R·I·T
KATE GLEASON
College of ENGINEERING

Fabrication of AlGaN/GaN High Electron Mobility Transistors

Vijay Gopal T.V. , Advisors: Matthew Hartensveld, Dr. Zhang, Dr. Pearson, Dr. Ewbank
Rochester Institute of Technology, Department of Electrical and Microelectronic Engineering, Rochester NY 14623

MicroE
Microelectronic Engineering

Project Objectives

Goal: Fabricate and test enhancement-mode AlGaN/GaN HEMTs

- **Test and characterize devices electrically:**
- **Produce family of curves and I_D-V_G curves.**
- **Analyze effects of processing parameters on threshold voltage.**
- **Identify sources of improvement within the process for better future results.**

Motivation

- High Electron Mobility Transistors have never been fabricated at RIT before.
- Establish a baseline process and acquire some initial results to start possible future work within the area of HEMTs at RIT.
- Fabricating HEMTs on Si substrates provides the future possibility of integrating Si with GaN technology.

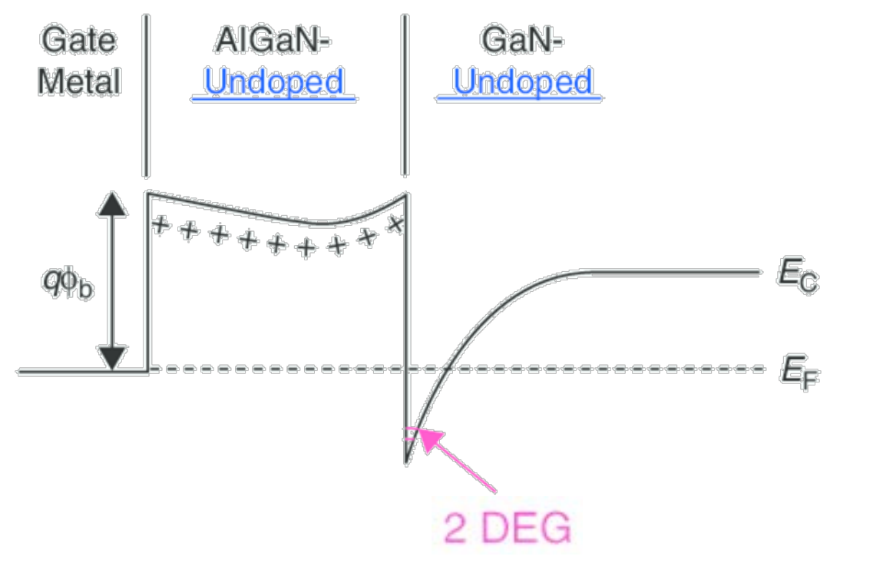
Why are AlGaN/GaN HEMTs important?

- AlGaN/GaN HEMTs are of great interest for high frequency and high power devices and applications.
- AlGaN/GaN HEMTs are inherently depletion-mode devices. It is of great interest to make enhancement-mode devices for integrated circuitry and high-power switching applications.

Theory

Device Theory

- AlGaN and GaN have two different bandgaps which yields a heterojunction.
- The bandgap of the AlGaN layer can be modified by modifying the ratio of Al to Ga present. This variation closely follows Vegard's Law.
- The heterojunction interface leads to the formation of a triangular quantum well within which the electrons are confined.
- The 2 Dimensional Electron Gas (2-DEG) forms where the electrons are free to move in two dimensions while being confined in the third.



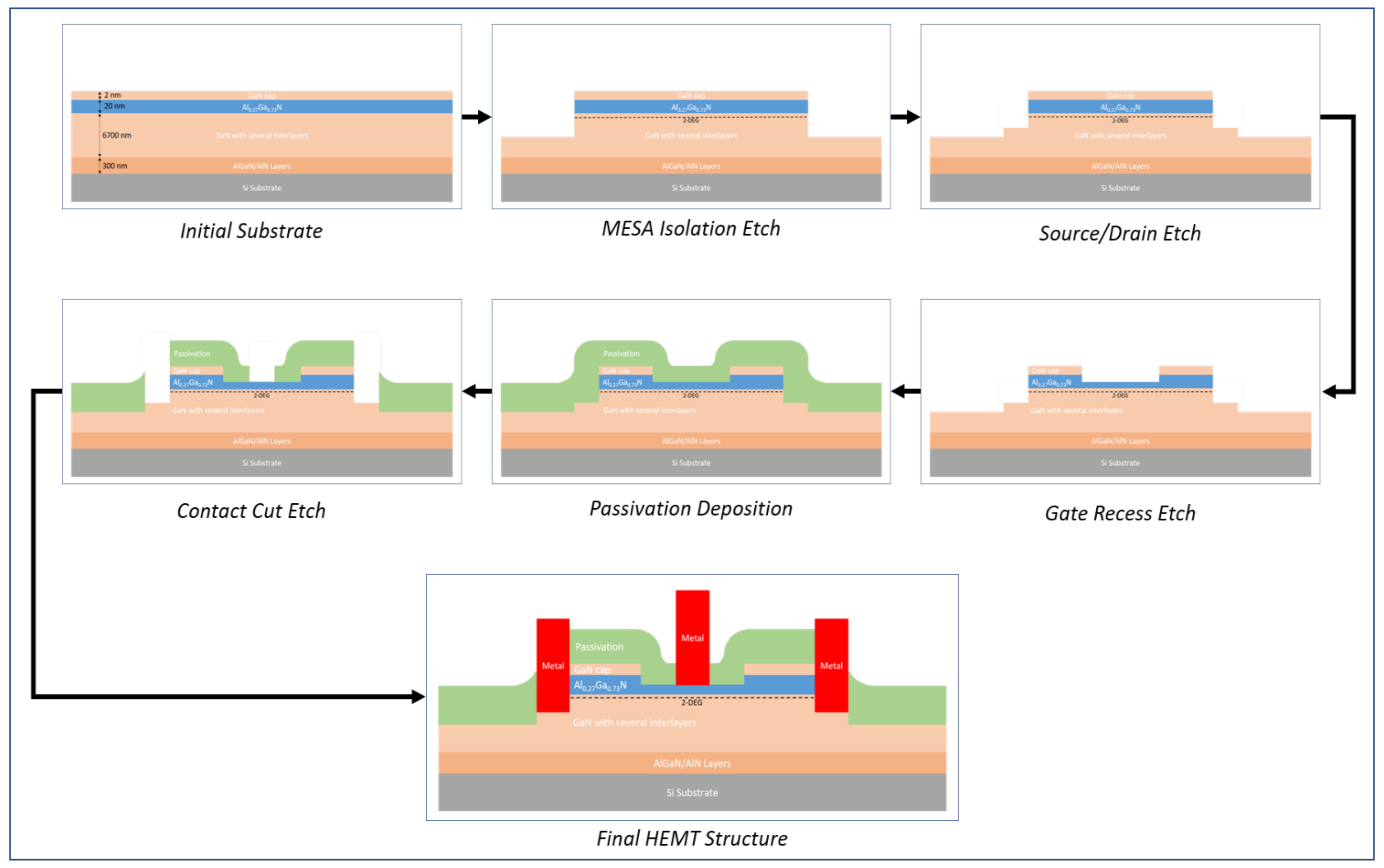
Band Diagram of AlGaN-GaN Interface

Processing Theory and Aspects of Consideration

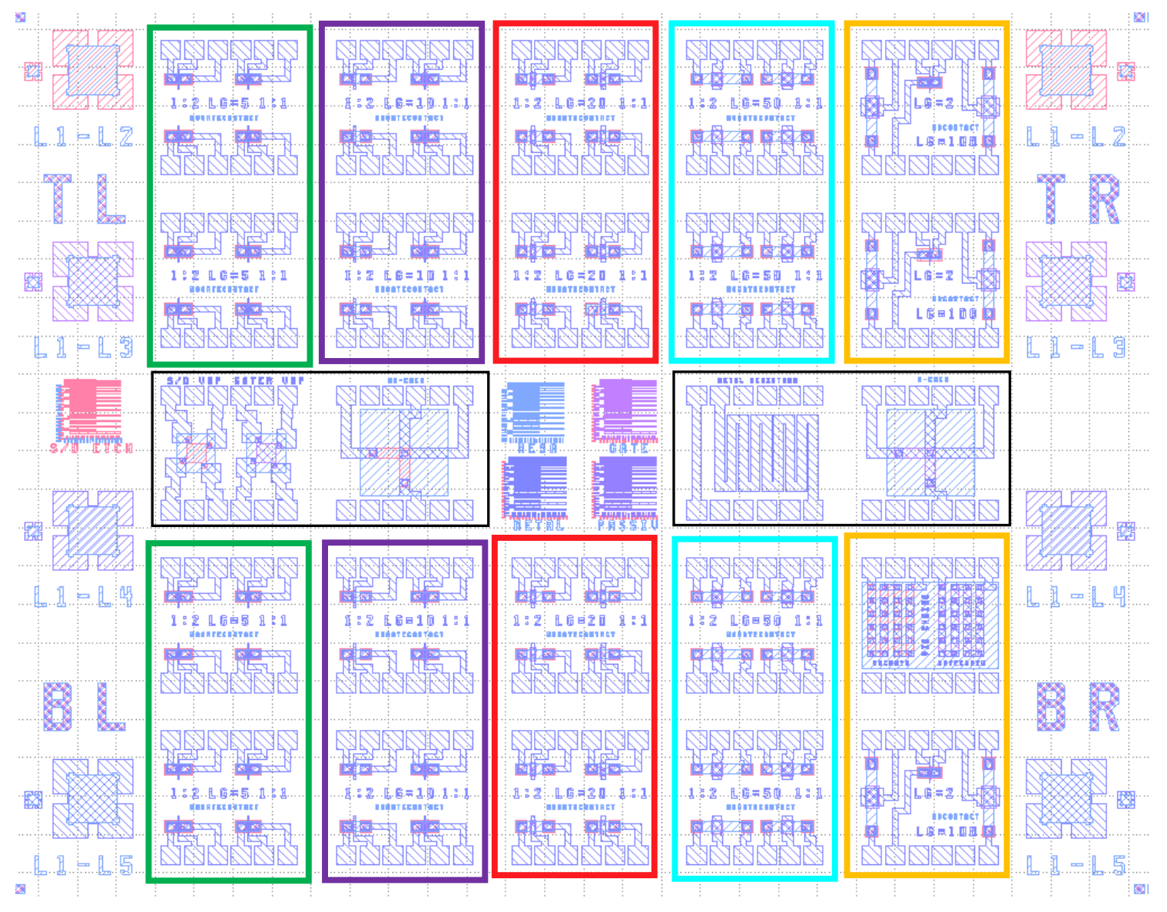
- Research work has shown effective shifts in threshold voltages of AlGaN/GaN HEMTs by recessing the gate region.
- Research work has also shown effective shift in the threshold voltage by exposing the gate region to a fluorine plasma. The F ions present within the gate regions have been shown to contribute to the shift in the threshold voltage.

- GaN and AlGaN can only be etched with Cl-based dry etch tools. RIE etching can lead to possible surface damage of the GaN and AlGaN layers if high powers are used.

Process Flow and Mask Design

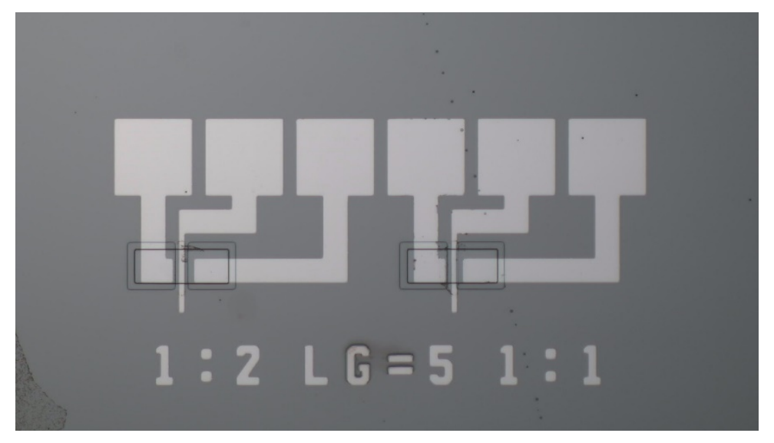


Initial Substrate
MESA Isolation Etch
Source/Drain Etch
Contact Cut Etch
Passivation Deposition
Gate Recess Etch
Final HEMT Structure

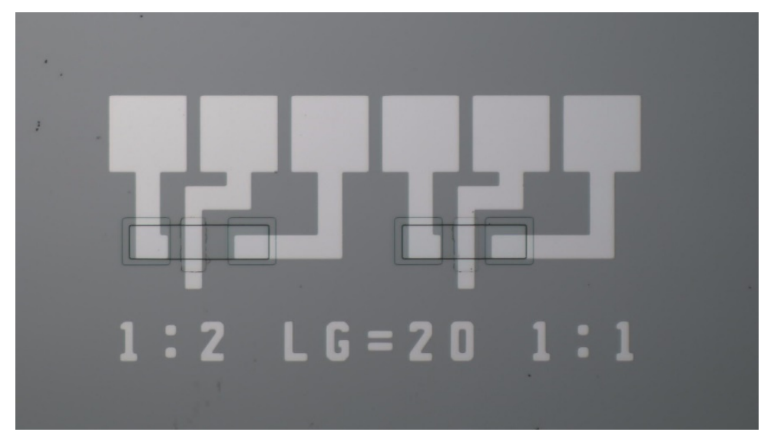


Mask Layout of a Single Test Cell

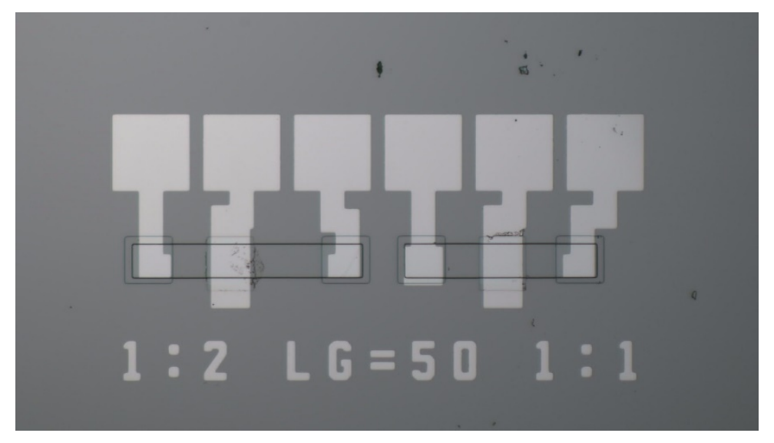
🟩 5µm Devices
🟪 10µm Devices
🟥 20µm Devices
🟦 50µm Devices
🟨 100µm Devices
⬛ Test Structures:
Van der Pauw's
CBKRs
Metal Resistor



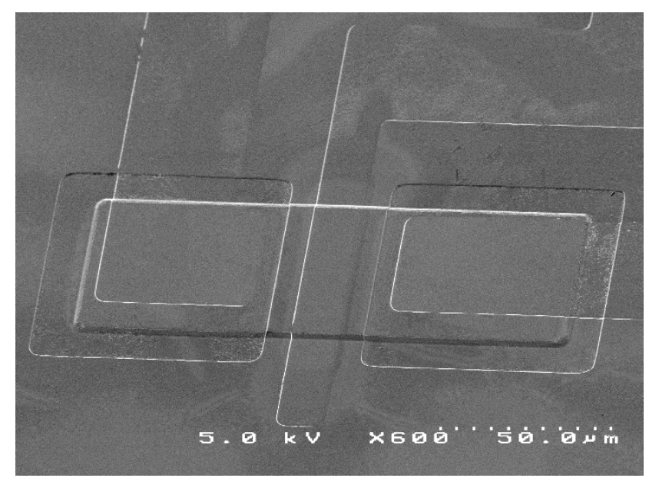
5µm Gate Length



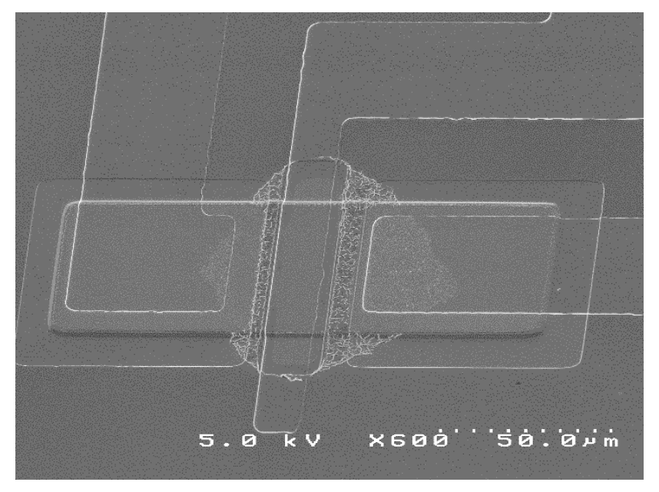
20µm Gate Length



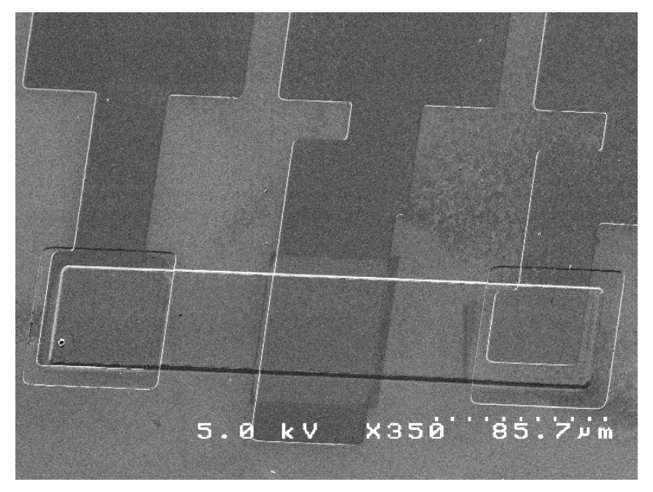
50µm Gate Length



SEM Image of 5µm Device



SEM Image of 5µm Device with Gate Recess

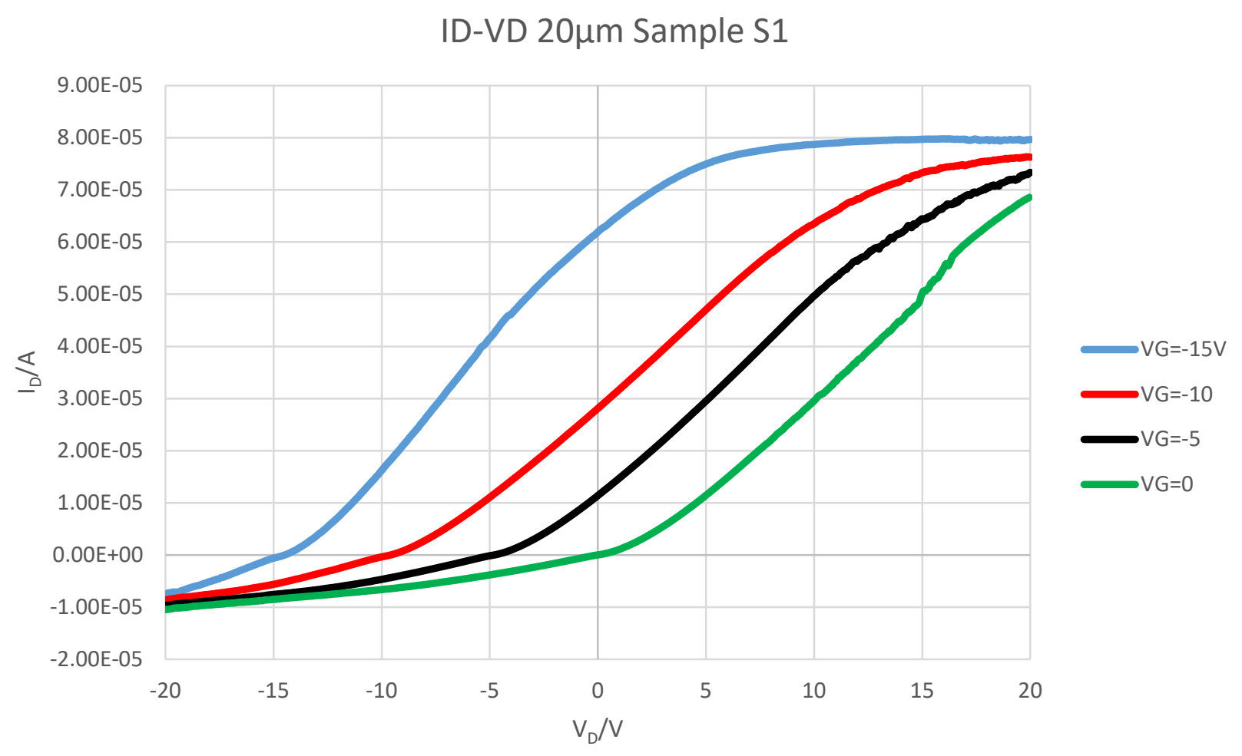


SEM Image of 50µm Device

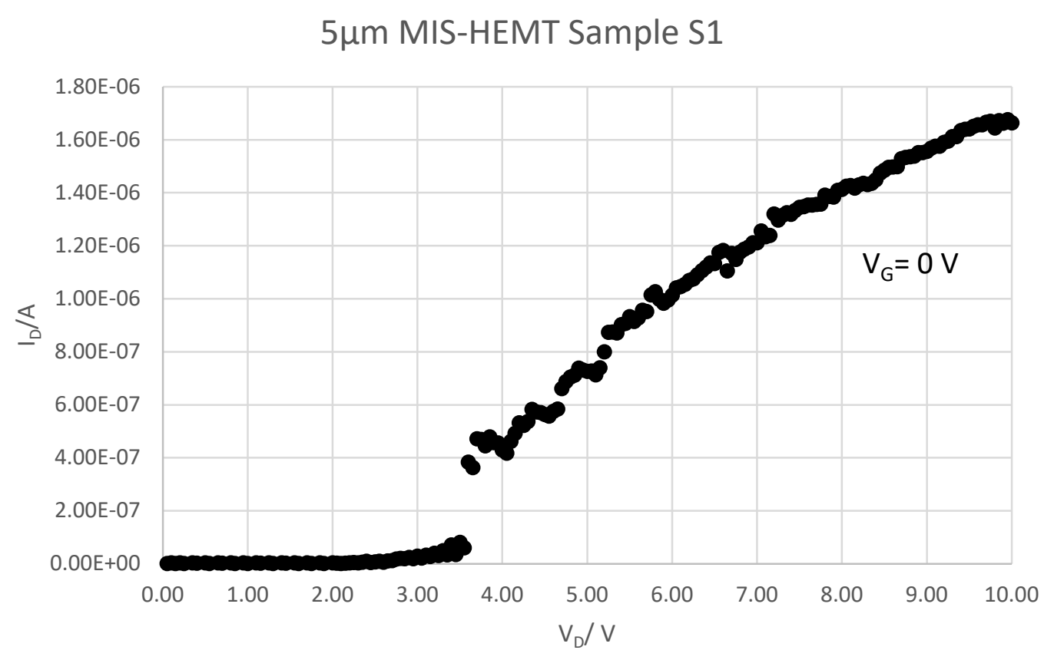
Results

The process developed used only a single metallization step. Ni was used as the metal. This resulted in Schottky contacts forming in Source, Drain and Gate regions. While it is advantageous to have Schottky contacts for the gate regions, it results in diode-like characteristics in the Source and Drain regions. The Schottky contact formation was confirmed by setting V_{GS} of a MIS-HEMT device to 0V and sweeping the Drain from 0V to 10V. The diode characteristic can be seen in the plot.

Results (cont.)



Family of Curves for Different Gate Voltages



Source and Drain Schottky Contact

The family of curves shown for a sample shows slight gate control by showing a change in the I_D-V_D curve as the gate voltage is varied. The family of curves also however shows a significant amount of gate leakage.

V. Conclusions

The first fabrication run for AlGaN/GaN HEMTs at RIT was completed.
An initial basic process flow and mask set was designed and developed.
Slight gate control was shown within the fabricated devices.
Source and Drain metal contacts were tested to show Schottky characteristics that would need to be changed by changing the metal stack for future work.

Future Work

This work provides a basis for possible future work and enhancement of processing parameters towards fabricating AlGaN/GaN HEMTS. Possible future work includes:

- Working on the metal stack for the Source and Drain.
- Working on etch parameters and developing further recipes for more accurate AlGaN etching within the Cl-based RIE etcher at RIT
- Working on optimizing effects of fluorine plasma treatment on the threshold voltage

Acknowledgements

- Matthew Hartensveld
- Cheng Liu, Bryan Melanson
- Dr. Jing Zhang, Dr. Robert Pearson, Dr. Dale Ewbank
- Patricia Meller, Sean O' Brien and SMFL Staff
- Class of 2019

R·I·T Semiconductor & Microsystems Fabrication Laboratory