High-voltage AlGaN/GaN-on-Si HEMTs with ohmic and Schottky drain electrodes

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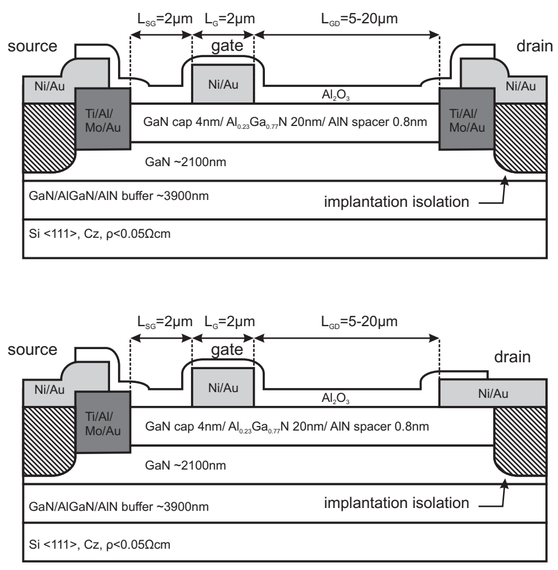
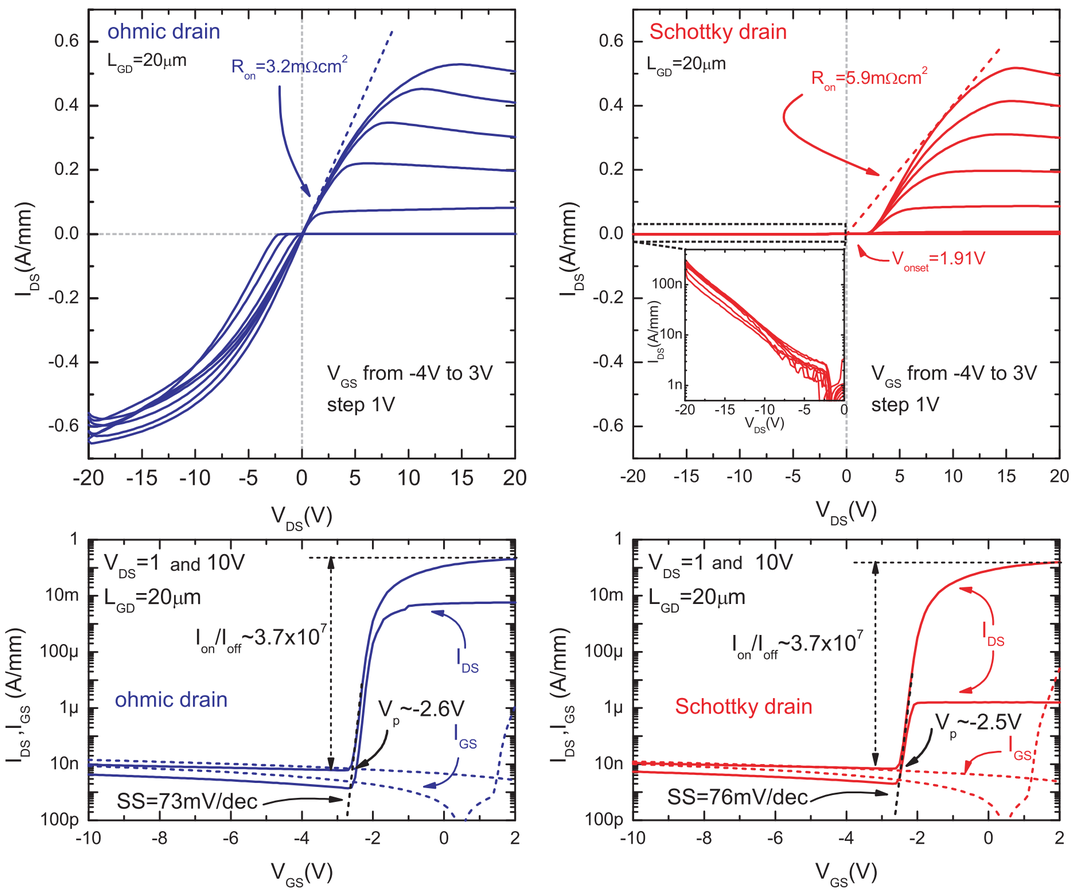
Introduction

AlGaN/GaN High Electron Mobility Transistors (HEMTs) are capable of achieving a high breakdown voltage, small losses and large switching speed due to the excellent properties of III-N materials. Moreover AlGaN/GaN heterostructures can be grown on large diameter, low cost silicon (111) substrates allowing high volume production of power devices. The main obstacle to commercialisation of the AlGaN/GaN-on-Si power devices is much lower breakdown voltage than in the case of HEMTs grown on silicon carbide substrates. To enhance breakdown voltage several approaches have been developed ie. replacement of conventional ohmic drain contacts by the Schottky contacts, use of the regrown n^+- GaN ohmic contacts or use of field-plates. In this work we present characterisation of high-voltage AlGaN/GaN-on-Si HEMTs with mentioned above structures. An increase of breakdown voltage (V_{BR}) in comparison to conventional structure was observed and maximum breakdown voltage was over 1100V, limited by voltage source range.

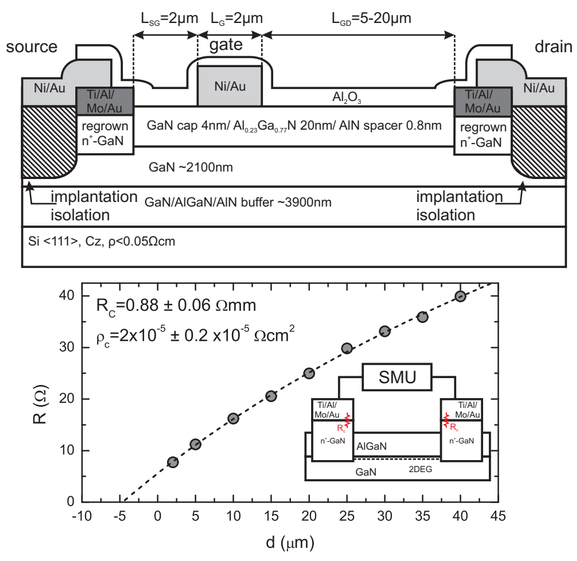
AlGaN/GaN-on-Si high-volatge HEMTs with standard ohmic and Schottky contacts

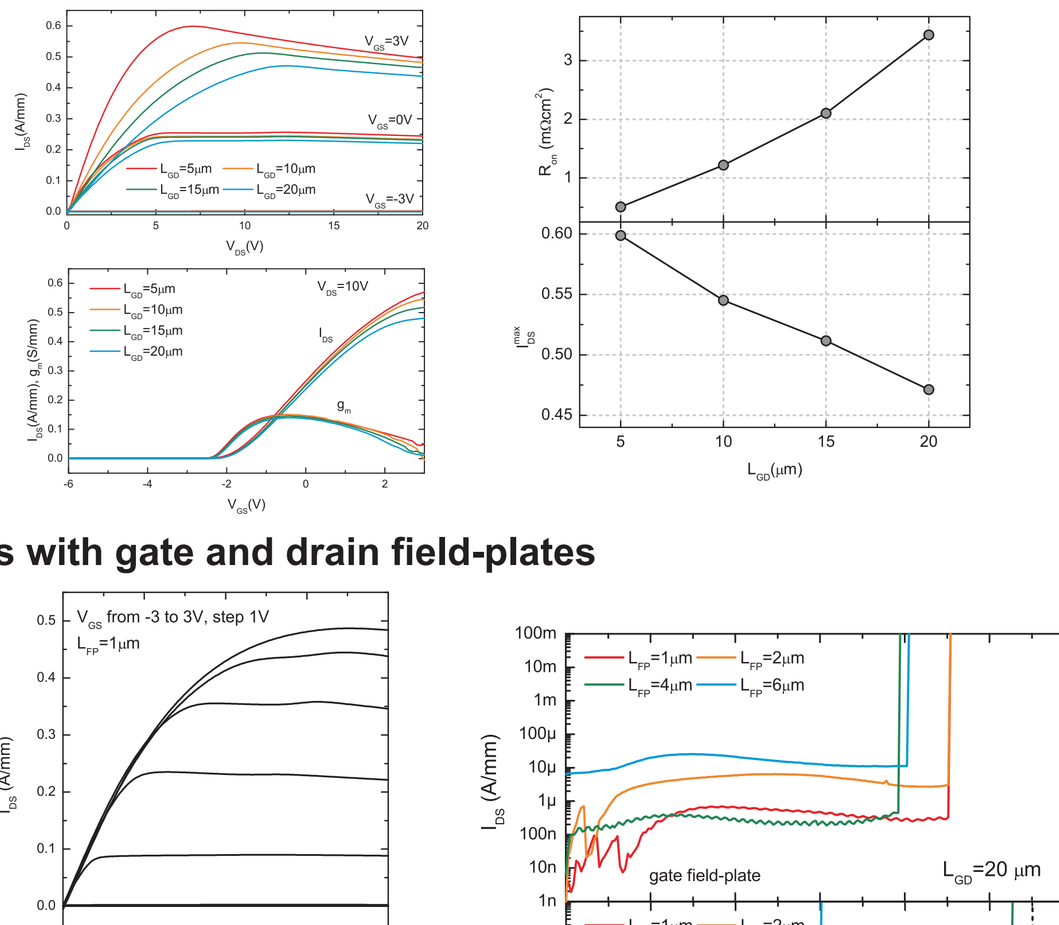


- HEMT structure:
  cap GaN 4nm/$Al_{0.23}Ga_{0.77}N$ 20nm/spacer AlN 0.8 nm/GaN 2.1μm/
  buffer GaN/AlGaN/AlN ~3.9 μm/ Si<111>, ρ<0.05Ωcm
- iisolation: Al^+ implantation, dose and energy -
  800 keV, $1x10^{13}$ cm^{-2} oraz 300 keV, $1.5x10^{13}$ cm^{-2}
- source contacts: Ti/Al/Mo/Au, annealing 850°C, N_2
- gate contacts: Ni/Au
- drain contact: ohmic ***Ti/Al/Mo/Au*** or Schottky ***Ni/Au***
- passivation: ALD Al_2O_3 (100nm)

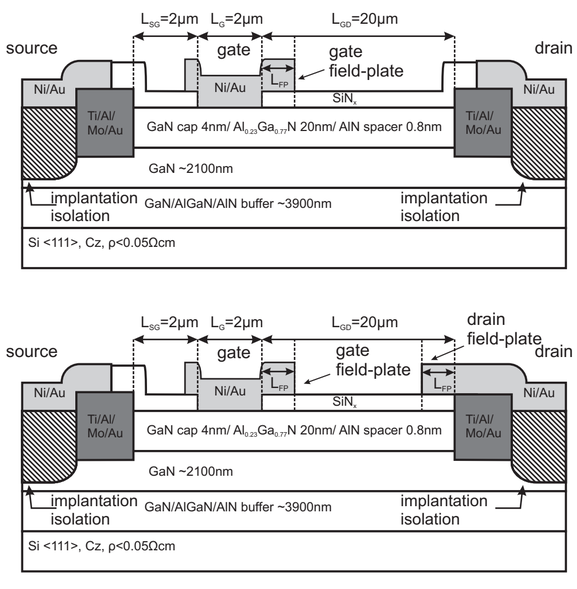


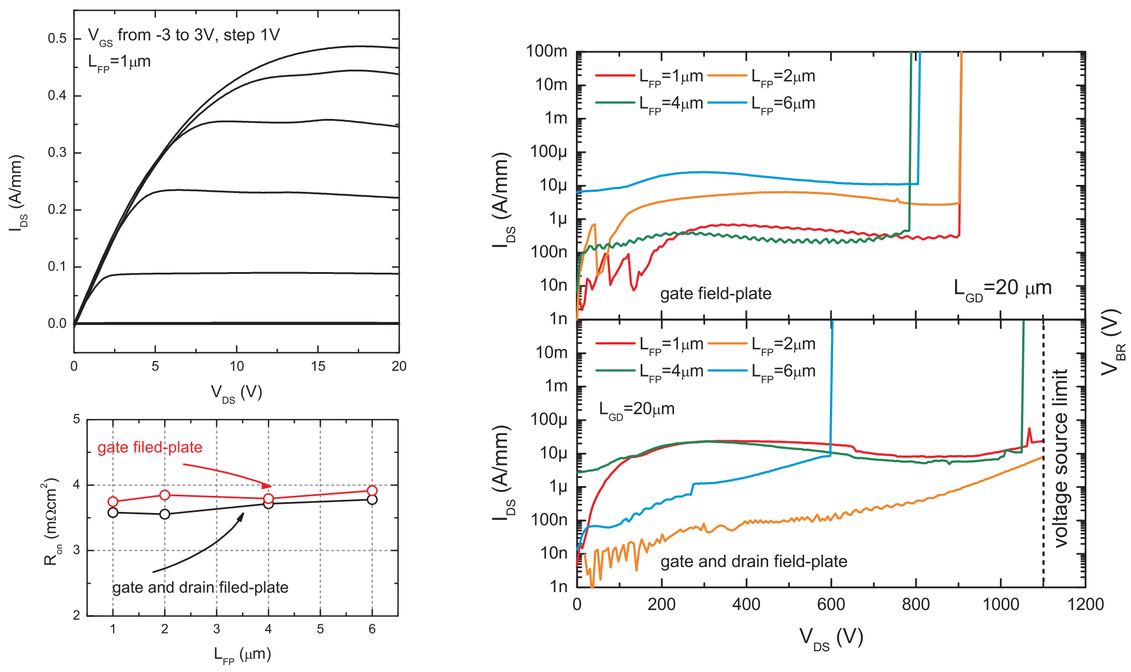
AlGaN/GaN-on-Si high-volatge HEMTs with n^+-GaN regrown ohmic contacts





AlGaN/GaN-on-Si high-volatge HEMTs with gate and drain field-plates





Conclusions

We have experimentally studied high-voltage AlGaN/GaN-on-Si HEMTs:

- Schottky drain structure - V_{BR} increased from 505V to 900V (L_{GD}=20μm), but increasing of $R_{on.}$ Schottky-drain HEMTs are unidirectional devices i.e. there is no current flow for negative V_{DS} bias.
- using regrown ohmic contacts - decreasing R_{on} and increased breakdown voltage to 720V, contact resistance R_c=0.8 Ωmm
- by using drain and gate field-plate maximum V_{BR} over 1100 V was obtained, limited by voltage source range. R_{on} was constant regardless field-plate length

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