hashizume of Hokkaido University, partly supported by Cross-ministerial Strategic Innovation Promotion Program (SIP), "Next-Generation Power Electronics" (funding agency: NEDO) of Council for Science, Technology and Innovation (CSTI) of the Cabinet Office, Government of Japan.

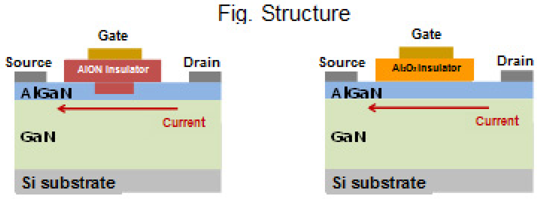
[Product Features]

1. Continuous stable operation
   For MIS type GaN power transistors, the issue was that a hysteresis attributed to electron traps within the gate insulator was often observed in the drain current characteristics resulting in a variation of the threshold voltage. In this development, the device structure as well as the fabrication process was improved to suppress such hysteresis. As a result, it has become possible to achieve continuous stable operation with a gate voltage up to +10 V.
2. High current and high voltage operation
   In GaN power devices, achieving both a normally-off operation and a high-current operation was an issue. In this development, the introduction of a recessed gate structure that formed directly under the gate electrode made it possible to achieve a high-current operation up to 20 A while maintaining a normally-off operation. In addition, a high breakdown voltage of 730 V was achieved by increasing the distance between the gate and the drain electrodes.
3. High-speed switching
   GaN power devices with a horizontal structure possess a small parasitic capacitance, making high-speed switching possible. In order to operate at a higher speed during switching operations, it is necessary to apply a higher gate voltage and perform switching operations in a shorter time. In this development, faster switching is possible because a gate voltage up to +10 V can be applied.

[Technological Details]

1. Use of AlON gate insulator
   In this development, the use of aluminum oxynitride (AlON) and the improvement of the insulator formation processes significantly reduced electron traps within the insulator. This results in the stable threshold voltage, which enables continuous switching operation. By suppressing the hysteresis at gate voltages up to +10 V, the stable operation of power conversion equipment with Panasonic's MIS type GaN power transistors is expected to be realized.
2. Introduction of damage-free recessed gate structure
   When introducing the recessed gate structure necessary for high-current operation, suppressing processing damages under the gate electrode was an issue. In this development, it was possible to suppress such processing damages by forming the outermost layer at high temperature following the formation of the recess. As a result, normally-off operation as well as the suppression of hysteresis was achieved.
3. Advanced GaN on Si technologies
   Panasonic has been already mass-producing GaN power transistors called GIT. This new MIS type GaN power transistor was developed as a future technology to achieve higher-speed operation. By applying the fabrication process technologies acquired through the mass production of GITs on silicon (Si) substrates, high current as well as high breakdown voltage was achieved.

Fig. Structure



AlON MIS GaN (New technology) Al_2O_3 MIS GaN (Conventional)

[Definitions]

[1] MIS: Metal Insulator Semiconductor
Structure in which a metal, an insulator, and a semiconductor are bonded. By using this structure for the gate electrode of the transistor, a high positive gate voltage can be applied.
[2] Threshold voltage
Gate voltage required to flow a current between the source and the drain in a transistor. The transistor becomes conductive (ON) when a voltage equal to or greater than the threshold voltage is applied to the gate. The transistor is in a non-conductive state (OFF) as long as the voltage applied to the gate is lower than the threshold voltage.
[3] AlON: aluminum oxynitride
AlON is an insulating material composed of aluminum (Al), oxygen (O), and nitrogen (N). It has been confirmed that electrons are not easily trapped within an AlON insulating film.
[4] Hysteresis
Phenomenon in which the relation between the gate voltage and the drain current in a transistor varies when the gate voltage is enhanced or applied repeatedly, resulting in unstable operation.

[5] Recessed gate structure
Gate structure with a recess formed under the gate electrode. By changing the thickness of the semiconductor beneath the gate from the thickness of the sides of the gate in this structure, it is possible to achieve both a positive threshold voltage and high-current operation capability.
[6] Normally-off operation
Characteristics of a semiconductor device in which no current flows between the source and the drain when no voltage is applied to the gate. This is a necessary feature to ensure the safety of equipment without creating a short-circuit between the source and the drain when the control circuit fails.

About Panasonic

Panasonic Corporation is a worldwide leader in the development of diverse electronics technologies and solutions for customers in the consumer electronics, housing, automotive, and B2B businesses. Celebrating its 100th anniversary in 2018, the company has expanded globally and now operates 495 subsidiaries and 91 associated companies worldwide, recording consolidated net sales of 7.343 trillion yen for the year ended March 31, 2017. Committed to pursuing new value through innovation across divisional lines, the company uses its technologies to create a better life and a better world for its customers. To learn more about Panasonic
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