HEMTs Oxygen plasma treatment eliminates the need for a GaN cap

If oxygen plasma treatment is used to address current collapse, the benefits of adding a GaN cap are negligible

ONE OPTION for improving the electrical performance of a GaN HEMT is to add a GaN capping layer. But this step has almost no benefit if devices are subjected to an oxygen plasma treatment, according to recent work by a Japanese team from the University of Fukui and Hokkaido University.

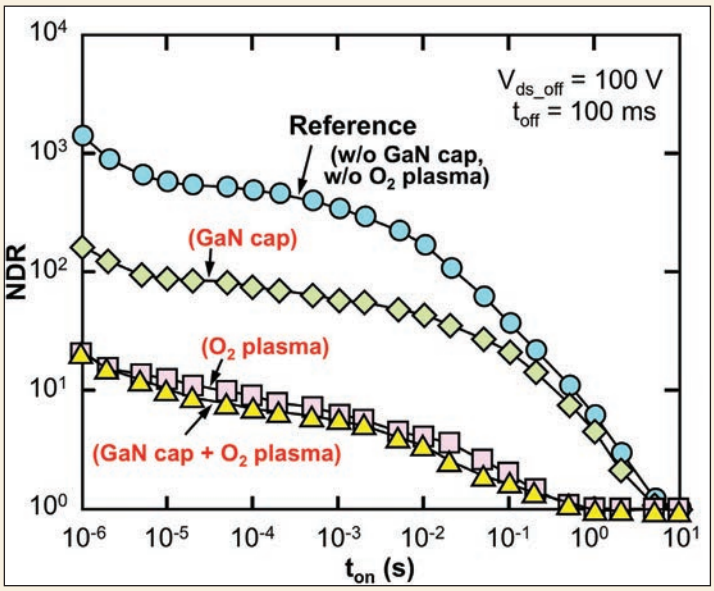
"Using oxygen plasma treatment of the surface alone, we can avoid problems associated with GaN cap layers, such as obtaining good ohmic contacts when using undoped GaN; and increased leakage, and the associated decrease in breakdown voltage, when using an *n*-type GaN cap," says corresponding author Joel Asubar from the University of Fukui.

There are also other drawbacks of an *n*-type GaN cap, says Asubar, such as inferior gate control of the current, which stems from an increase in the gate-to-channel distance.

To highlight the futility of incorporating a GaN cap in a GaN HEMT that has been subjected to plasma treatment, the team from Japan fabricated a range of devices and carried out a series of electrical measurements on them.

All devices were grown on SiC, and featured a 500 nm-thick layer of GaN, followed by a 25 nm-thick layer of $Al_{0.2}Ga_{0.8}N$. After source, drain and gate contacts were formed, sputtering added a 150 nm-thick SiN passivation layer.

Four types of device were formed, distinguished by whether or not they had been treated with an oxygen plasma for 60 s at a power of 100 W prior to SiN passivation, and whether or not they featured a GaN cap.



Oxygen plasma treatment is a very effective way to reduce current-collapse, which has been evaluated by considering the ratio of dynamic on-resistance to static on-resistance.

Cap-free devices with and without plasma treatment produced very similar values for maximum drain current density, threshold voltage, leakage current and breakdown voltage. This indicates that plasma treatment does not have a negative impact on the DC characteristics of the device.

The researchers also investigated current collapse in a range of devices, evaluating the ratio of the dynamic on-resistance to static on-resistance – the higher this value, known as the normalised dynamic on-resistance (NDR), the greater the current collapse.

Measurements on the uncapped structures revealed that oxygen plasma treatment mitigates current collapse (see figure).

These experiments also show that a GaN cap can combat current collapse, but this is not as effective as oxygen plasma treatment – and combining a GaN cap with oxygen plasma treatment produces only a very marginal improvement over just plasma treatment.

Further insight into the benefits of plasma treatment came from numerical modelling of the dependence of the NDR on the on-time of the device.

Simulations show that oxygen plasma treatment completely eliminates the two deepest trap levels, occurring at 0.62 eV and 0.67 eV, while the GaN cap only eliminates the deepest trap at 0.67 eV.

To understand the impact of plasma treatment, the researchers employed X-ray photoelectron spectroscopy to investigate the nature of the AlGaN surfaces.

They found that oxygen plasma treatment creates a surface oxide layer that is about 2 nm-thick, and probably contains a combination of Al_2O_3 and Ga_2O_3.

This finding led the team to conclude that the reduction in current collapse produced by oxygen plasma treatment results from the termination of near-surface gallium and aluminium atoms, and the probable occupation of nitrogen vacancies by oxygen atoms.

Asubar and co-workers are now aiming to realise true collapse-free operation with their GaN HEMTs. "We are planning to combine the oxygen plasma-treatment approach with other approaches against current collapse, such as the use of field plates."

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