Linearity Performance Enhancement of DMG AlGaN/GaN High Electron Mobility Transistor

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ABSTRACT

In the work presented, Dual Material Gate (DMG) AlGaN/GaN HEMT is studied for its superior linearity performance as compared to the conventional Single Metal Gate (SMG) HEMT using ATLAS device simulator. The device transconductance, drain conductance, VIP3 and IMD3 have been used for the performance assessment of the DMG HEMT and the results indicate an appreciable reduction in IMD3 and significant increase in VIP3 as compared with the SMG counterpart for its application in low noise amplifiers and 3-G mobile communication.

Keywords: ATLAS, DMG, HEMT, Linearity, Transconductance, RF , VIP3.

1 INTRODUCTION

HEMTs are promising devices for high speed integrated circuits and RF wireless communications [1-3]. Recent experiments indicate that owing to the material properties of GaN, AlGaN/GaN HEMTs demonstrate higher unity-gain cutoff frequency putting the material system in a good position for RF/microwave transistors [4]. During the last few years, outstanding high speed performance has been achieved through better design and gate length reduction. However, reduction of gate length down to deep sub-micron leads to undesirable short channel effects (SCE) such as drain induced barrier lowering (DIBL), hot electron effect and poor carrier transport efficiency. In 1999, Long [5-7] proposed a new structure (DMGFET) wherein the two materials with different workfunctions are amalgamated together to form a gate. The use of the two gate metals leads to a step function in the channel potential and a peak in the electric field distribution at the interface of the two gate metals. This results in reduced SCEs like DIBL, increased transconductance and on current and reduced drain conductance .

For wireless communication applications and RF circuit design, linearity is one of the most important issues. This is because the devices used in the system may produce non-linear distortion and thus degrade the S/N ratio of the system. For short gate HEMTs, the transconductance and output drain conductance become important sources of non-linearity. Thus, the device structure needs to be tailored to improve the RF performance of the devices used in the system. Since, in DMG HEMT [8] peak transconductance occurs at much lower V_{gs} and it exhibits lower drain conductance in the saturation region, hence, it is worth exploring its linearity performance.

This present work sheds light on the improved linearity performance of DMG $Al_{0.2}Ga_{0.8}N$/GaN HEMT in comparison with the corresponding SMG HEMT in terms of IMD3, which represents the third order intermodulation distortion power and mainly determines the harmonic distortion. Other parameters used as linearity metrics are *gm2*, *gm3*, *gd2*, *gd3* and *VIP3*, the extrapolated input voltage at which the first and the third harmonics are equal. All simulations have been performed using ATLAS [9] device simulation software. The models used in simulation include CONMOB and FLDMOB for mobility

2 SIMULATION RESULTS AND DISCUSSION

In the figures shown the solid symbol denote the conventional HEMT and hollow symbols denote DMG AlGaN/GaN HEMT (Fig.1).

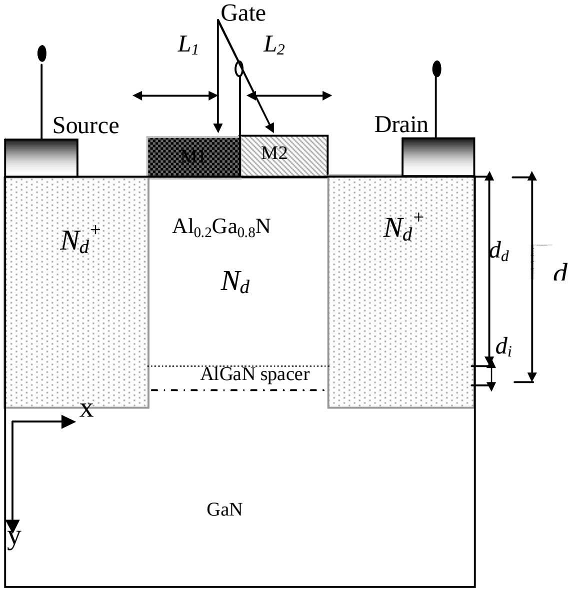

Fig.1 Schematic diagram of Al0.2Ga0.8N/GaN HEMT with $Nd^+=1x10^{26}m^{-3}$, L=L1+L2=120nm, d=30nm, W=20μm

At higher frequencies, g_{m3} and g_{d3} are the dominant nonlinear sources. Harmonic distortion is present due to the nonlinearity of these higher order components and hence their amplitude should be minimized. Fig. 2 and 3 give the variation of g_{m1}, g_{m2} and g_{m3} with gate bias for SMG HEMT and DMG HEMT respectively and clearly depict that peak in g_{m3} occurs at a lower V_{gs} and is less for DMG HEMT . Fig. 4 and 5 give the plot of g_{d1}, g_{d2} and g_{d3} with gate bias for SMG and DMG respectively. Although g_{d3} for DMG HEMT is marginally higher than SMG HEMT, the zero crossover occurs at a much lower V_{ds} implying that a lower V_{ds} is needed to minimize this harmonic distortion.

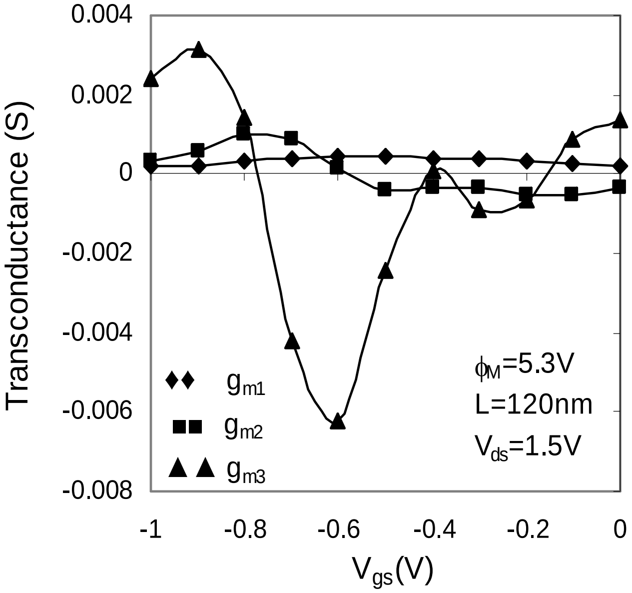

Fig.2 shows the simulated g_{m1},g_{m2} and g_{m3} vs V_{gs} characteristics for conventional HEMT.

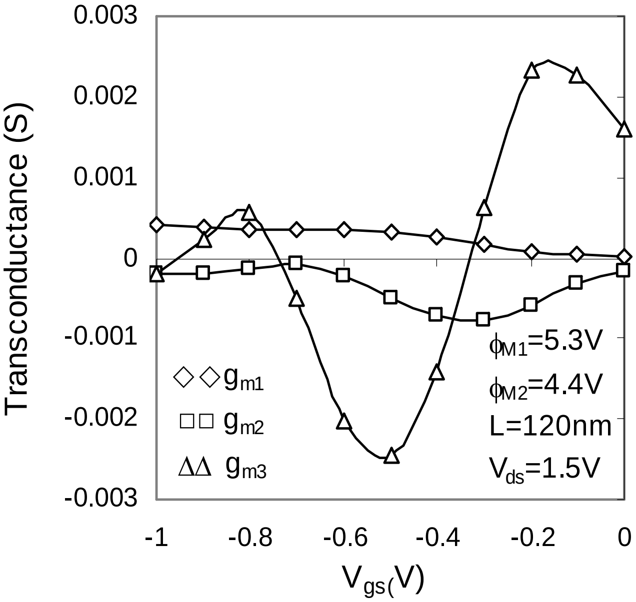

Fig3. shows the simulated g_{m1},g_{m2} and g_{m3} vs V_{gs} characteristics for DMG HEMT.

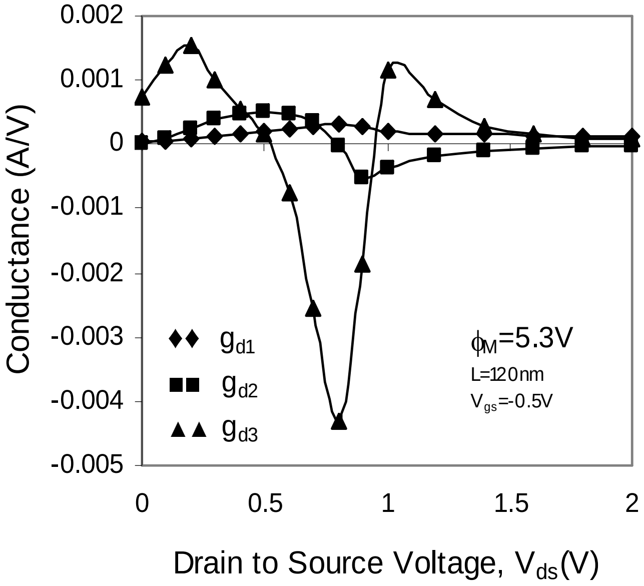

Fig.4. shows the simulated g_{d1},g_{d2} and g_{d3} vs V_{gs} characteristics for conventional HEMTs.

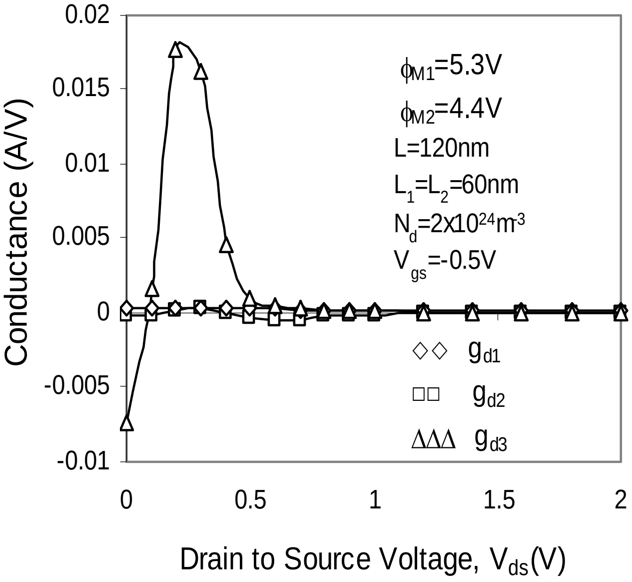

Fig.5 shows the simulated g_{d1},g_{d2} and g_{d3} vs V_{gs} characteristics for DMG HEMTs.

Figure 6 shows the *VIP3* variation with the applied gate bias. For linearity, *VIP3* is used as a first order parameter and a large *VIP3* is required for high linearity. Figure shows that in DMG HEMTs the singularity in *VIP3* occurs at a much lower V_{gs}. The shift of peak towards higher V_{gs} (as in SMG HEMT) is not desirable as it implies that a higher V_{gs} is needed to preserve the linearity. Fig. 7 shows the plot of third order intermodulation distortion power (*IMD3)* with the gate bias. This linearity parameter should be minimized to reduce distortion. IMD3 originates from the nonlinearity exhibited by the transistor's I_{ds}-V_{gs} characteristics and leads to corrupting signals in the wireless systems Figure clearly shows that DMG HEMT exhibits a much lower *IMD3*due to reduction in hot carrier effect. Thus, by applying DMG architecture on the conventional HEMT, we can minimize the linearity degradation and improve the RF performance of these devices.

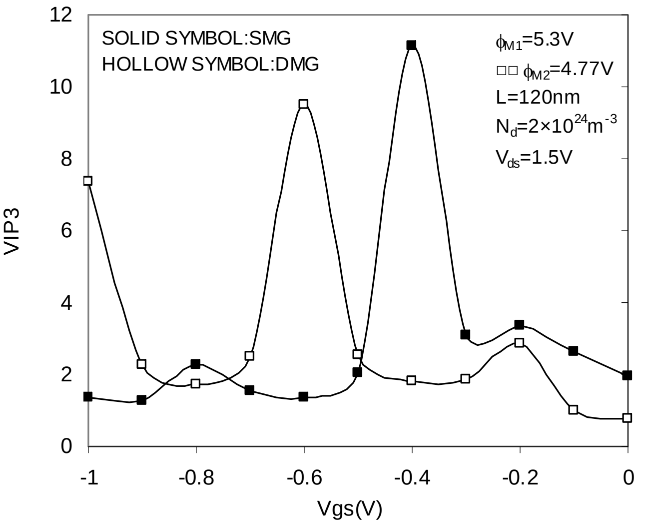

Fig.6 shows the simulated *VIP3* variation with applied gate bias for DMG and conventional HEMTs.

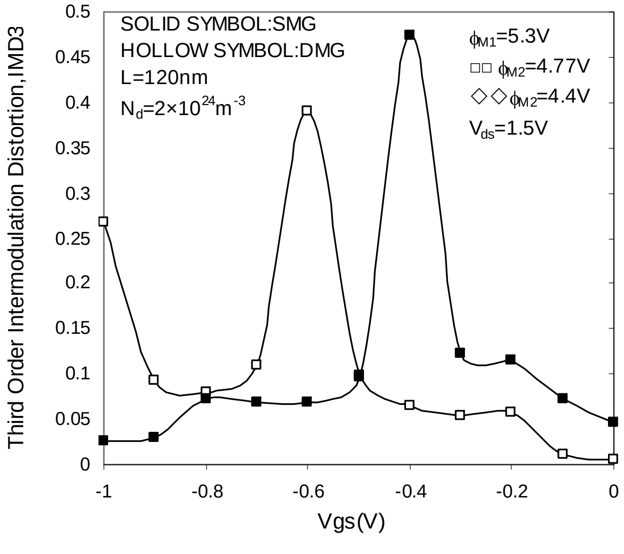

Fig.7 shows the simulated *IMD3* vs V_{gs} characteristics for DMG and conventional HEMTs.

3 CONCLUSION

In this paper, DMG AlGaN/GaN HEMT has been analysed through ATLAS device simulation. On comparison with the SMG counterpart, we conclude that DMG HEMT is more linear as it exhibits a much higher VIP3 and reduced IMD3 due to better screening which in turn leads to reduced hot carrier effect and better gate control. As a result, DMG HEMT is more suitable for communication systems that require high linearity operation.

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