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Effect of Buffer Mole Fraction on AlGaN/GaN Field-Plated HEMT on Threshold, Device Leakage and Frequency

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ABSTRACT: In this paper,the effect of buffer mole fraction on AlGaN/GaN fieldplated High Electron Mobility Transistor(HEMT)with composite AlGaN/GaN buffer were investigate.The sandwich of AlGaN and GaN mainly depends on Al mole fraction as it defines the bandgap and lattice constant of AlGaN.TheLow Al composition (7%) delivers an increased breakdown voltage and decreased drain leakage current.So,the mole fraction of AlGaN bufferis varied from 0.0 to 0.07 and the device characteristics such as threshold voltage,device leakage and frequency are measured.

KEYWORDS: Field-Plate,Composite Buffer,Mole Fraction.

I. INTRODUCTION

Gallium nitride(GaN) based HEMTs are used for high temperature and high power microwave applications due to its large energy bandgap,high electron saturation velocity,and high 2-Dimensional Electron Gas(2DEG) Density at AlGaN/GaN heterointerface.Due to the large conductionband discontinuity between
AlGaN and GaN high electron mobility and high electron saturation velocity have been demonstrated in the AlGaN/GaN system.These parameters are essential for high frequency operations.The presence of piezoelectric and spontaneous polarization in GaN leads to a high carrier concentration which results in high current density at interface without any intentional doping.Moreover, GaN has wide band gap and high breakdown electric field.The advantage of high current density and high breakdown field enable this material to be an excellent candidate for high power application. AlGaN/GaN HEMTs are usually grown on silicon carbide substrate(SiC). SiC is a good substrate because of its high thermal conductivity.During, heteroepitaxy,impurities are introduced at the interface and may leads to leakage path,which reduce the on off ratioand off-state breakdown voltage. Several solutions are introduced to reduce the buffer leakage,suchas deliberate introduction of deep-level impurities,Fe or C into GaN buffer.In this work,Low Al composition AlGaN buffer technology are introduced in the buffer to suppress buffer leakage and short channel effects (SCE)[1-2].

II. DEVICE STRUCTURE

The AlGaN/GaN HEMT wafers are prepared by MOCVD,Aixtron 2400.The cross-sectional schematic structure and material parameters are shown in Fig.1 and Table.1.The composite AlGaN/GaN buffer were adopted to realize better 2DEG confinement.

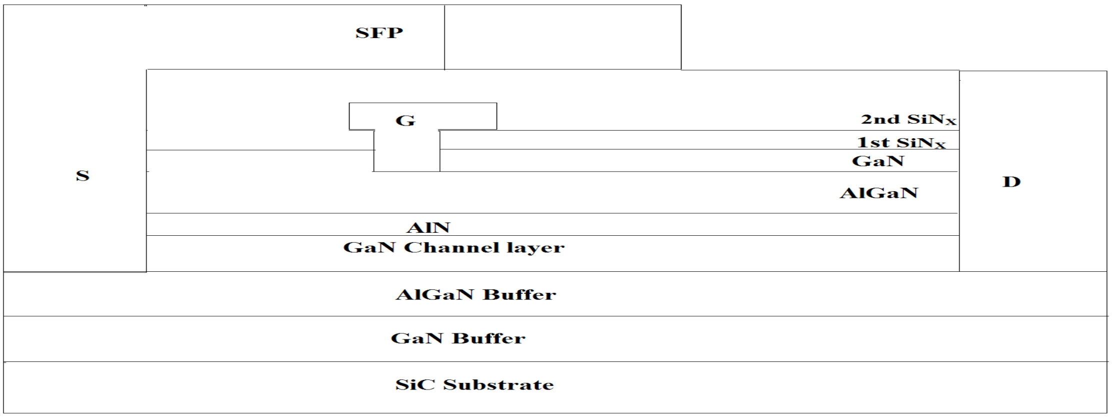

Fig.1.Cross sectional schematic view of AlGaN/GaN HEMT.

Layer	x	d(nm)
GaN Cap	-	2
AlGaN Barrier	21%	25
AlN interlayer	-	1
GaN Channel	-	150
AlGaN buffer	0-7%	1000
GaN buffer	-	1000
Sheet density(C-V)	7.9x1012cm^{-2}	-
Sheet resistance(TLM)	336Ω/sq	-

X=Al mole fraction d=thickness

Table.1.Material parameters

The HEMT fabrication was started with ohmic contact formed by a Ti/Al/Ni/Au metal stack.The specific contact resistance is 0.8Ω.mm.A 120-nm thick SiN_x surface passivation layer was grown by plasma-enhanced chemical vapour deposition(PECVD) to passivate the surface and to assist the fabrication of gate electrode. Device isolation was done by multiple energy N^+ implantations. The 0.35µm gate was accomplished by electron beam lithography and dry etching through PECVD-SiN_xlayer and recess of the GaN cap layerfollowed by a secondlithography and schottky gate fabrication.A second PECVD_SiN_x of 200nm was grown to facilitate the fabrication of source-connected field plates.Finally,multi-finger source electrodes are connected with air-bridge formed by sputtered seed metal Ti/Au and thick Au electro-platting.Meanwhile,circular schottky diodes are fabricatedfor 2DEG density determination.

As shown in Fig.1 the source-drain spacing(L_{SD})and source-gate spacing(L_{SG}) of AlGaN/GaN HEMTs are 4µm and 1µm respectively.Devices with 10X100µm gate width used for DC and RF characterization.

III. RESULTS AND DISCUSSION

A.DC and RF Charaterization

Fig.2(a) shows the transfer characteristics of AlGaN/GaN HEMTs with different mole fractions of AlGaN buffer ,measured at $V_{ds=}$5V.Increasing mole fraction will results in increased drain current.This can be explained by the fact that the incresing mole fraction leads to higher polarization

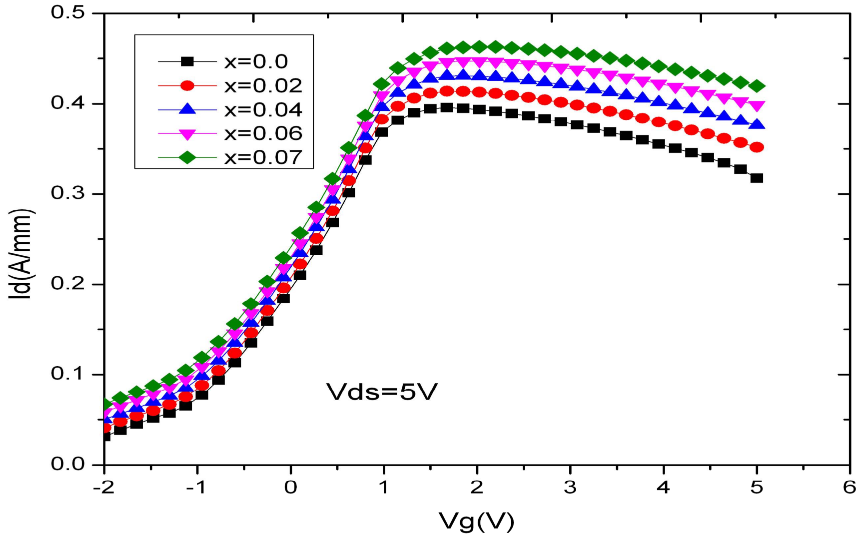

Fig.2(a).Transfer charaeristics of AlGaN/GaN HEMT with Different AlGaN buffer mole fraction.

induced elecrtric field.As a result,the conduction band at the heterojunction rises,leads to increase in electron confinement.Increase in electron confinement reduce the scattering of electron from 2DEG into the GaN buffer.This leads to reduced short channel effect which results in high output resistance R_{ds}.

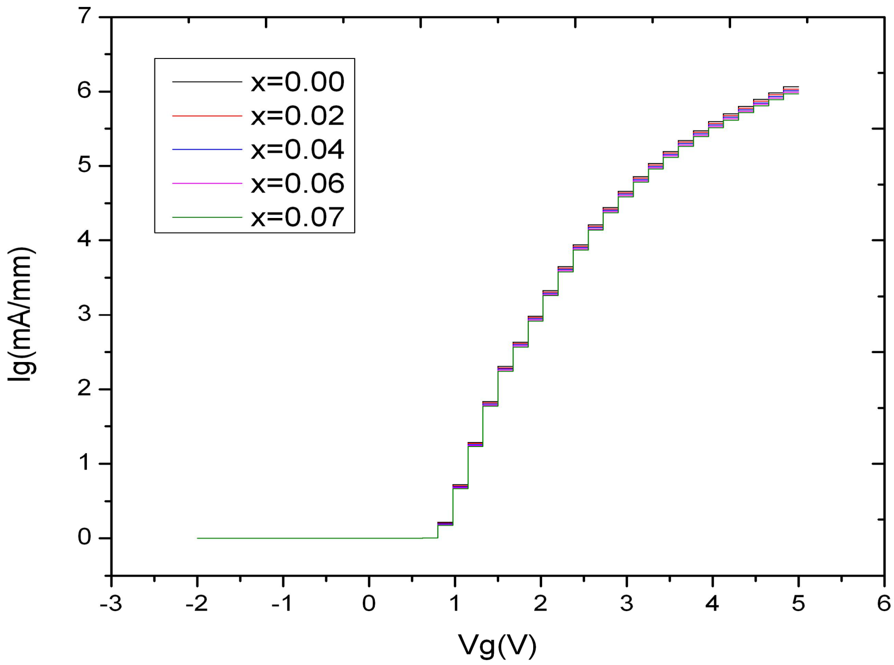

Fig.2(b).Gate leakage characteristics of AlGaN/GaN HEMT with different AlGaN buffer mole fraction.

In Fig.2(b).we can see that the gate leakage of AlGaN/GaN HEMT is reduced for AlGaN buffer mole fraction of 0.07.

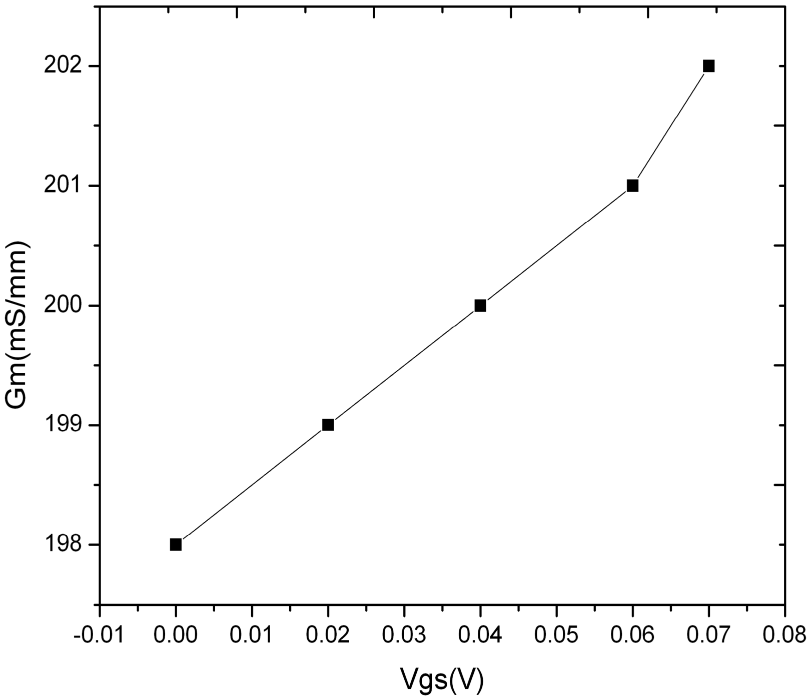

Fig.3.Transconductance for different AlGaN buffer mole fraction.

From Fig.3.for mole fraction x=0.07 the maximum transconductance is 202 mS/mm.It is clear that for increasing mole fraction transconductance is increases. This isbecause the electron confinement at interface is high.

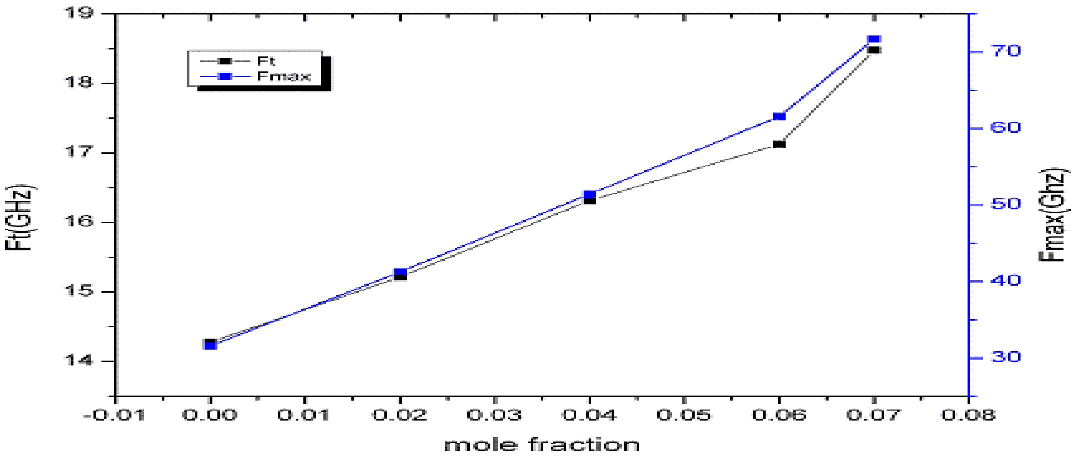

Fig.4.RF characteristics of AlGaN/GaN HEMT with different AlGaN buffer mole fraction.

For high mole fraction 2DEG confinementat interface is high.This leads to reduced short channel effect and high output resistance $R_{ds.}$Since F_{max} is proportional to the output resistance R_{ds}there will be increased $F_{max.}$In Fig.4.The maximum F_{max} 71.2138GHz and F_t 18GHz is obtained for the mole fraction of x=0.07.

IV. CONCLUSION

The effect of AlGaN buffer mole fraction on threshold voltage,device leakage and frequency were systematically investigated.Al mole fraction controls the conduction band edge discontinuity at the heterojunction and therefore the confinement of electron GaN channel is high.This leads to increased 2DEG,drain current,transconductance and frequency.

REFERENCES

[1]M. J. Uren *et al.*, "Punch-through in short-channel AlGaN/GaN HFETs,"*IEEE Trans. Electron Devices*, vol. 53, no. 2, pp. 395–398, Feb. 2006.

[2]S. Heikman, S. Keller, S. P. DenBaars, and U. K. Mishra, "Growth of Fe doped semi-insulating GaN by metalorganic chemical vapour deposition,"*Appl. Phys. Lett.*, vol. 81, no. 3, pp. 439–441, Jul. 2002.

[3]Y. F. Wu *et al.*, "30-W/mm GaNHEMTs by field plate optimization,"*IEEE Electron Device Lett.*, vol. 25, no. 3, pp. 117–119, Mar. 2004.

[4]J. S. Moon *et al.*, "Gate-recessed AlGaN-GaNHEMTs for high performance millimeter-wave applications," *IEEE Electron Device Lett.*,vol. 26, no. 6, pp. 348–350, Jun. 2005.

[5]S. C. Binari *et al.*, "Trapping effects and microwave power performance in AlGaN/GaN HEMTs," *IEEE Trans. Electron Devices*, vol. 48, no. 3,pp. 465–471, Mar. 2001

.[6] Shihyun Ahn, Weidi Zhu, Chn Dong, Lingcong Le, Ya-Hsi Hwang, Byung-Jae Kim, Fan Ren, Stephen J.Pearton, Aaron G. Lind, Kevin S. Jones, I. I. Kravchenko, and Ming-Lan Zhang."Study of the effects of GaN buffer layer quality on the dc characteristics of AlGaN/GaN high electron mobility transistors"**.** Journal of Vacuum Science & Technology B **33**, 031210

[7]Matteo Meneghini, *Senior Member, IEEE*, Isabella Rossetto, Davide Bisi, Antonio Stocco, Alessandro Chini,Alessio Pantellini, Claudio Lanzieri, Antonio Nanni, Gaudenzio Meneghesso, *Fellow, IEEE*,and Enrico Zanoni, *Fellow, IEEE"* Buffer Traps in Fe-Doped AlGaN/GaN HEMTs:"Investigation of the Physical Properties Basedon Pulsed and Transient Measurements"IEEE TRANSACTIONS ON ELECTRON DEVICES, VOL. 61, NO. 12, DECEMBER 2014.

[8]Lu Liu, Chien-Fong Lo, Yuyin Xi, Fan Ren, Stephen J. Pearton, Oleg Laboutin, Yu Cao, J.Wayne Johnson, andIvan I. Kravchenko"Effect of buffer structures on AlGaN/GaN high electron mobilitytransistor reliability"Journal of Vacuum Science & Technology B 31, 011805 (2013).

[10] Ma Juncai., Zhang Jincheng, Xue Junshuai, Lin Zhiyu,Liu Ziyang, Xue Xiaoyong, Ma Xiaohua, and Hao Yue"Characteristics of AlGaN/GaN/AlGaN double heterojunction HEMTs with animproved breakdown voltage" Vol. 33, No. 1 Journal of Semiconductors January 2012.