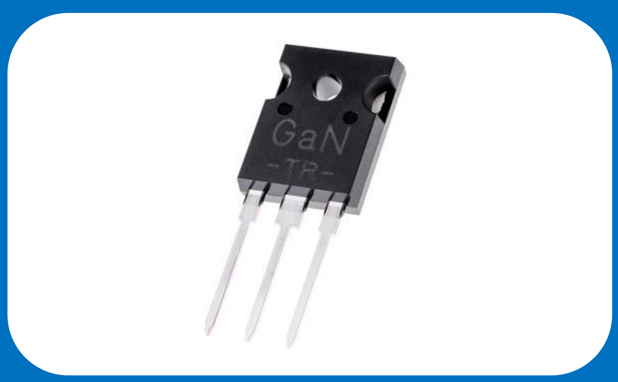
2020 6th International Conference on Mechanical Structures and Smart Materials
JULY 25-26, 2020 HO CHI MINH CITY, VIETNAM

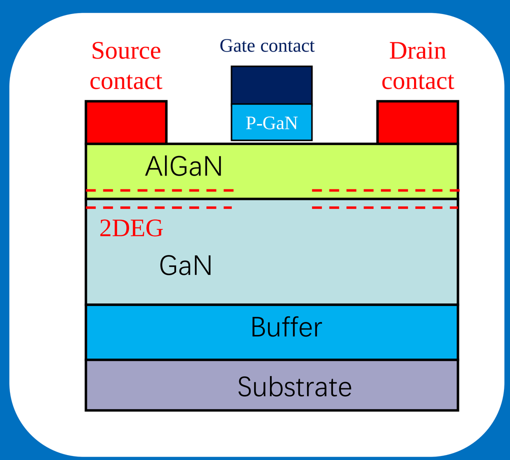
Simulation of Electrical Characteristics on Inhomogeneous Strains in Normally-off HEMTs with p-GaN Gate

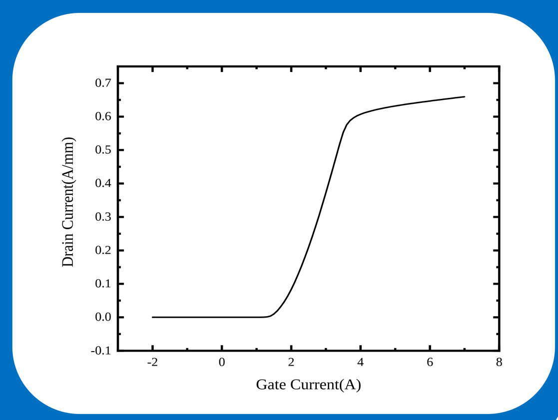
Jing Zhou[1,a*], Hongjun Chen[1,b], Yang Wang[1,c] and Xingming Long[2,d]
[1]Full State Key Lab of Power Transmission Equipment and System Security & New Technology, Chongqing University, Chongqing400047 China
[2]Department of Physics, Chongqing Normal University, Chongqing 401331 China

Introduction

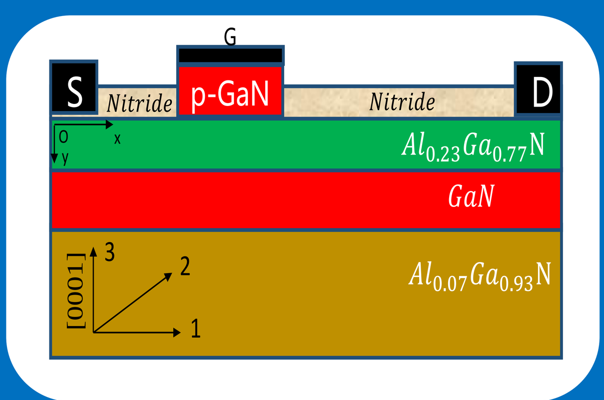
- High Electron Mobility Transistors (HEMTs) based on AlGaN/GaN heterostructures became attractive candidates for high switching frequency, high breakdown voltage and high power due to their excellent electrical properties, compared to their silicon (Si) counterparts[1]
- Several approaches have been reported to obtain normally-off GaN-based HEMTs ,to date the most typical way to yield a normally-off device is the use of a p-GaN gate
- gate bias-induced or passivation layer-induced inhomogeneous strain in the AlGaN barrier will cause a decrease in polarization charge and reduction in two dimensional electron gas 2DEG,which will affect electrical characteristics of devices



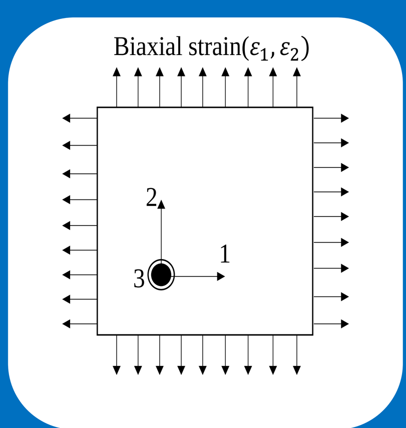




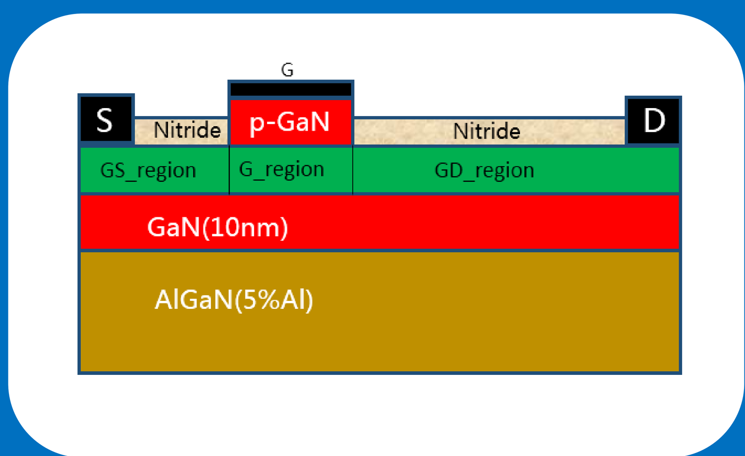
Structure Model and Analysis Method



Schematic diagram of HEMT



HEMT under biaxial applied strain



Schematic diagram of HEMT under inhomogeneous strain

- We simulated the uneven stress (biaxial strain) of the three regions by adjusting the lattice constants[2] of the materials in the three regions of the AlGaN barrier layer, and observed the effect of non-uniform strain on the electrical characteristics of the device.

$$\epsilon_1' = \epsilon_2' = \frac{a - a_0}{a_0}, \quad \epsilon_3' = -2\frac{C_{13}}{C_{33}}\epsilon_1'$$

Conclusion

In Region-G or gate region, the strain has the most predominant impact on V_{br} with *a* decreasing of 39%, while I_{sat} with an increasing of 97% as the *a* increases from 3.173061Å to 3.187229Å. In addition, the V_{br} can be improved with 12% by strain between the gate and drain electrode or Region-GD when the *a* increases.

Results

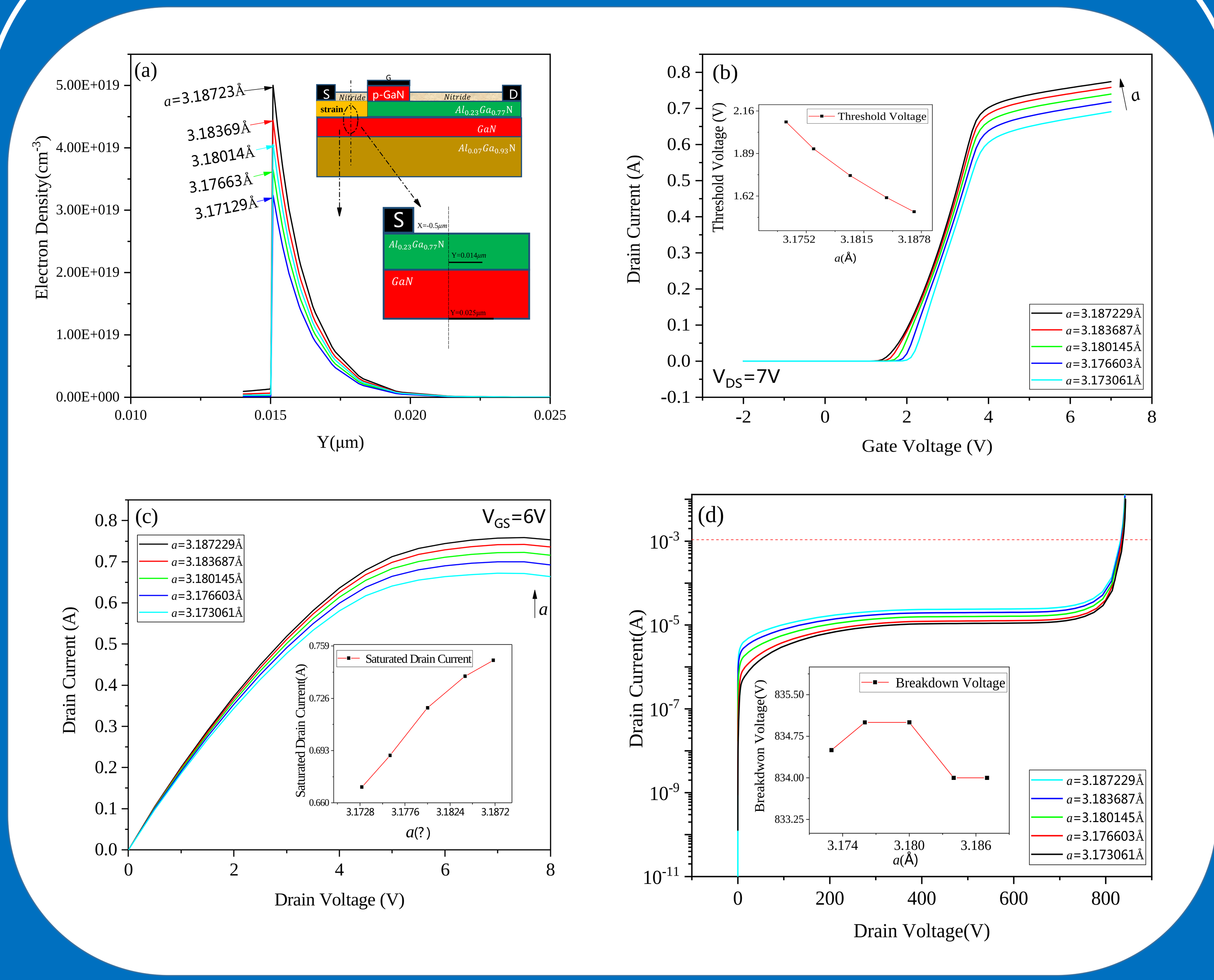
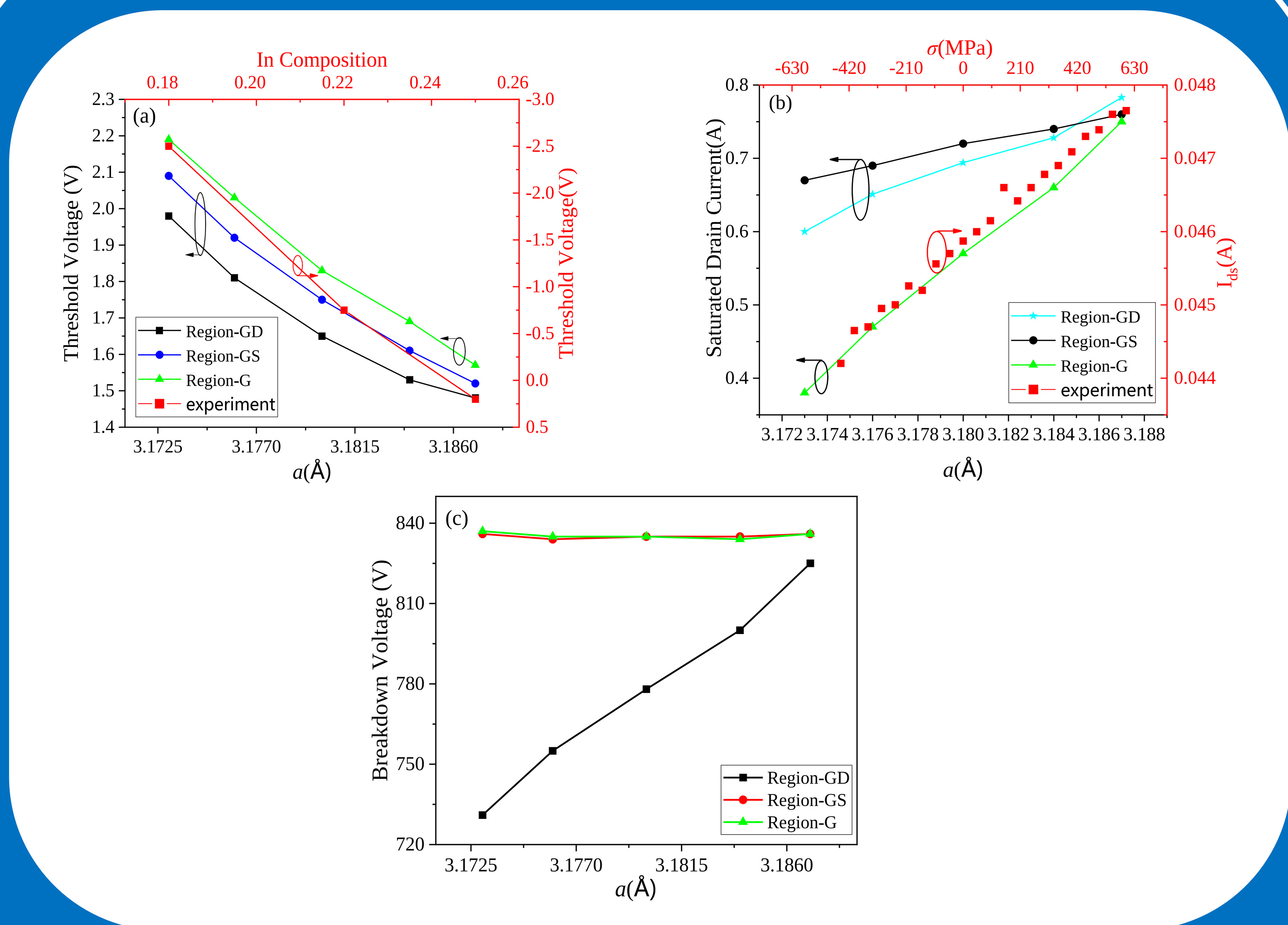


Fig.1 The impact of strained lattice constant a in Region-GS on electrical characteristics.(a) the cross-sectional 2DEG density at x= -0.5μm where the peak 2DEG density was located close to the AlGaN/GaN interface.(b) transfer characteristics.(c) output characteristics.(d)breakdown characteristics. The insets give the change of V_{th}, I_{sat}, V_{br} against strained lattice constant a.

- Strain-enhanced V_{th} can be derived from reduced density of 2DEG in the Region-GS, and the gate voltage required to open the channel shift positively
- This reduction in I_{sat} may be caused by the lower density of 2DEG due to a smaller a in the Region-GS which affecting the sheet resistance and current drive
- The results in Fig.1(d) denote that local strain in Region-G has a little impact on the off-state breakdown characteristics

Results



The relationship between the strained lattice constant a of Region-GS, Region-G and Region-GD in HEMT and the electrical features, compared to the experimental data: (a) the threshold voltage V_{th}, (b) the drain saturation current I_{sat}, and (c) the breakdown voltage V_{br}.

- The results indicate that strain in Region-G has the most significant influence on V_{th}
- Strain in Region-G has the most influence on I_{sat}
- The breakdown voltage has an evident positive shift under the strain of Region-GD

References : 1 Greco, Giuseppe Iucolano, Ferdinando Roccaforte, Fabrizio, “Review of technology for normally off HEMTs with p-GaN gate,” MAT SCI SEMICON PROC., no. 78, pp. 96-106, Oct. 2018.
2 Tong W, Tang W, Zhang Z. “Electron transport in AlGaN/GaN HEMTs using a strain model.” COMP MATER SCI, vol. 143, pp. 391-397 Nov 2017.