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The GaN based HEMT and Schottky diode with filed plate technology for DC/DC converter

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1. Introduction

High performance AlGaN/GaN HEMTs and Schottky diodes have been successfully applied to power electronics. This is due to the excellent characteristics of GaN, namely a wide bandgap (3.4eV), a high breakdown filed (2×10^6 V/cm), and a high saturation velocity (2.2×10^7 cm/s) [1]. In order to achieve a enhancement of device breakdown performance, the filed plate technology is commonly used in the GaN HEMT device [2]. In this study, we applied the filed plate technology not only on GaN HEMTs [3-4] but also on Schottky diodes for the application of DC/DC converter. Additionally, the detail analysis of parasitic capacitance in the field plate GaN HEMTs by using various layouts was discussed. Then a better layout for providing a enhancement of breakdown performance and owing lower parasitic capacitance can be got. Finally, the combination of GaN GaN HEMT and Schottky diode was fabricated as a cell for the demonstrating of boost converter.

2. The field plate on GaN HEMT

The field plate connected with source electrode with two different layout designs was fabricated on GaN HEMT. The main difference is the overlapping between gate and field plate, which is shown in the Fig. 1. The gate-to-source and gate-to-drain distance were 1.5 µm and 10 µm, respectively. The gate length of GaN HEMT was 1 µm, and the field plate length was designed from 2 µm to 8 µm to observe how the field plate length affects the device performance. Fig. 2 shows the device off-sate avalanche breakdown voltage. The V_{br} was increased with field plate length until the length of 4 µm, and decreased when the length was increased from 6 to 8 µm. The enhancement of V_{br} was attributed the lower maximum electric field and more smooth distribution of electric potential in the field plate structure. Because the field plate can generate an extra higher electric field at the edge of field plate and decrease the main electric field of gate edge. The decrease of V_{br} is owing the too short distance between field plate and drain side will result in an another higher electric field. The maximum V_{br} of this study was 105 V when the field plate length was 4 µm.

For the discussion of parasitic capacitance in these two field plate layouts, the main issue is the extra induced capacitance caused by the overlapping between gate and field plate. The detail comparison of C_{gs} and C_{gd} was shown in Fig. 3 (a) and (b), where the layout with overlapping structure indeed introduce a larger C_{gs} and C_{gd} in comparison with another field plate structure Consequently, the lower parasitic capacitance of GaN HEMT (a) can achieve a higher f_T. For the field plate length of 4 µm, the fT was enhanced from 5.5 GHz to 9 GHz by using the non-overlapping layout.

3. The field plate on Schottky diode and DC/DC converter

On the other hand, the field plate technology can also be applied into the Schottky diode The photos of diodes w/wo field plate were shown in the Fig. 4. The field plate was connected with the circular Schottky metal and placed over the interjection of Schottky electrode, where the electric field was stronger and un-uniform. Additionally, the shape of ohmic metal near the interjection of Schottky metal was also a key parameter to affect the V_{br}. In this study, a smooth and sharp design in the edge of ohmic metal was done to be compared in the performance of V_{br}. The measurement result was shown in the Fig. 5, where both designs of field plate and smooth metal edge can enhance the V_{br} of diode. The field plate and smooth metal width can effectively decrease the maximum electric field and

Finally, we combine the GaN HEMT and GaN Schottky as a converter cell, to demonstrate a boost converter. The passive components such as inductor and capacitor were connected with cell by using bonding wires. The measure result of boost converter was shown in Fig. 6, where the ideal dc voltage gain was 2. The lower voltage gain in the higher voltage region was owing to the leakage current in the GaN HEMT device when the V_{ds} was over 30 V.

4. Conclusion

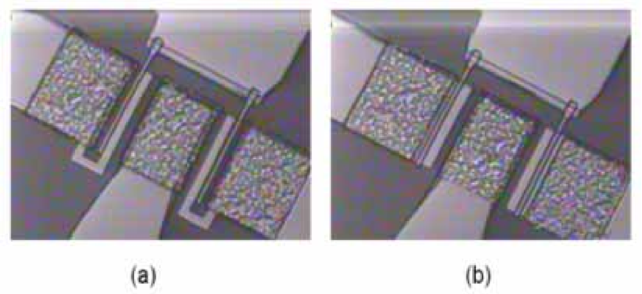
In this study, a field plate technology was simultaneously applied into the GaN HEMT and GaN Schottky diodes for the application of GaN dc/dc converter. By using a non-overlapping field plate structure, the device demonstrated a good enhancement of breakdown performance, and the parasitic capacitance will not be increased as much as overlapping field pate structure. Besides, the field plate technology can also obviously enhance the V_{br} of GaN Schottky especially for the un-continued region in ohmic and Schottky metals.

Reference:

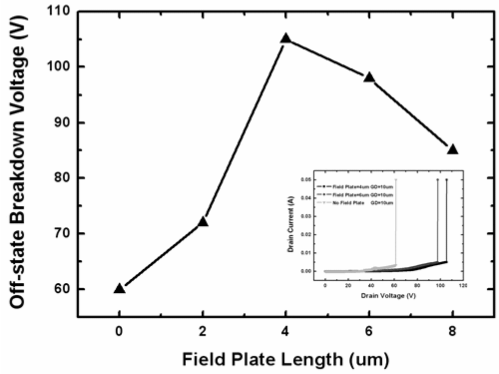
[1] L. Shen, et. al. "AlGaN/AlN/GaN high-power microwave HEMT," *IEEE Electron Device Letters*, vol. 22, pp. 457-9, 2001.

[2] V. Adivarahan, et. al. “Stable CW operation of field-plated GaN-AlGaN MOSHFETs at 19 W/mm”, *IEEE Electron Device Letters*, vol. 26, pp. 535-537, 2006.

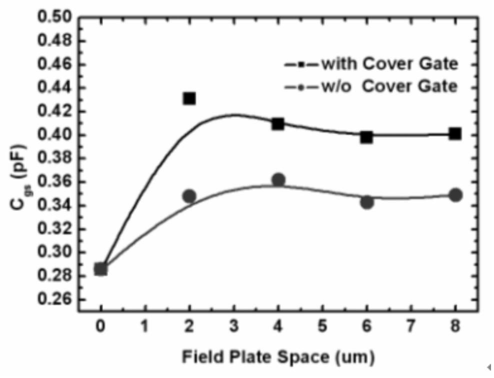
[3] W. Saito, et. al., “Design optimization of high breakdown voltage AlGaN-GaN power HEMT on an insulating substrate for R/sub ON/A-V/sub B/ tradeoff characteristics”, IEEE Trans, Electron Device, vol. 52 106-111, Jan. 2005.



Fig, 1 The photos of two field plate layouts

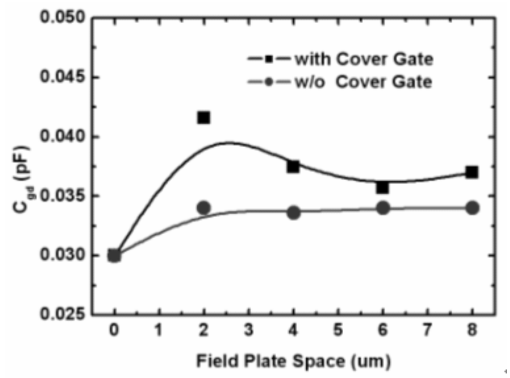


Fig, 2 The V_{br} versus field plate length



Fig, 3 (a) The comparison of C_{gs} in these two device.

[4] W. Saito, et. al., “High breakdown Voltage undoped AlGaN-GaN power HEMT on sapphire substrate and its demonstration for DC-DC converter application”, IEEE Trans, Electron Device, vol. 51 1913-1917, Jan. 2004.



Fig, 3 (b) The comparison of Cgd (b) in these two device.

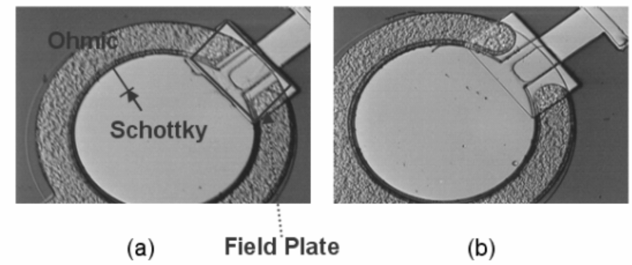


Fig. 4 The photos of two diodes with sharp and smooth ohmic metal edge.

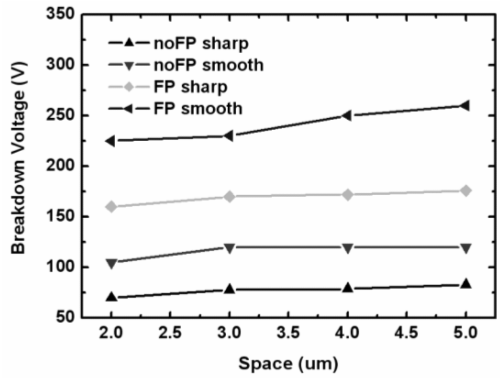


Fig. 5 The V_{br} versus spacing between ohmic and Schottky contact.

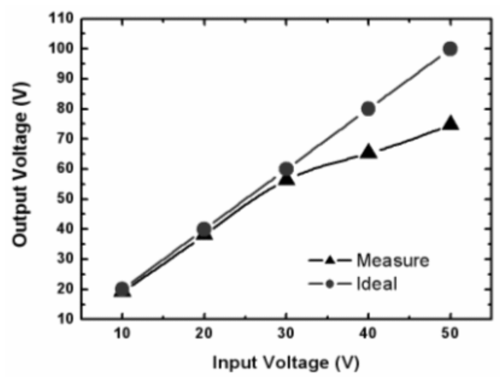


Fig. 6 The measurement result of dc/dc converter