ECEn 452 – Semiconductor Devices Lab

Week 8: "Diffusion"

Objectives

Introduction

In this lab you will begin building a MOSFET in earnest. You have already grown a thick oxide on 4 wafers in Week 6 that will serve as the field oxide for your MOSFET. In this lab you will complete the second major component of building a MOSFET – doping your semiconductor. We are using p-type wafers and will dope them with Phosphorous – created NMOS transistors.

Prelab Questions

1. What are the two types of diffusion mechanisms?
2. Why is diffusion a necessary step in creating a MOSFET?
3. What type of diffusion profile are we using?

Objectives

This lab has a set procedure that must be performed in the proper sequence.

1. Applying the Source-Drain Mask:

Dopants will be applied only to certain areas in our MOSFET structure (the Source and the Drain). For this to happen, we need to expose these areas to the dopant. The rest of the wafer will remain covered in the thick silicon dioxide layer you grew in Week 7. The exposed areas will be defined using photolithography. You will be given a photomask called "Source/Drain Diffusion" to be used to obtain these features.

This is done with the following procedure
1. Dehydration bake your wafers for 10 minutes at 120ºC
2. Spin on HMDS
3. Spin on photo resist (AZ3330).
4. Soft bake for 60 seconds at 90º C
5. Expose wafer for the optimal time (from Lithography Lab)
6. Develop wafer for the optimal time (from Lithography Lab)
7. Hard bake for 60 seconds at 110º C

2. Plasma Etching – Descum:

When you have finished developing your photoresist, whether you can see it or not, there is a small amount of "hydrocarbon" material still on the wafer. If this is not removed it can affect any etching that takes place using a pattern. Removing this very thin layer is something we call "descum." To descum we will use an oxygen plasma generated in a parallel-plate etcher. The oxygen plasma interacts with our undesirable hydrocarbon layer and burns it away (this process is called ashing). Have the lab instructor show you how to use the Asher. Because the layer we want to descum is so thin, about 15 seconds in the oxygen plasma should suffice (250 watts of power). Make sure to descum all four of your wafers before etching.

3. Oxide Etching:

Silicon dioxide etching is done using BOE (Buffered oxide etch or Buffered HF). Because HF is dangerous, you need to be very careful during this processing step. It is pretty easy to determine when BOE has etched through an oxide layer to an underlying silicon layer, because the silicon layer will appear dry when withdrawn from the BOE. If oxide still remains on the surface, a wafer will appear wet. Etch your wafer until the BOE runs off the wafer making it appear dry. Buffered oxide etch etches silicon dioxide at 1000 Angstroms per minute. Given the oxide thicknesses you grew, this should give a good idea as to how long it will take to etch through your oxide. How close was your calculated time to the actual time?

4. Plasma Etching – Bulk PR Removal:

The plasma etching method you used for descum in Objective 2, can also be used to remove large amounts of photoresist – it just takes more time. This is an alternative to using solvents (Acetone) to strip photoresist from a wafer. Use the parallel plate etcher and an oxygen plasma to remove the photoresist coating on your four silicon wafers after completing Objective 3. You will need to etch these wafers for a longer time to remove the thick photoresist (12 minutes at 250 Watts). Be sure to check under a microscope to ensure the photoresist is gone.

5. Dopant Application (SOG):

After windows are etched into your oxide mask, you are ready for the application of your dopant source. Doping will be done using a solid source first applied as a spun-on-liquid. Specifically you will use spin-on-glass doped heavily with Phosphorous as your source. This liquid is applied like photoresist using the spinner, except you will spin for 10 seconds at 2000 rpm. (Before spinning, be sure to dehydration bake your wafers). Try it on a dummy wafer first to make sure you are applying the correct amount of liquid before spinning. Afterward, coat all four of your “processing wafers” with the spin-on-glass.

6. Spin-on-Glass Curing:

The spin-on-glass applied in Objective 5 must now be cured in a vacuum oven to drive out solvents and provide some solidification. This curing will take place in a vacuum oven at 140C for 60 minutes.

After the spin-on-glass cure, the wafers are ready for the pre-deposition and drive in diffusion steps. Because these steps are very long, all the wafers from the groups will be done together by the lab supervisors. The first step, the pre-dep will be done at 1000C for 90 minutes. The spin-on-glass will then be etched off the wafer and a drive-in-diffusion done. The drive in will be done at 1050C for 8 hours in a dry oxygen environment. How much oxide will grow in the previously etched regions? How thick will the field oxide be after the drive in?