ECEn 452 – Semiconductor Devices Lab

Week 12/13: "MOSFET Characterization"

Objectives

Introduction

This lab will be the last of the year and comes after the complete processing of your MOSFETs. As you are about to discover, the processing steps to create a MOSFET are straightforward, but that does not mean fabrication is a "slam dunk." One mistake along the way (an over etched oxide or misaligned mask perhaps) and your transistors will not work the way you would hope they would. Much of good science and engineering is being able to identify problems and learn from them. If your MOSFETs display abnormal behavior, much of this lab will be trying to discern why. Because there are a lot of parameters to measure for your MOSFET, you will have two weeks to complete this lab to allow everyone adequate time on the Parameter Analyzer or Curve Tracer.

Prelab Questions

1. Consider an ideal n-channel MOSFET operating in the saturation region with a width of 225 μm, a length of 20 μm, a transconductance of $g_{m,sat}$ = 1.95 mS, an oxide thickness of t_{ox} = 1200 Angstroms, and a threshold voltage of V_T = 0.65 V. Determine the mobility for the transistor when VGS = 5 V.

2. Now consider an ideal n-channel MOSFET operating in the linear region with a width of 300 μm, a length of 50 μm, a transconductance of $g_{m,lin}$ = 2.15 mS, an oxide thickness of t_{ox} = 1000 Angstroms, and a threshold voltage of VT = 0.7 V. Determine the mobility for the transistor when V_{GS} = 5 V.

3. For the MOSFET in problem (1.) Calculate the cut off frequency.

Objectives

1. Sizes of MOSFETs:

In this objective you will measure the dimensions of the transistors you have made. To do this you will use the microscope and video camera, a known scale, and a ruler. First put the scale under the microscope and display it on the screen. Measure the features on the screen using the ruler and come up with a scale you can use to determine the size of your MOSFETs – for example 1 inch on the ruler = 100 μm on the screen. Measure a large variety of transistors, including the ones you plan to test. Come up with estimates for the smallest and largest gate lengths that you created.

2. I-V Curves:

In this objective you will use the HP4145 Parameter analyzer like you did in Week 6. Because the 4145 is able to output several voltage signals at one time, you can test drain

current vs. voltage as you vary gate voltage. Place your semiconductors on the probe station. Connect the SOURCE of a MOSFET to GND. Connect the DRAIN to a variable voltage V_D. Connect the GATE to a variable voltage V_G. Sweep V_D and measure Id while stepping through several values for Vg. If the curves for your MOSFETs do not look close to the ideal, your job is to document what is happening and try to explain why. Some obvious possibilities for why your transistors don't work are the following: Over-etched oxides, incomplete via etching, improper doping, oxides with large amount of charge in them, large surface charges on the gate, improper mask design. Make plots showing the performance of a large variety of MOSFETs and include explanations if things are not working properly. Save some of the plots to disk.

3. Threshold Voltage:

Choose a MOSFET with a good I-V curve to find the threshold voltage (V_T). To do this, sweep V_G while holding V_D constant. Your value of V_T may be negative ($-5V < V_T < 1V$). What could cause a negative threshold voltage? What does this mean about your transistor when $V_G = 0V$?

4. Transconductance:

For MOSFET curves created in Objective 2, determine the transconductance (g_m) and channel conductance (g_D) in linear and saturation regions for both. Using these numbers and the sizes computed in Objective 1, determine the mobility for your transistors. Is this number what you would expect for silicon? If not, how far are you off and why? Next, calculate the 3-dB frequency (f_T) for your MOSFET.

5. Temperature Variations:

Measure the operation of your MOSFETs at different temperatures.
To do this you can use a heat gun for high temperatures and either liquid nitrogen or dry ice for low temperatures. Plot IV curves and determine threshold and transconductance for a variety of devices. Does mobility change with temperature?