DC and Breakdown Characterization of InGaAs based on HEMTs

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***Abstract*—**In this paper, we present a novel InGaAs HEMT for future 3-5 logic FETs. This work demonstrate the potential of InGaAs HEMT (high electron mobility transistor).This device shows high drain current I_{ds}=0.7A/mm, transconductance G_m=0.00055 S/mm or 0.5 s/mm, ON_state V_{on}=10v and OFF_state breakdown voltage V_{off} of 20v by using TCAD sentaurus simulation. This feature make device suitable for high power and breakdown application.

***Keywords*—**Breakdown Characterization; FET Logic Devices; HEMT; Indium Gallium Arsenide (InGaAs); Transconductance.

***Abbreviations*—**High Electron Mobility Transistor (HEMT); Indium Gallium Arsenide (InGaAs); Millimeter Wave (MMW).

I. INTRODUCTION

ELECTRONICS up to 100 GHz have applications in atmospheric sensing, radio astronomy, passive imaging applications, wide-band communication systems. Millimeter Wave (MMW) analog and numerical circuits have to be developed. HEMTs on GaAs substrate are largely used in D-band (110-150GHz) and G-band (140-220GHz) circuits. Improvement of frequency operation has been obtained by reduction of gate length to nanometer values and higher Indium content up to 80%.Another field of application is induced by the demand of higher bit-rate communication, which is rapidly growing. 40Gbit/s system has been recently developed and intensive research on 80Gbit/sand 160Gbit/s is being done. Analog and numerical circuits used in such optical transmission systems can also be realized with nanometer gate length InGaAs-based HEMTs. With InGaAs-based HEMTs, it is possible to reach fT higher than 472GHz with 30 nanometer gate length. To obtain that good value, gate recess InGaAs channel device focused in this work [1; Kim & Del Alamo, 2; Saguatti et al., 3].

RECENT excellent results achieved by short-channel InGaAs HEMTs have demonstrated the potential for using III–V as a channel material in future CMOS generations. To date, InGaAs HEMTs have typically been used for fiber-optic front-end systems and millimeter-wave applications [Bouloukou et al., 4; Zafar et al., 5].

II. DEVICE STRUCTURE

The device consists of following dimensions. GaAs substrate of 0.8µm, thereby InGaAs channel length of 10nm, spacer of 34.5nm of AlGaAs, cap layer 30nm, and passivation layer of 50nm nitride. Location of high delta doping layer is 31nm and thickness is 2nm [Malmkvist et al., 6; Watanabe et al., 7].

The gate schotty contact into spacer layer of 15nm deep. The gate length is 0.25µm.

2.1. Device Diagram

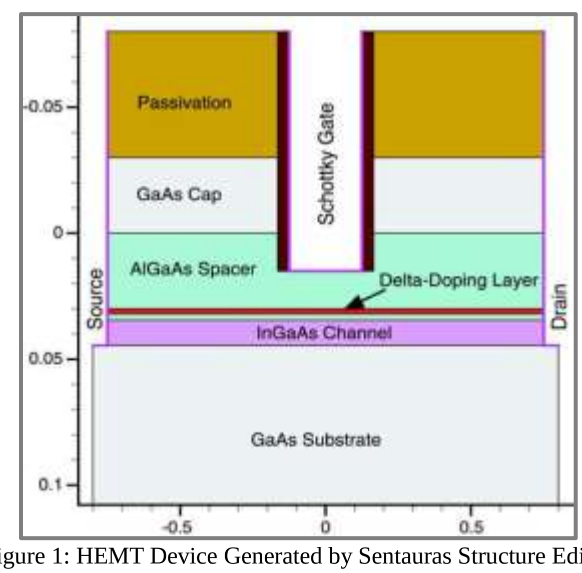

Figure 1: HEMT Device Generated by Sentauras Structure Editor

2.2. Mesh Diagram

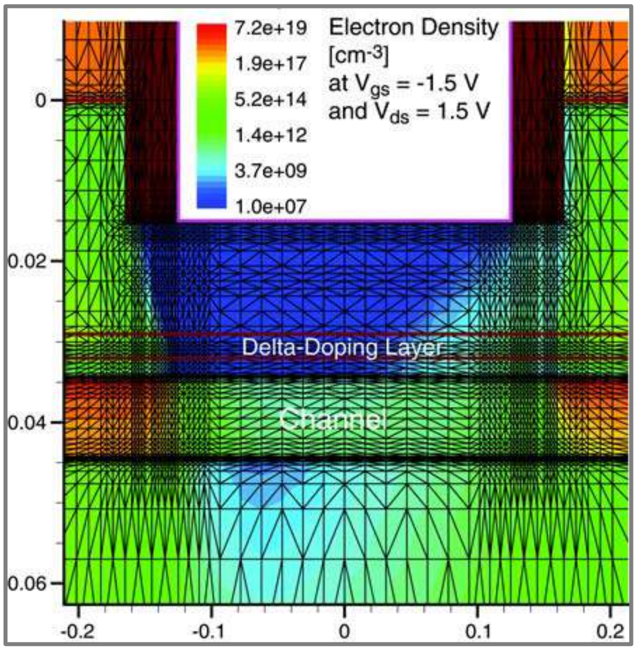

Figure 2: Mesh Diagram of InGaAs HEMT

Figure 2 shows the electron concentration under the gate at Vgs=-1.5V and Vgs=1.5V. The mesh in this circuit area is shown [Mohapatra et al., 8; Bhattacharya et al., 9].

III. Results and Discussions

3.1. DC Characterization

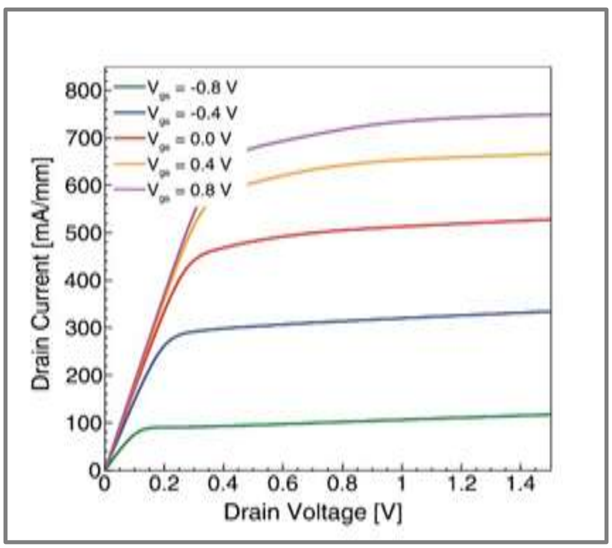

Figure 3: Variation of Drain Current versus Gate Voltage

Figure 3 shows the variation of drain current versus gate voltage with V_d=0.8V. The device reached a threshold voltage V_T=-1.01V and saturation of I_d=700mA/mm at V_d=1.5V [Moran et al., 10; Moran et al., 11].

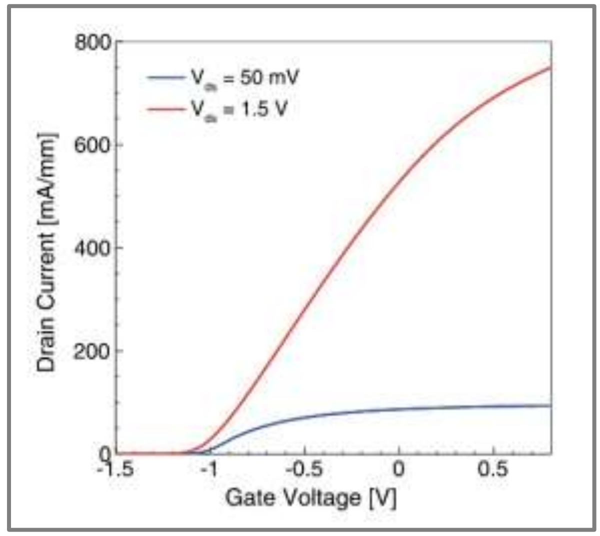

Figure 4: Variation of Transconductance

Figure 4 shows the variation of transconductance (g_m) characteristics for the device with V_{gs}=1.5V.The larger value of g_m lead to high saturation velocity and higher sheet carrier density. For higher values of V_{gs}, the g_m decreases because n_s saturate and current density no longer increased with V_{gs} [Khakifirooz & Antoniadis, 12].

3.2. Breakdown Simulations

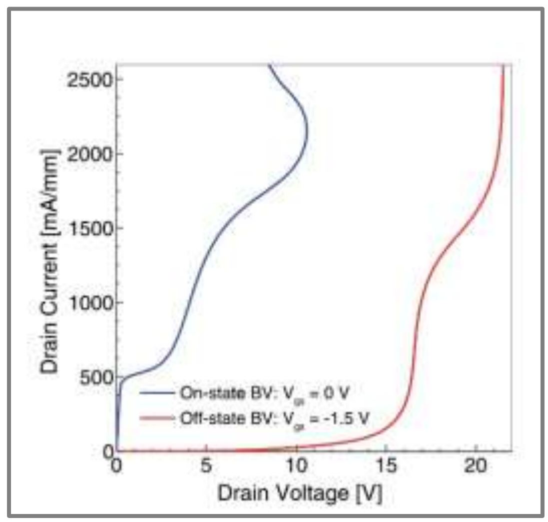

Figure 5: Breakdown Analysis

Figure 5 shows the breakdown analysis (ON state and OFF state simulation) using drain current injection.

From figure 5, it is clear that breakdown shows the maximum operating voltage and the device measured at Vgs=0V and Vgs=-1.5v for ON state and OFF state simulation. We abstract a maximum voltage V_{ON}=10V for ON state and V_{OFF}=20V for OFF state.

For the breakdown simulations, the Ohmic contact at source is set to 150Ω µm. The drain contact resistance is set to 150Ω µm for the drain current injection. The gate is defined as schottky contact with a schottky barrier height of 0.9eV and electron and hole recombination velocities of 10^7cm/s [Crook et al., 13].

ISSN: 2321-2403

IV. APPLICATIONS

4.1. Today's Applications

- Communications (Gigabit Wireless, cellular backbone, etc)
- Defense (Radar, guidance, countermeasure, weaponry, navigation)
- Test and Measurement (electronic devices, electronic materials, subsystems, and systems)
- Automotive Radar (77 GHz for LRR, 79 GHz for SRR)

4.2. Emerging Applications

- Medical (treatment, diagnostic)
- Homeland Security (People screening, stand off explosives detection)
- Nano scale measurements (near field microscopy)
- Image (mmWave image radar for All-Weather Landing)

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