Electrical characterisation of InAlN/AlGaN/GaN HEMT on Si substrate with varying InAlN thickness

Konstantinos Floros[a], Xu Li[a], Ivor Guiney[b], Sung-Jin Cho[a], Gary Ternent[a], Dilini Hemakumara[a], Olesya Ignatova[a], David A.J. Moran[a], Edward Wasige[a], Colin J. Humphreys[b] and Iain G. Thayne[a]
[a] School of Engineering, University of Glasgow, Rankine Building, Oakfield Avenue, Glasgow, G12 8LT
[b] Department of Materials Science & Metallurgy, University of Cambridge, Cambridge CB3 0FS UK
e-mail: k.floros.1@research.gla.ac.uk

Introduction

Semiconductor nitrides such as aluminium nitride (AlN), gallium nitride (GaN) and indium nitride (InN) are attractive for high power applications due to their large band gap, high critical electric field and good electron transport properties. These materials and their ternary alloys, especially AlGaN and GaN are widely used in high electron mobility transistors, where 2-D electron gas (2DEG) sheet charge is created by spontaneous and piezoelectric polarisation at the AlGaN/GaN interface [1]. Compared to AlGaN/GaN, InAlN based heterostructures can induce higher quantum well polarisation charges, which in turn result in higher device currents [2].

Hiroki et al [3-4] have demonstrated the growth of InAlN/AlGaN/GaN on sapphire (Al_2O_3) substrates. They tested Schottky gate HEMT based on these structures and reported improved gate leakage current and sub-threshold swing compared to devices that use an InAlN/AlGaN based structure with similar barrier heights. These promising epi-layer structures are limited by the choice of substrate. An extension of the technology to silicon substrates is more cost-effective and important for future commercialisation.

In this work, we have demonstrated InAlN/AlGaN/GaN HEMT on Si substrates and characterised three wafers with different InAlN thicknesses using room temperature Hall measurements and transfer length method (TLM) measurements.

Experiments and Results

The HEMT structures were grown on 6″ diameter silicon wafer by MOCVD. The structures were first isolated by a 600nm deep mesa etch using $SiCl_4$ reactive ion etching (RIE). Consequently, Ti/Al/Ni/Au source and drain ohmic contacts of 30/180/40/100 nm thicknesses were deposited by lift-off and annealed at 770° C for 30s in N_2 atmosphere. This was followed by the formation of Schottky gate Ni/Au contacts of 20/200 nm thicknesses, also using the lift-off technique.

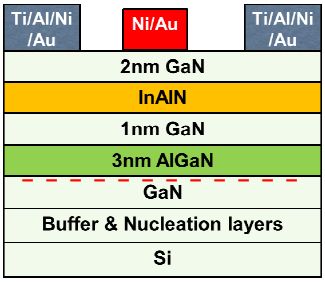

Fig.1. InAlN/AlGaN/GaN HEMT layer structure.

Table 1: TLM and Hall measurements for varying InAlN thicknesses.

x nm InAlN	TLM		Hall measurements		
	R_c (Ωmm)	R_{sh} (Ω/sq)	R_{sh} (Ω/sq)	μ_H (cm^2/Vs)	n_H ($x10^{13}$ cm^{-2})
x = 5nm	0.95	273	277	1540	1.47
x = 6nm	0.67	300	301	1370	1.52
x = 8nm	0.67	306	323	1060	1.82

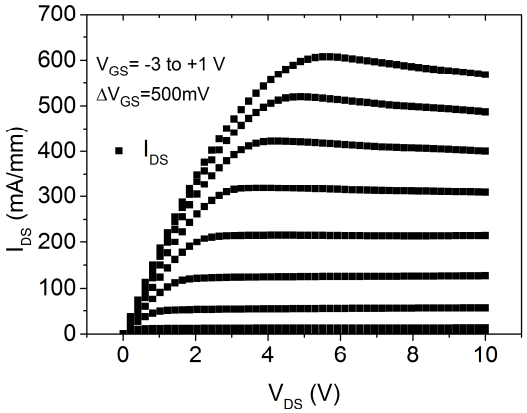

Fig.2. DC output characteristics of 8nm InAlN/3nm AlGaN/GaN HEMT (W_g=100µm, L_{ds}=12µm, L_g=3µm).

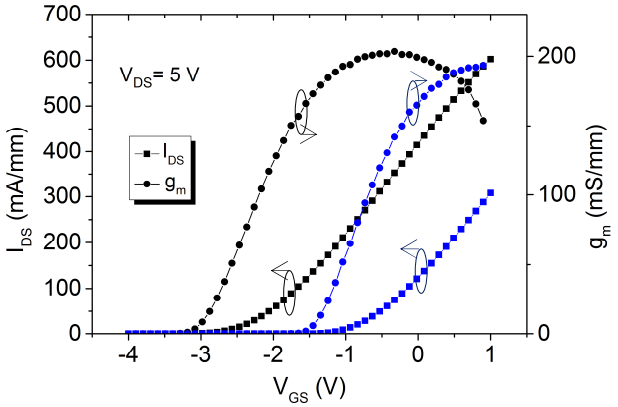

Fig.3. Comparison of transfer characteristics for 8nm InAlN (black) and 5nm InAlN (blue). The increased polarisation-induced charge for thicker (8nm) InAlN, results in a more negative threshold voltage.
(W_g=100µm, L_{ds}=12µm, L_g=3µm)

The low sheet and contact resistances as well as the smooth surface of the wafers grown resulted in high maximum currents I_{DS} > 600mA/mm and transconductance g_m > 200 mS/mm.

Acknowledgments

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References

[1] A. Bykhovski, B. Gelmont, and M. Shur, "The influence of the strain-induced electric field on the charge distribution in GaN-AlN-GaN structure," *J. Appl. Phys.*, vol. 74, no. May 2013, pp. 6734–6739, 1993.

[2] J. Kuzmík, "Power electronics on InAlN/(In)GaN: Prospect for a record performance," IEEE Electron Device Lett., vol. 22, no. 11, pp. 510–512, 2001.

[3] M. Hiroki, N. Maeda, and T. Kobayashi, "Electrical properties and device characteristics of InAlN/AlGaN/AlN/GaN heterostructure field effect transistors," *Phys. Status Solidi Curr. Top. Solid State Phys.*, vol. 6, no. SUPPL. 2, pp. 1–5, 2009.

[4] M. Hiroki, N. Maeda, and T. Kobayashi, "Fabrication of an InAlN/AlGaN/ AlN/GaN Heterostructure with a Flat Surface and High Electron Mobility," *Appl. Phys. Express*, vol. 1, p. 111102, 2008.