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A New n-GaAs/n$^+$-InGaAs Doped-Channel MIS-Like FET

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A new doped-channel MIS-like FET has been demonstrated and prepared by LP-MOCVD technique. An n$^-$-GaAs and n$^+$-InGaAs layers were employed as gate Schottky contact layer and active channel, respectively. The reported device (gate length = 2μm) takes advantages of high saturation current density (930mA/mm), high extrinsic transconductance (230mS/mm), high breakdown voltage (17.4V) and very large gate voltage swing (more than 3.2V), which are attributed to the excellent carrier confinement, reduced parallel conduction and improved Schottky contact.

1. INTRODUCTION

The use of pseudomorphic strained layers of InGaAs in the channel region of high electron mobility transistor (HEMT) structures has led to considerable improvements in device performance[1,2] due to the lower effective mass and larger Γ-L separation. However, for the applications to high-speed, high-frequency, and high-power circuits, the FET devices are required to present high current handling capability, high breakdown voltage, good current linearity, high cut-off frequency, and broad range of high transconductance for large input signal operations.[3,4] For conventional HEMT structures, highly doped layer just under the gate is difficult to obtain a higher breakdown voltage. Meanwhile, the parallel conduction in the n-AlGaAs layer usually gives rise to a significant trans- conductance g_m compression effect[5], and leads to a lower gate voltage swing that is not suitable for large input signal operations. Other problems such as the DX centers generated in the n-type-AlGaAs layers and the difficulty for growing high-quality AlGaAs layers may limit the further developments on AlGaAs system.

In order to overcome these problems, Hida et al. have proposed the doped-channel MIS-like FET structures[3,4,6]. In their reported devices, the output current drivability, gate voltage swing for high transconductance, and gate breakdown voltage etc. were all improved significantly. In this letter, we propose a new doped-channel MIS-like FET structure. This device presents the advantages of (1) very large gate voltage swing, (2) high current drivability, (3) high breakdown voltage, and (4) absence of the AlGaAs layers. Furthermore, due to its simple structure, this device is relatively easy to fabricate.

2. EXPERIMENTS

The studied device structure was prepared by low-pressure (80Torr) metalorganic chemical vapor deposition (MOCVD) on a (100)-oriented semi-insulating GaAs substrate. The layer structure consisted of a 0.5μm undoped GaAs buffer layer, a 120A n$^+$-In$_{0.2}$Ga$_{0.8}$As (n$^+$ = 4×10^{18}cm^{-3}) active layer, a 500A n$^-$-GaAs (n$^-$ = 5×10^{16}cm^{-3}) Schottky-contact layer, and finally a 300A n$^+$-GaAs (n$^+$ = 3×10^{18}cm^{-3}) cap layer. After layer growth, a conventional evaporation, lift-off, and wet chemical etching techniques were employed to fabricate the mesa-type device. Figure 1 shows the schematic diagram of the presented device structure with the gate dimension of 2×100μm^2.

3. RESULTS and DISCUSSIONS

Figure 2 shows the gate breakdown measurement at 300K. A breakdown voltage as high as 17.4V with low leakage current is observed. This value is superior to conventional MESFET's and HEMT's, which is attributed to the presence of n$^-$-GaAs Schottky barrier layer. The low-doping concentration in n$^-$-GaAs layer must low enough to enhance the Schottky effect while its total doping amount (integrate the doping concentration through

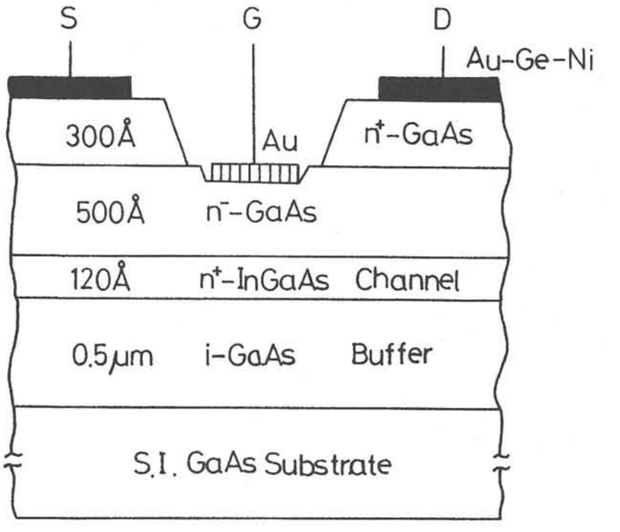

Fig.1 Schematic cross section of the studied device.

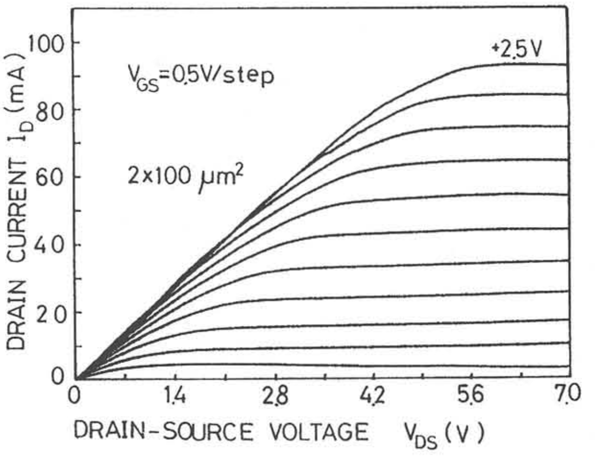

Fig.3 Current-voltage characteristics of a $2\times100\mu m^2$ gate device. The maximum applied gate-source voltage is +2.5V, and the gate-source voltage is supplied by 0.5V/step.

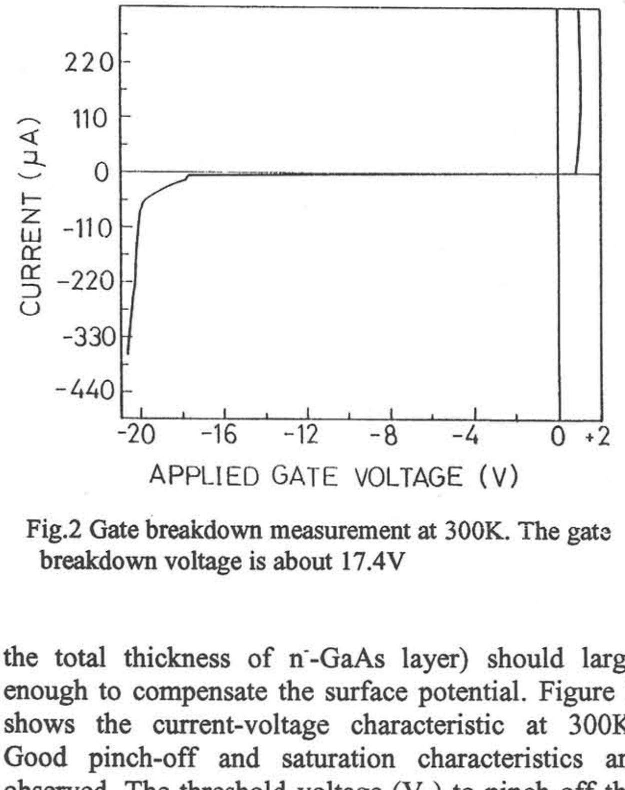

Fig.2 Gate breakdown measurement at 300K. The gate breakdown voltage is about 17.4V

the total thickness of n⁻-GaAs layer) should large enough to compensate the surface potential. Figure 3 shows the current-voltage characteristic at 300K. Good pinch-off and saturation characteristics are observed. The threshold voltage (V_T) to pinch-off the drain current is about -2.92V. Obviously, a very high output current and an excellent current linearity in a wide range of gate voltage were obtained. The maximum saturation current density and extrinsic transconductance are 930mA/mm and 230mS/mm, respectively. High current density along with high breakdown voltage in this device leads to a high power application. Due to the discontinuity of the band structure, high mobility electrons are retained within the InGaAs quantum well even at high positive applied gate voltage. The maximum applied gate-source voltage to sustain a high transconductance in this work is V_{GS} = +2.5V, which causes the expected high output current drivability. The maximum output power density up to 950mW/mm exhibits a good potential for power device applications.

It is noted that the region of transconductance versus gate bias, as shown in Fig.4, extending through a broad and flat range of more than 3.2V may yield a reduction on the thrid-harmonic distirtion and thus perform as a linear amplifier. This very large gate voltage swing is due to the excellent carrier confinement in doped channel as well as the employment of n⁻-GaAs layer which may reduce the parallel conduction in barrier layer and hence reduce the transconductance compression effect.

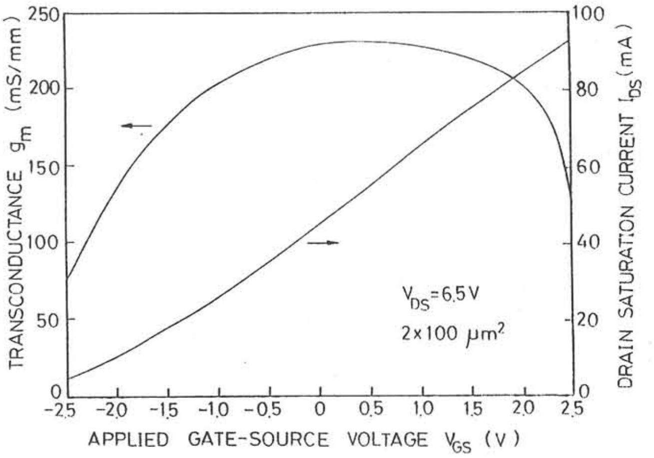

Fig.4 Transconductance and drain saturation current density versus gate-source voltage for a $2\times100\mu m^2$ device.

4. CONCLUSIONS

In this work, we have demonstrated a new n^--GaAs/n^+-InGaAs doped-channel MIS-like FET. A n^--GaAs and n^+-InGaAs layers were respectively employed for Schottky contact layer and active channel in the presented structure. Due to the better carrier confinement in doped channel, the reduced parallel conduction in n^--GaAs layer and the improved Schottky contact on n^--GaAs layer, a high transconductance, high saturation current density, high breakdown voltage, and very large gate voltage swing were obtained. These excellent results exhibit the performance potential of the studied device when scaled down to submicrometer dimensions.

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