UNIVERSITY OF CALIFORNIA

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Electrical and Computer Engineering Department

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Integrated Circuit Design and Fabrication

Introduction to NMOS Processing

In this lab you will be fabricating, measuring and analyzing NMOS field effect transistors. The processing sequence involves four mask layers, three alignment steps, three oxidations, one diffusion and one evaporation. You are expected to refer to the attached lab handouts for the detailed process instructions. A flow chart and brief instructions are given here.

NMOS Process sequence:

Wafer cleaning and growth of oxide for diffusion mask

1. Start with p-type <100> Silicon of resistivity 10-30 ohm-cm. Record the casette data. Cleave the wafer into 4 samples and clean them using the standard wafer cleaning procedure . (ACEtone, ISOpropanol, DIonized water).
2. Etch off the native oxide and measure the resistivity using the four point probe. If the resistivity is very different from the above mentioned value then start with a different wafer.
3. **Piranha clean** the samples prior to oxidation. The **instructions for the piranha clean are included in the lab handout on phosphorous diffusion**.
4. Since the devices are extremely sensitive to impurities in the oxide take extra precautions in handling the oxidation furnace. Use the designated boat and push rod for the silicon oxidation furnace. **Clean the Boat and push rod with HF prior to each oxidation**.
5. Grow **at least 5000 Angstroms** of **wet oxide** on your samples. Use the oxidation times on the chart next to oxidation furnace. Verify the oxide thickness using the **color chart** and the **Rudolf FTM**. You should **include a test wafer** in the oxidation step and mask and etch down a portion of the oxide to measure the oxide thickness on the Dektak profilometer.

Lithography using Mask-1 for opening the diffusion windows

1. Clean the samples with the 5000 Angstroms of oxide on them using the standard cleaning process. **Remember to go through all the steps listed in the handout on lithography** in order to prepare the wafer for spinning on the positive photoresist **(Shipley 812 or Clarient AZ4210)** including the dehydration bake and HMDS treatment.
2. Spin on Shipley 812 or AZ4210 and then softbake the resist for 3 min. @ 85 deg C
3. Expose for the appropriate time using **Mask-1.** There is no alignment at this stage. Use the exposure times suggested by your TA. Literature for Shipley 812 suggests about 130mJ (17 sec. @ 7.5 mW/cm2) [The lamp is preset for 7.5mW/cm2 by Martin]
4. Develop the patterns in straight **MF321** or **4:1 AZ 400K developer.** Again use the develop times of 45-60 seconds or as instructed by TA.
5. Inspect the photoresist under the optical microscope and ensure that the patterns have been transferred accurately.
6. **Etch the oxide in buffered HF**. Perform a 20% over etch to make sure that the oxide is completely removed. Etch rate of buffered HF is about 1000Å/min.but you should verify the etch rate. **Immerse the wafer in DI for 1 minute before you place it in HF. This prevents bubble formation and ensures uniform etching in HF.**
7. Strip off the photoresist in acetone and then rinse the samples in isopropyl alcohol and DI H_2O.

Phosphorous predeposition, drive-in and field oxide growth

1. Assure that the solid sources have been annealed as recommended in the PDS literature.
2. Prepare the wafers for the predeposition by going through the various cleaning cycles listed in the handout. This is extremely important to avoid furnace contamination. **Remember to include some test wafers along with your actual samples for process characterization**.
3. The required **pre-deposition time** for this experiment is **15 minutes at 950 degrees centigrade.** Verify by consulting the curves in the PDS literature.
4. Etch off the phosphorous glass in **10:1 DI H_2O:HF**, calculate the etch time from literature.
5. Measure the resistivity of the **test sample (no oxide)** and note the results.
6. Now load the samples in the oxidation furnace and grow **3500 Å of wet oxide**. This step serves two purposes-1) drives in the dopant 2) Field oxide grows thicker.
7. Verify the thickness of the oxide in the various regions. The field oxide should be about 7500-8000 Angstroms thick while the source and drain regions are covered by about 3500 Angstroms of oxide.

Gate Lithography and gate oxide growth

1. Using the standard cleaning and lithographic procedures, spin positive resist on your samples if using the darkfield mask or reversal resist (**AZ 5214**) if using lightfield mask.
2. **Expose the samples using Mask-2 (gate oxide mask)**. Remember to align this layer to the alignment marks already transferred to the samples in the previous lithography. Align the alignment marks on this mask to the alignment marks on the substrate.
3. Develop the samples for the appropriate time. Inspect the alignment before you proceed to the next step. In case the alignment is bad, repeat the lithography.
4. **Etch down the oxide in buffered HF** till you reach the substrate in the gate region. Make sure that all oxide is removed by performing a 20% over-etch and check your test wafer.
5. The **gate oxide** to be grown next must be kept free from impurities so perform a **Piranha clean** on the samples. Also clean the boats and push rods with HF.
6. Grow **dry oxide** of thickness **500 Å** to **800 Å**. **Include test samples to measure the oxide thickness that you grow.**

Contact lithography and etching

1. Use the standard lithographic techniques to transfer the pattern from **Mask-3 (Vias)** to the samples. At the end of this step, photoresist covers the gate while openings are left over portions of the drain and source. Again you may be using a lightfield or darkfield mask.
2. **Etching the contact windows** in the source and drain regions is an **extremely critical step**. Immerse the samples for **1 minute** in **DI H_2O** prior to placing the samples in **buffered HF.** It is essential to remove all the oxide in these regions. Perform a 20% over-etch and inspect visually to confirm the complete etching of the oxide on your test sample. It may be a good idea to profile the window on the dektak .
3. Strip off the photoresist in acetone and rinse the samples in ISO, DI.

Lift-Off lithography, Metallization and Sintering

1. Use Mask-4 (Contact Metal) to transfer the lift-off pattern to the samples. See the lift off handout for the detailed process steps. Remember that there is an additional **toluene soak step** involved here. Also the **exposure and develop times required are longer**. Inspect the patterns under the optical microscope for alignment as well as overhang profile.
2. Prepare the evaporator to evaporate **3000 Å of Aluminum**. Meanwhile, etch off the native oxide formed in the source and drain regions by immersing the samples in **50:1 DI H_2O:HF for 10 seconds**. Load the samples in the evaporator, pump down to mid 10^{-6} torr and then deposit at least 3000 Å of Aluminum.

3. Lift-off the undesired metal by placing the samples in Acetone. Be extremely gentle or all the metal may come off.
4. Sinter the contacts for at least 10 minutes at 450 degrees centigrade on the strip annealer.

Your devices are now ready to be tested. Meet the TA to see how the measurement system is set up to probe the devices.