BCB encapsulation for high power AlGaN/GaN-HFET technology

P. Kurpas, O. Bengtsson, S. A. Chevtchenko, I. Ostermay, R. Zhytnytska, W. Heinrich, J. Würfl

Ferdinand-Braun-Institut (FBH), Leibniz Institut für Höchstfrequenztechnik,
Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany,
e-mail: paul.kurpas@fbh-berlin.de, Tel. +49-(0)30-6392-2674, Fax. +49-(0)30-6392-2685

AlGaN/GaN-HFET fabrication for microwave, devices and MMICs has reached a mature state providing devices capable of delivering high RF power levels at high operating voltages. However, technological improvements as device encapsulation or tailored low-loss metal lines [1] are still in focus.

In this work we report on successful implementation of a BCB encapsulation layer in the FBH´s baseline GaN-HEMT process for power applications and MMICs. The details of the general GaN-HEMT processing are described elsewhere [2]. Here, we used a 2.6 µm thick BCB layer deposited on top of the final device silicon nitride passivation. The BCB was cured at 240°C and contact openings were dry etched by ICP plasma. Finally, 6 µm Au was plated as a second interconnecting metal. Fig. 1 shows a viewgraph of a fabricated GaN-HEMT power bar with BCB encapsulation.

The major point of interest addressed in this work is the question whether the additional BCB layer will impact the transistor´s performance. Fig. 2 shows a comparison of leakage currents measured on wafers without and with additional BCB layer. This result verifies that no increase in leakage current occurs when BCB encapsulation is used. Furthermore, there was no significant change of other transistor parameters like threshold voltage.

Fig. 3 confirms that the BCB layer does not affect the available RF power levels. For both wafers, with and without BCB, the same power dependency on drain voltage was measured. Furthermore, the transistors encapsulated with BCB achieved equally high power density of more then 6 W/mm at 50 V. Fig. 4 presents the resulting optimum load matching conditions for both wafers showing that the BCB does not change the matching impedance significantly at 2 GHz.

Since trapping effects resulting in current dispersion are well known issues of AlGaN/GaN HFETs a special investigation was focused on determination of transistor behavior under pulse operation conditions. A standard evaluation method is now established at FBH [3] which allows for a reproducible comparison of transistor pulse responses. Fig. 5a shows the pulse response measurements on transistor with BCB layer which confirms that no deterioration in dynamic behavior occurred here as compared with the reference transistor without BCB (fig. 5b). However, this result was only obtained on an epitaxial structure with moderate Al-content of 18% in the 18 nm thick AlGaN barrier layer. On wafers with increased Al composition (25%) and/or increased barrier thickness (25 nm) lagging effects became more pronounced in the pulse response measurements. These results could indicate a higher sensitivity of higher-current related epitaxial designs toward changes in local strain situations. This effect may be explained by the higher local fields at the drain side edge of the gate for designs with higher Al content in the AlGaN barrier.

In conclusion, GaN-HEMT technology with BCB encapsulation was successfully established without compromises in DC and RF performance. However, transistor´s dynamic behavior especially with high Al-content barrier layer is still a topic of investigations.

References
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[3] O. Bengtsson, S. A. Chevtchenko, A. Liero, J. Würfl, W. Heinrich, "An improved VSWR ruggedness test for RF-power GaN HEMTs", presented at Microwave Technology and Techniques Workshop, May 21st – 23rd, 2012, ESA-ESTEC, Noordwijk, The Netherlands.

keywords: AlGaN/GaN HEMT, BCB, processing, reproducibility

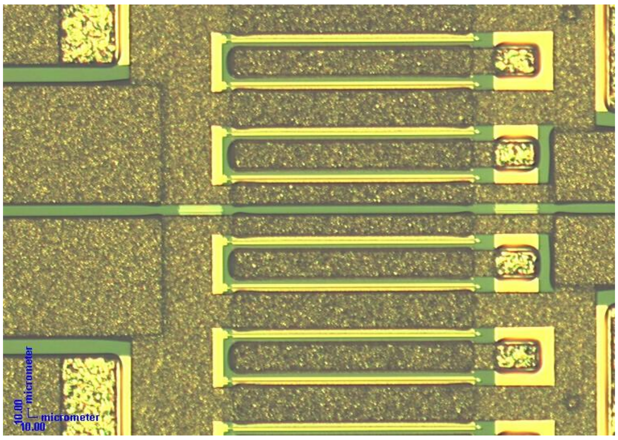

Fig. 1: Chip photograph of a GaN-HEMT power bar with BCB encapsulation.

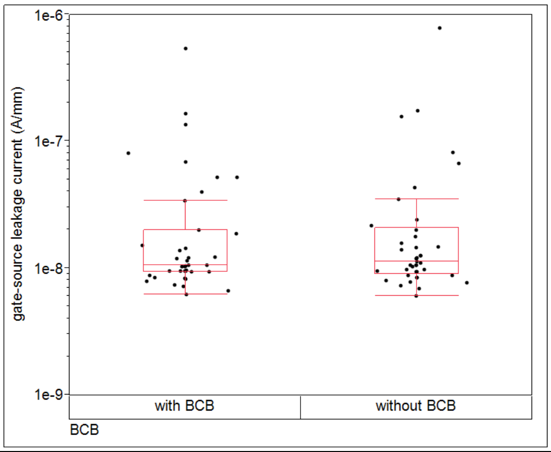

Fig. 2: Comparison of gate-source leakage currents measured on 2x125-µm GaN-HEMT devices on wafers without or with additional BCB layer.

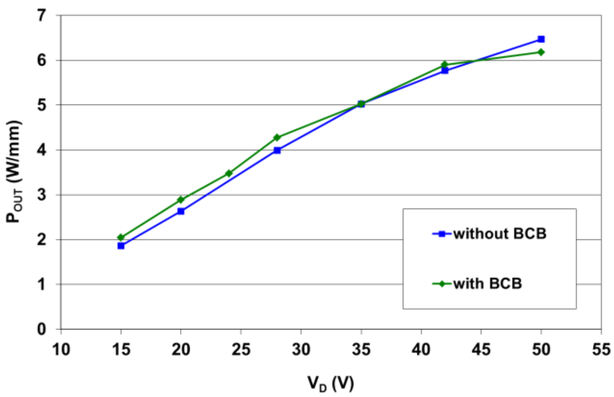

Fig. 3: RF power in dependence on drain voltage for a GaN-HEMT with BCB in comparison with a reference transistor without BCB measured on 2x250-µm devices at 2 GHz.

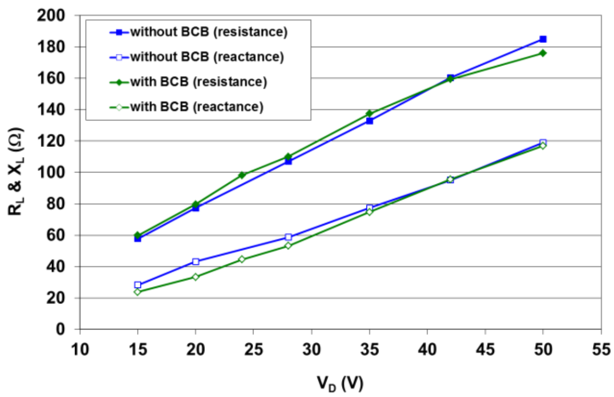

Fig. 4: Matching impedance for a 2x250-µm GaN-HEMT with BCB in comparison with a reference transistor without BCB.

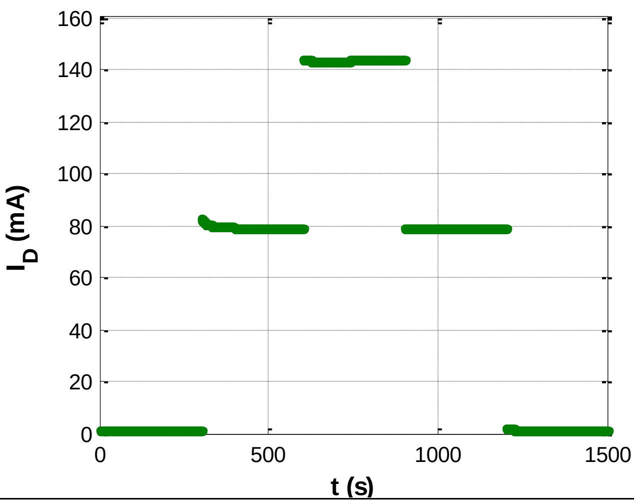

Fig. 5a: Pulse response results measured on a GaN-HEMT transistor with BCB encapsulation.

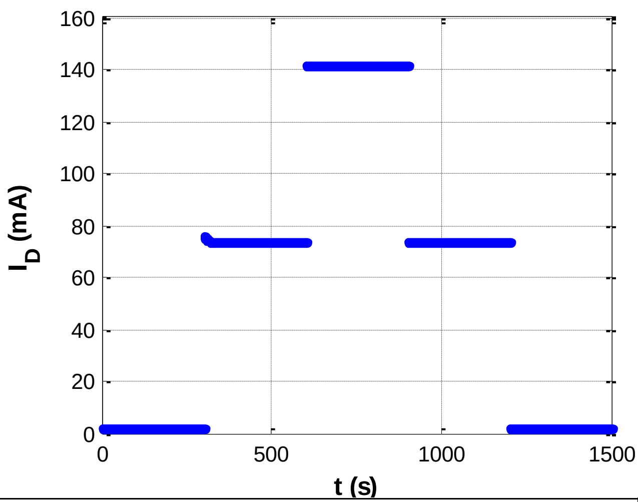

Fig. 5b: Pulse response results measured on a GaN-HEMT transistor without BCB encapsulation.