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Enhancement of RF Characteristics of AlGaN/GaN HEMTs with Shield Source Field Plate using BCB

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1. Introduction

AlGaN/GaN HEMTs have great potential in high power microwave application due to their superior material properties, such as high breakdown field, high electron mobility and high carrier density [1-3]. Field plate structures have been developed to extend the performance limit of microwave GaN HEMTs.[4] Great enhancement in radio frequency (RF) current–voltage swings was achieved with acceptable compromise in gain, through increase in breakdown voltages [5]. A benzocyclobutene (BCB) passivated device exhibited a better RF performance than silicon nitride passivated device due to its low dielectric constant ($\varepsilon r = 2.7$) that decreased the capacitance [6].

This letter presents the effects of source field-plate (SFP) structures on RF characteristics using low-k benzocyclobutene (BCB) layer.

2. Device fabrication process

The epitaxial layers grown on Si substrate consisted of a 20 Å GaN capping layer, an 175 Å $Al_{0.26}GaN$ barrier layer, an 1 ㎛ GaN buffer layer, and AlN/GaN transition layers from top to bottom. A pre-passivation process began with SiN_x deposition at 350 °C using a remote ICP-CVD system [7]. The thickness of SiN_x layer was 1200 Å. After silicon nitride layer was etched by a low-damage SF_6 based dry etching process, drain and source ohmic contacts were formed by using a Si/Ti/Al/Mo/Au (=5/20/60/35/35 nm) metal stack, followed by 800 ℃ for 30 sec in the N_2 ambient. Mesa isolation was then carried out using an ICP-RIE system with Cl_2 gas. The SiN layer under the gate region was etched prior to Pd/Ir/Au (=3/20/377nm) evaporation using the same silicon nitride etching method described above. Surface treatment before BCB passivation was carried out by O_2 plasma ashing in which the RF power was 50W and the pressure was 200 mTorr for 3min. Then, dipping in acid solutions for 1 min followed by D.I. water rinsing for 1min was carried out. BCB (Cyclotene 3022–46, Dow Chemical) was spin-coated at 5000 rpm resulting in a 5 ㎛ thick layer. It was soft baked on a hotplate at 110℃ for 3min to remove the solvent and to stabilize the film. Followed by hard curing under 210℃ for 40min in a vacuum oven with a 300 Torr pressure to achieve 80% polymerization. The final thickness of BCB layer was 1.4 ㎛ by a etch back process. A Ti/Au metal stack was used for the SFP electrode. Two types of SFP structures were compared as shown in Fig. 1, i.e., conventional SFP and deep shield SFP.

3. Device performance and Discussion

Gate width and length were 2 x 50 ㎛, and 0.3 ㎛, respectively The direct current (DC) characteristics were measured using 4155A. No noticeable difference was observed between two types. Fig. 2 shows the measured I-V characteristics. The device exhibits a maximum drain current density of 820 mA/mm at $V_{gs} = 1$ V and a maximum transconductance of 355 mS/mm. Small-signal characteristics are shown in Fig. 3. Both f_t and f_{max} were improved by employing the deep shield SFP structure. The f_t increased from 34 GHz to 54 GHz and the f_{max} increased from 53GHz to 85 GHz. The maximum stable gain (MSG) at 10 GHz increased from 11.6 dB and 13.4 dB. It is suggested that the vertical shield field plate redistribute the electric field on the drain side of the gate edge to further reduce the electric field peak. In addition, the deep shield SFP reduces the gate-drain capacitance (C_{gd}).

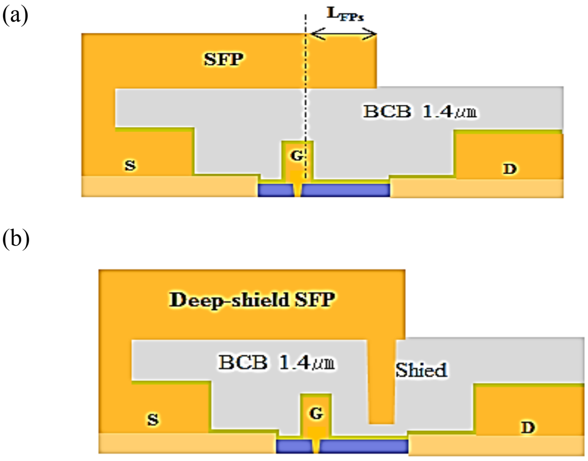

Fig. 1 Cross-sectional view of BCB passivated AlGaN/GaN HEMTs with (a) SFP, and (b) deep shield SFP near to drain region

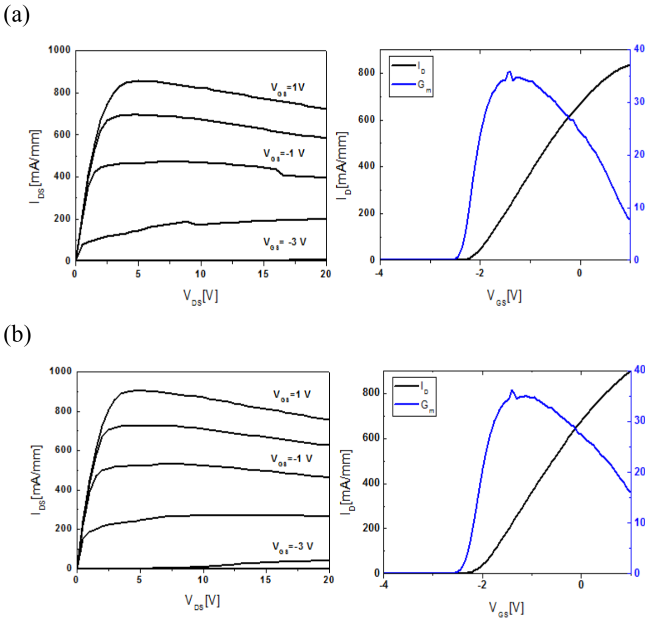

Fig. 2 *I-V* characteristics and transfer characteristics of the $0.25\mu m$ x 0.1 mm AlGaN/GaN HEMT. (a) SFP, and (b) deep shield SFP near to drain region

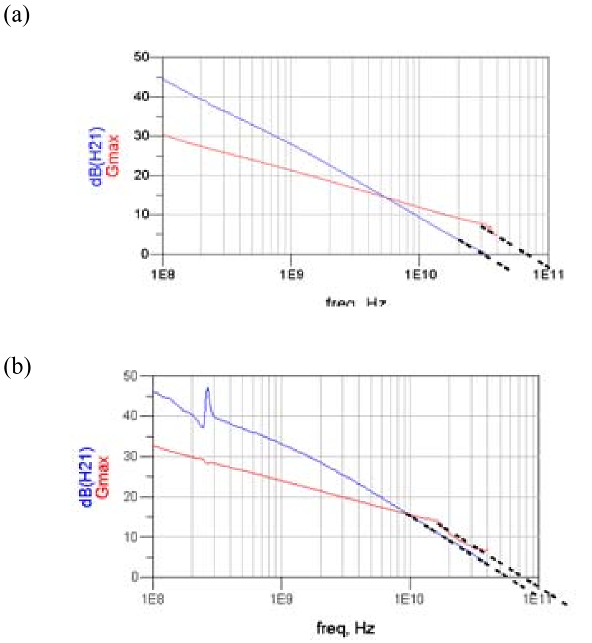

Fig. 3 Small-signal gain versus frequency for (a) SFP, and (b) deep shield SFP near to drain region

4. Conclusions

A novel deep-shield SFP structure was successfully applied to improve the RF performance of AlGaN/GaN HEMTs. The f_{max} increased from 53 to 85 GHz by employing the shield SFP. The deep-shield SFP structure reduced C_{gd} which in turn increased MSG by 2 dB at 10 GHz.

Acknowledgements

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References

[1] Mishra, U.K., Parikh, P., and Yi-Feng Wu: ‘AlGaN/GaN HEMTs-an overview of device operation and applications’, Proc. IEEE., 2008, 90, (6), pp. 1022-1031.

[2] Binari, S. C., Kruppa, W., Dietrich, H. B., Kelner, G., and Jr, J. A. F: ‘Fabrication and characterization of GaN FETs’, Solid State Electron., 1997, 41(10), 1549-1554.

[3] Keller, S., Wu, Y.-feng, Parish, G., Member, S., Ziang, N., and Xu, J. J.,: ‘Gallium Nitride Based High Power Heterojunction Field Effect Transistors’ : Process Development and Present Status at UCSB, 2001, 48(3), 552-559.

[4] Wu, Y., Moore, M., Saxler, A., Wisleder, T., & Parikh, P. (2006). 40-W/mm Double Field-plated GaN HEMTs improvements v, 2005-2006.

[5] Wu, Y., Saxler, A., Moore, M., Smith, R. P., Sheppard, S., Chavarkar, P. M., Wisleder, T., et al. (2004). 30-W / mm GaN HEMTs by Field Plate Optimization, *25*(3), 2003-2005.

[6] Wang, W.-kai, Lin, C.-huao, Lin, P.-chen, Lin, C.-kuo, Huang, F.-hsiu, Chan, Y.-jen, Member, S., et al. (2004). Low- BCB Passivation on AlGaN – GaN HEMT Fabrication, *25*(12), 763-765.

[7] Her, J.-C., Cho, H.-J., Yoo, C.-S., Cha, H.-Y., Oh, J.-E., and Seo,K.-S:‘ SiNx Prepassivation of AlGaN/GaN High-Electron-Mobility Transistors Using Remote-Mode Plasma-Enhanced Chemical Vapor Deposition’. J. Appl. Phys., 2010, 49(4), 041002.