AlGaN/GaN HEMTs on Free-standing GaN Substrates with Critical Electric Field of 1.2 MV/cm

Graduate School of Engineering, University of Fukui
°(M2)J. H. Ng, J. T. Asubar, Hirokuni Tokuda, Masaaki Kuzuhara
E-mail: jiehongng@gmail.com

Introduction Owing to its expected high critical electric field (E_{cr}) of over 3 MV/cm, GaN is predicted to play the role of key semiconductor material for realizing high-voltage and low-loss power devices [1]-[2]. This is partially because AlGaN/GaN HEMTs are usually fabricated on foreign substrates such as sapphire, SiC, and silicon, which have thick and complicated buffer layer structures that could be the source of leakage current. In this work, we have investigated the relationship between breakdown voltage and gate-to-drain spacing (L_{gd}) of AlGaN/GaN HEMTs fabricated on free-standing GaN substrates.

Experiment All the devices were fabricated on AlGaN/GaN heterostructures grown by MOCVD on a 2-inch free-standing GaN substrate with a nominal low dislocation density of 10^6 cm^{-2}. The GaN substrate were prepared by HVPE and doped with Fe to ensure semi-insulating property. The epitaxial structure consists of a 25 nm-thick AlGaN barrier layer with an Al composition of 0.2, a 900 nm-thick undoped GaN channel layer, and a 300 nm-thick Fe-doped GaN buffer layer. Room-temperature Hall-effect measurements revealed an electron sheet concentration of 8×10^{12} cm^{-2} together with a Hall mobility of 1800 $cm^2V^{-1}s^{-1}$. Mesa isolation for device where mesa isolation surface falls on semi-insulating GaN substrate was carried out for 170 min with BCl_3/Cl_2.

Results Figure 1 shows the breakdown voltage as a function of ohmic-to-ohmic spacing for GaN substrates with different Fe doping concentrations. The GaN substrate with higher Fe doping concentration exhibited an E_{cr} of 1.3 MV/cm whereas the one with lower Fe doping concentration exhibited an E_{cr} of 1 MV/cm. Figure 2 shows the breakdown voltage as a function of L_{gd} for AlGaN/GaN HEMTs with different mesa isolation depths. Breakdown voltages in devices where mesa surface falls on GaN channel and Fe-doped GaN buffer increase linearly up to a L_{gd} of 55 μm and then became saturated at around 4 kV. The breakdown voltage in device where mesa surface falls on semi-insulating GaN substrate increase linearly with L_{gd} without saturation up to 4.8 kV corresponding to an E_{cr} of 1.2 MV/cm.

Conclusion By further increasing the Fe doping concentration in the semi-insulating GaN substrate, we have succeeded in achieving an E_{cr} of 1.2 MV/cm and high breakdown voltage of 4.8 kV for AlGaN/GaN HEMTs on free-standing GaN substrates. This is the highest breakdown voltage ever reported among planar AlGaN/GaN HEMTs having all electrodes formed on the front surface. This work was partially supported by a Super Cluster Program from JST.

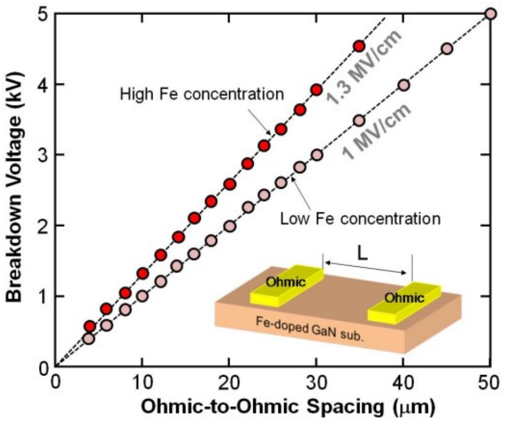

Fig. 1. Breakdown voltage as a function of ohmic-to-ohmic spacing for GaN substrates.

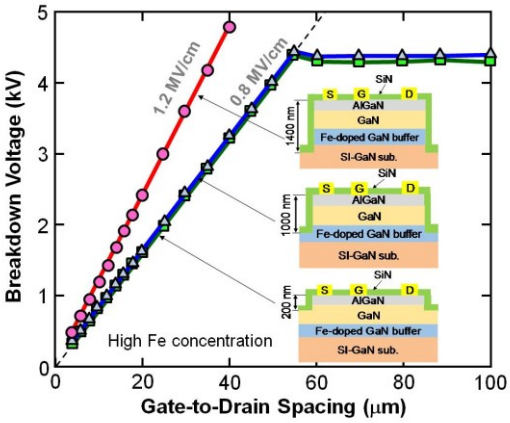

Fig. 2. Breakdown voltage as a function of gate-to-drain spacing for AlGaN/GaN HEMTs.

[1] M. Kuzuhara and H. Tokuda, *IEEE Trans. Electron Devices*, vol. 62, pp. 405-413, Feb. 2015.
[2] M. Kuzuhara, J. T. Asubar and H. Tokuda, *Jpn. J. Appl. Phys.*, vol. 55, p. 070101, Jun. 2016.