UNIVERSITY OF CALIFORNIA
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Semiconductor Device Processing

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 cassette 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.
5. Grow **about 5000 Angstroms** of **wet oxide** on your samples. Use the oxidation times on the chart next to the oxidation furnace. Verify the oxide thickness using the **color chart**, **ellipsometer**, and the **Filmetrics**. You should **include a test wafer** in the oxidation step 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 **(Clarient AZ4110)**, including the dehydration bake and HMDS treatment.

2. Spin on AZ4110 and then softbake the resist for 1 min @ 95 deg C.
3. Expose for the appropriate time using **Mask-1.** There is no alignment at this stage. Refer to the 'lithography' handout for details [The lamp is preset for 7.5mW/cm^2 by Bob].
4. Develop the patterns in **4:1 AZ 400K developer.** Again use a develop time of about 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. Perform an O_2 plasma descum.
7. **Etch the oxide in buffered HF**. Make sure to agitate during etching. 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 with agitation before you place it in HF. This prevents bubble formation and ensures uniform etching in HF.**
8. Strip off the photoresist in acetone and then rinse the samples in isopropyl alcohol and DI H_2O (standard cleaning procedure).

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 wafer cleaning 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 **predeposition time** for this procedure is **15 minutes at 950 degrees centigrade.** Verify by consulting the curves in the PDS literature.
4. After predeposition, etch off the phosphorous glass in **50:1 DI H_2O:HF** for **5 minutes**.
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 **2000 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 6000-6500 Angstroms thick while the source and drain regions are covered by about 2000 Angstroms of oxide.

Gate Lithography and gate oxide growth

1. Using the standard cleaning and lithographic procedures, spin positive resist on your samples.

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. Perform an O_2 plasma descum.
5. **Etch down the oxide in buffered HF** until 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.
6. The **gate oxide** to be grown next must be kept free from impurities so perform a **Piranha clean** on the samples, followed by a 15 second 50:1 DI H_2O:HF dip and a 1 minute rinse in DI H_2O.
7. Grow **dry oxide** of thickness **400 Å** to **500 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.
2. **Etching the contact windows** in the source and drain regions is an **extremely critical step**. Immerse the samples for **15 seconds** 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.
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 'Metal Liftoff' handout for the detailed process steps. Remember that there is an additional **toluene soak step** involved during the lithography step. Also the **exposure and develop times** may be different. 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 15 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, again refer to the 'Metal Liftoff' handout. Be extremely gentle or all the metal may come off.

4. Test your TLM contacts to see if they are ohmic. If they are, you may begin testing your devices. If not, sinter the contacts on the strip annealer. Bob Hill or the TA can provide you with instructions for sintering.

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