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EE 432 Lab
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Report 1

A. Overview

The goal of this lab is to go through the semiconductor fabrication process from start to finish. This report covers the oxidation, p-well photolithography, etching and boron doping. The oxidation consists of cleaning, placing wafers in the furnace, wet oxidation and then measuring the thickness. The P-well photolithography consists of spinning photoresist coating, prebaking the resist, exposing and developing. We observed the photoresist through the microscope after developing. Then the exposed oxide must be etched. The final Boron doping process consists of Standard cleaning, Placing source wafers and wafers in the furnace and pre-deposition. We did not perform the P-well drive as that was done by the TA over the weekend. This concludes all processes taken place up until this point in the lab.

B. Starting Wafer Specs

Number: 10 Total, 6 Device and 4 Test wafers

Type: N-type (phosphorous)

Resistivity: 1.289Ω*cm

Doping Level: $3.63 * 10^{15}\ cm^{-3}$

C. Standard Clean (RCA clean)

The purpose of the standard clean is to eliminate any contaminants before and in-between important process steps like oxidation and deposition.

Steps:

1. SC(Solvent Clean)-1 :15 minutes of soaking in 2500ml DI H_2O + 500 ml NH_4OH + 500 ml H_2O_2
    a. Removes organic residue from the wafers
2. 3 minutes cascade rinse
    a. Removes leftover SC-1 solution
3. 15 seconds HF dip
    a. Hydrofluoric acid removes native silicon dioxide from the wafer.
    b. Only needs a short time because it reacts quickly.
4. Cascade rinse
    a. Removes leftover HF.
5. SC-2: 3000 ml DI H_2O + 500 ml HCl + 500 ml H_2O_2
    a. Removes remaining traces of ionic contaminants.
6. 3 minutes cascade rinse
    a. Removes leftover SC-2 solution.
7. Spin rinse and dry
    a. Ensures removal of all solution and dries wafers

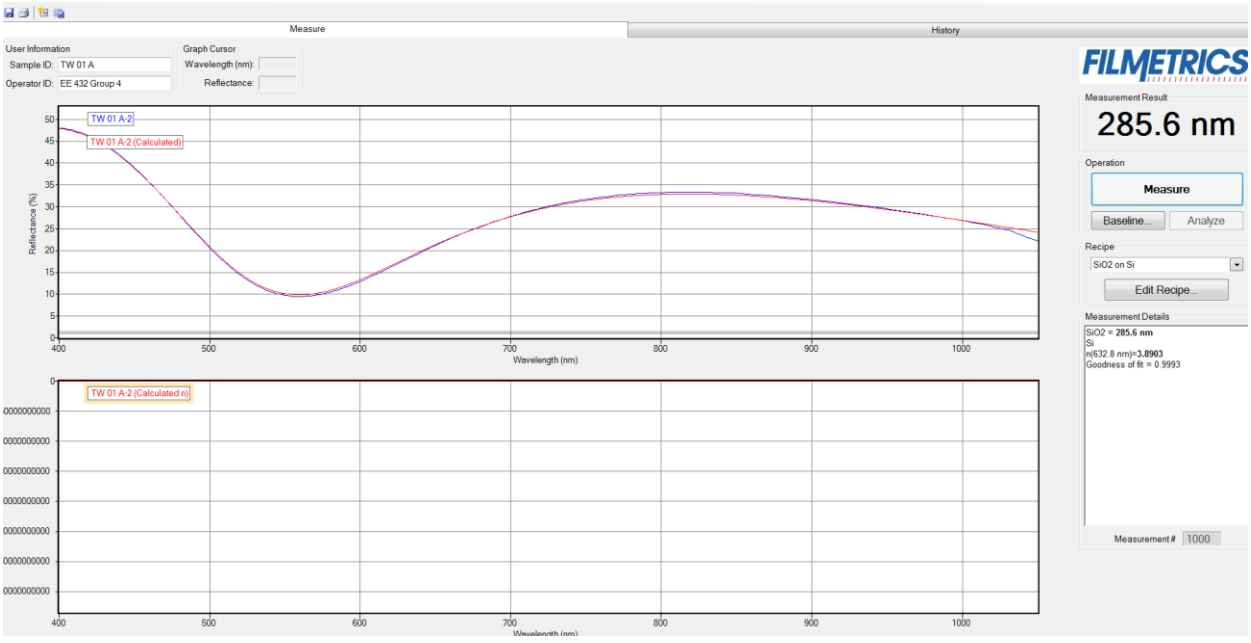
D. Wet Oxidation

The goal of this step is to create a uniform layer of silicon dioxide on top of the silicon wafer

Steps:

1. Set furnace temperature to 800°C
2. Put wafers in glass boat
3. Push in wafer boat
    a. Push at rate of 1 inch every 12 seconds
4. Ramp up temperature
    a. Set to 1100°C
    b. Waited 22 min to heat up
    c. End temp was 1080°C
5. Turn water bubbler on
    a. 200 sccm
    b. Turn vent on
6. Oxidize
    a. Switch N2 to tube
    b. Wait 15 minutes
7. Turn water bubbler off
    a. Power off bubbler, switch bubbler N2 valve to vent.
8. Ramp down temperature
    a. Set N2 flow to 1slpm
    b. Turn temperature to 600°C(we are last group of day)
9. Pull out
    a. Pull wafer boat at 1 inch per 12 seconds

Oxide thickness results:



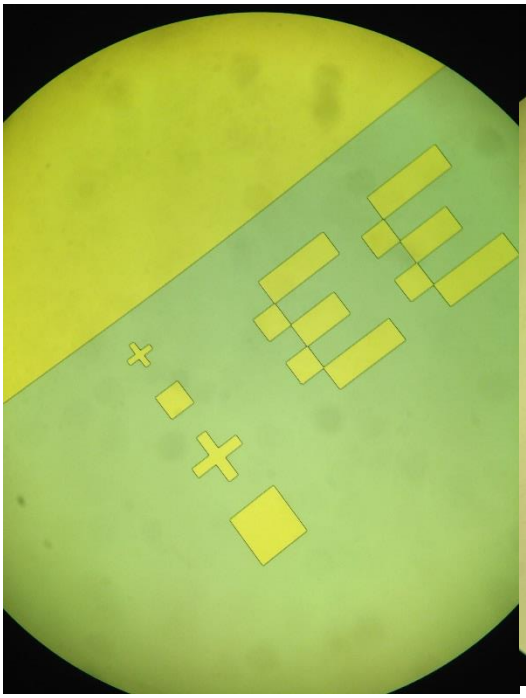
TW1: 285.6nm TW2: 285.5nm TW3: 286.4nm TW4: 284.8nm

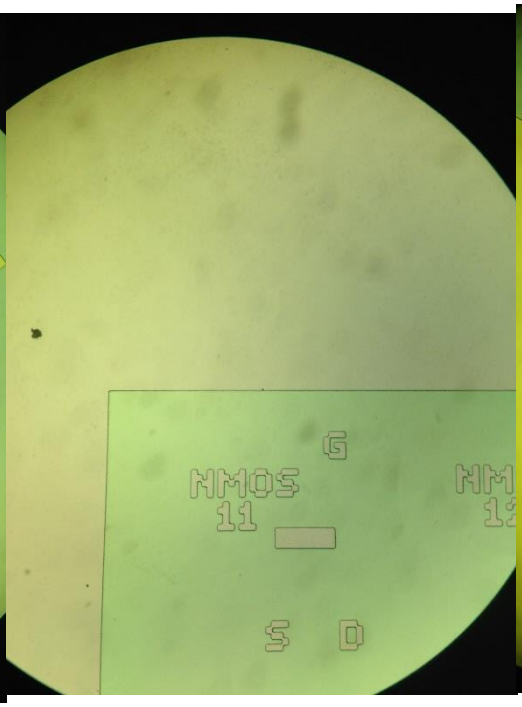
E. Photolithography

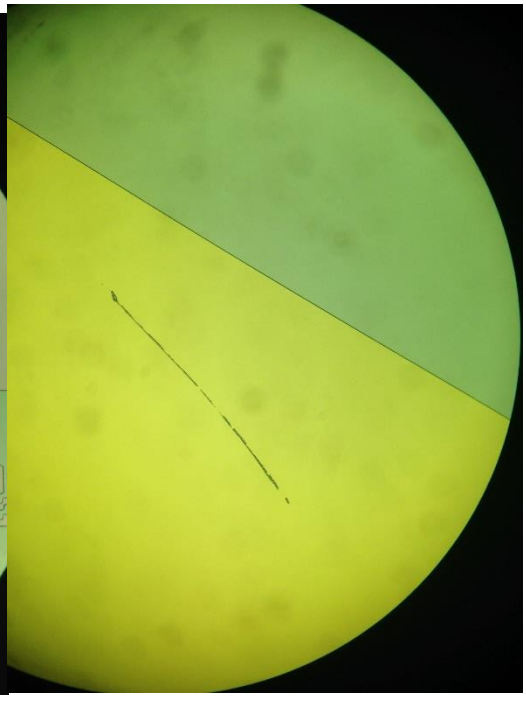
To create a photoresist mask pattern on the wafer, we need to coat the wafer with the photoresist and expose it to UV light.

Steps:

1. Spin HDMS (hexamethyldisilazane) adhesion layer
    a. Spins at 4000 rpm for 25 seconds
    b. We broke one of our backup wafers on this ☹ the first time
2. Prebake
    a. Cooked on hot plate at 120°C for 1 minute
3. Exposure
    a. Exposure machine for 90 seconds(no alignment needed for first layer)
4. Develop PR
    a. Soaked In MIF-300 developer for 60-90 seconds
5. Cascade rinse
    a. Soaked for 3 minutes to wash off developer
6. Dry
7. Inspect
    a. Used microscope to inspect the features on the wafer to make sure everything went well.
    b. They looked good. There were a few contaminations we spotted but most of the wafers were good.







F. Etch

To etch, we first dipped the Patterned and developed wafer in BOE solution and rinsed the wafer. Then we must strip the photoresist until the wafer only has the oxide and etched area.

Steps:

1. BOE (Buffer Oxide Etch)
    a. Submerged the device and test wafer 1 into the BOE solution until the test wafer 1 was hydrophobic.
    b. When the TW1 is hydrophobic, this means it is only silicon on the surface.
2. Cascade rinse
    a. Washes off excess chemicals
3. Acetone 1
    a. Removes photoresist
4. Acetone 2
    a. Removes remaining photoresist
5. Methanol
    a. Removes acetone and remaining photoresist
6. Cascade rinse
    a. Removes remaining chemicals
7. Spin rinse/dry
    a. Removes remaining chemicals if any and dries wafers

G. Boron Deposition and Drive

For boron deposition, we must do a standard clean and perform a deposition step, then a drive step.

Steps:

1. Standard clean
    a. All steps from C.
2. Place wafers in boat with device side facing boron source wafers and shield wafers on the other side of device wafers.
3. Boron Predeposition
    a. Push
        i. Tempuature at 850°C
        ii. Push at rate of 1 inch / 12 seconds
    b. Recovery
        i. Ambient 1 lpm N2+1 lmp O2
        ii. For 20 minutes
    c. Source
        i. Ambient 1lpm N2 + 1 lpm O2 + 40 sccm H2
        ii. Tempature 850°C
        iii. For 2 minutes
    d. Soak
        i. 2 lpm N2 flowing

        ii. 850C
        iii. For 50 min
    e. Pull
        i. 2lpm N2 850°C
        ii. Pull out at 1 inch / 12sec
4. Deglaze
    a. BOE
        i. 30 seconds
        ii. Takes off oxide layer
    b. Cascade rinse
        i. Takes off chemicals and residue
    c. Spin rinse and dry
        i. Cleans and dries wafers
5. Standard clean
    a. All steps from part C again
6. P-well Low -Temp Oxidation and Boron drive
    a. Bubbler on
        i. Temp at 98°C
        ii. 200 sccm N2
    b. Push
        i. 1 slpm dry N2
        ii. Furnace temp at 800°C
        iii. Rate at 1 inch/12 sec
    c. LTO
        i. 200 sccm bubbler N2 vent bubbler to tube
        ii. Temp at 800°C still
        iii. Let sit for 30 mins
    d. Turn bubbler off
    e. Pull
    f. Take wafers out of furnace boat
    g. Deglaze
        i. BOE for 30 seconds
        ii. Cascade rinse
        iii. Spin rinse/dry
    h. Put wavers back in furnace boat
    i. Push
    j. Ramp up
        i. Turn temp to drive tempature
        ii. Turn on bubbler
    k. Wait for furnace to reach drive temp and begin oxidation
        i. Let bubbler vent to furnace
        ii. Wait for desired oxidation time
    l. Bubbler off
    m. Drive

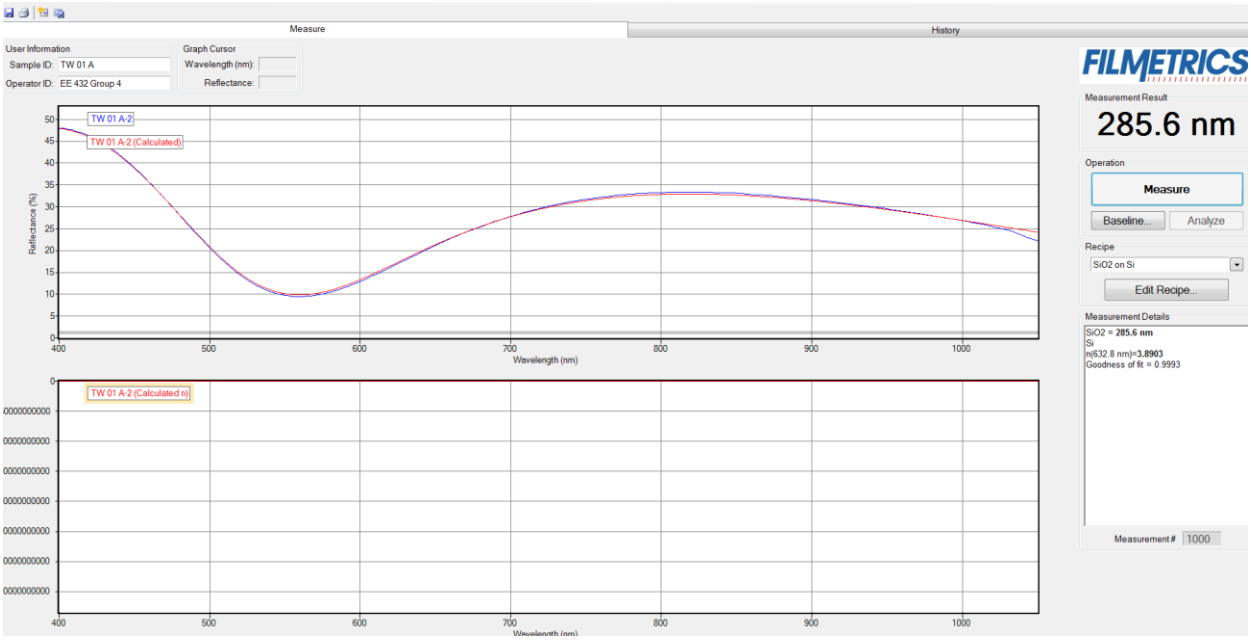
i. Set nitrogen to 1slpm
ii. Wait a long time

n. Ramp down to 800°C or 600°C
o. Remove wafers
p. Unload wafers and move to storage bin

H. Results

The filmetrics measurement system measures the film thickness by using an optical spectrometer to analyze the light reflection off the wafer surface. The film thickness will determine the reflected light spectrum depending on the material of the film.

The results of the filmetrics system are as follows:



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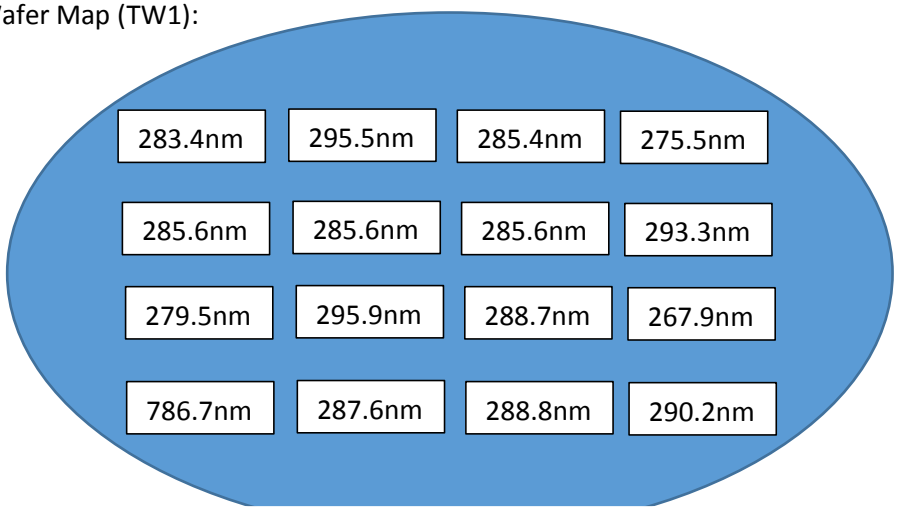
Wafer Map (TW1):



Appendix:

Oxidation Chemical Reactions:

$$Si + O_2 \rightarrow SiO_2$$

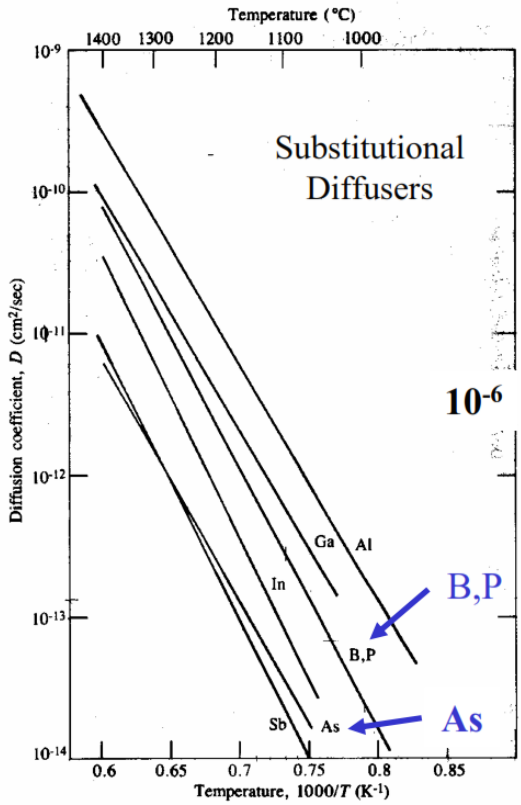
or $$Si + 2H_2O \rightarrow SiO_2 + 2H_2$$

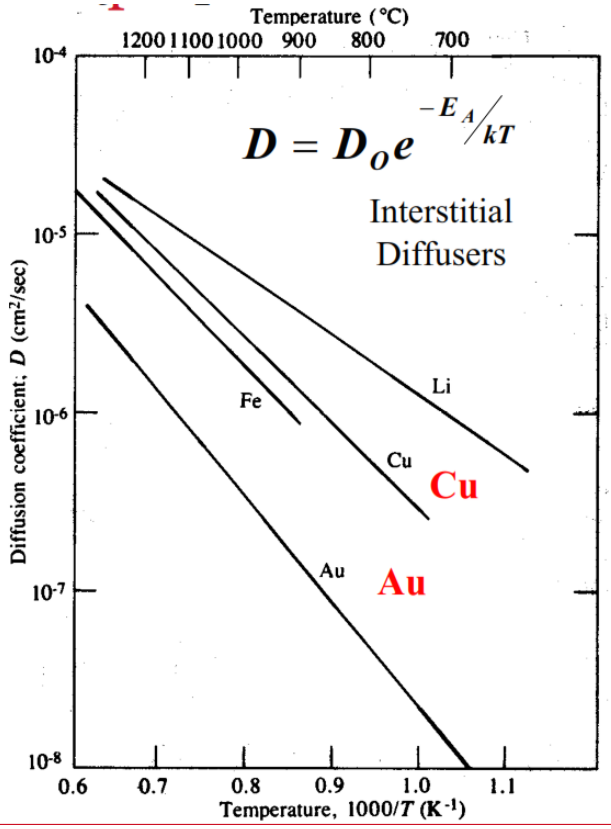
$$F_1 = h_G(C_G - C_S)$$

Oxidation Equations

$$\frac{x_o^2 - x_i^2}{B} + \frac{x_o - x_i}{B/A} = t \qquad \frac{B}{A} = C_2 \exp(-E_2/kT) \qquad B = C_1 \exp(-E_1/kT)$$

Diffusion Equations





$$D = D_0 e^{-E_A/kT}$$

Concentration : $N(x,t) = N_0 erfc\left(\frac{x}{2\sqrt{Dt}}\right)$

Total Dose : $Q = \int_0^\infty N(x,t)dt = 2N_0\sqrt{\frac{Dt}{\pi}}$

Concentration :

$$N(x,t) = N_0 \exp\left[-\left(\frac{x}{2\sqrt{Dt}}\right)^2\right] = \frac{Q}{\sqrt{\pi Dt}} \exp\left[-\left(\frac{x}{2\sqrt{Dt}}\right)^2\right]$$