LAB #3
Photolithography I and Wet Etching

Purpose:

Inspect oxide color and measure oxide thickness. Define active areas in the field oxide. This Lab will introduce you to photolithography techniques and wet etching. Starting with the wafers with field oxide produced in Lab #2.

Process Steps:

1. Inspect the color of your wafers under the white fluorescent lamp. Estimate the oxide thickness and uniformity based on the expected thickness from the oxidation charts, the color chart, and the Tsuprem4 simulations.
   Measure field oxide thickness using the ellipsometer (Gaertner L116B) and compare to the estimations.
   If possible, also measure the field oxide thickness with the spectral reflectometer (Lietz MPV-SP) and include these values in your comparisons. If this system is operational, make measurements at multiple points (say 5 or more, systematically) on your wafer to get a uniformity measure.

2. Resist Coating: **Only the Device Wafer will be used in Lab #3. The monitor wafers usually do not have patterns on them to make the measurements easier.**

   Coat wafers with resist (AZ 1813) and prebake.
   i. Dehydration bake on hotplate at 130 °C for 5 min.
   ii. Adhesion Layer
      a) Dispense HMDS onto entire wafer.
      b) Soak for 20 sec.
      c) 30 sec spin at 4000 rpm.
   iii. Photoresist Coating
      a) Turn on spread option.
      b) Spread photoresist for 3 sec at 1500 rpm.
      c) Spin photoresist for 30 sec at 4000 rpm.
   iv. Prebake on hotplate for 60 sec at 115 °C.

3. Align and expose first mask (active area definition):
   [DIFFUSION MASK]
   POSITIVE PROCESS
   Before using the mask, it should be cleaned:
   c. Mask Clean

a) Put mask in mask holder.
b) Submerge mask in mask cleaning solution (soapy water mixture).
c) While submerged take soft sponge tip brush and scrub both sides of the mask (ONLY scrub areas that are submerged, turn mask over if necessary).
d) Rinse in DI water.
e) Blow dry.

d. Expose Photoresist

1) Center the mask within the wafer. Roughly align the patterns on the mask to the flats on the wafer.
2) Exposure time ~6.5 sec.

4. Develop resist:
   i) ~30 sec development in AZ 319 MIF developer. In order to stop the development of photoresist, the wafer has to be transferred to the cascade rinser immediately when the development time is up.
   ii) 90 sec each side of cascade rinser.
   iii) The development time is just an approximation. Inspect under the microscope with the photoresist filter in to see if the patterns are fully developed. If not, continue to develop as advised by Mr. Briggs.
   iv) Postbake for 60 sec on 115 °C hotplate.

5. Descum: Use Technics PE II - A Plasma Etch System
   300 mTorr of O_2 for 30 sec at 25 W rf power
   This step removes residual organic residues that may remain after developing. The presence of residual layer would inhibit etching in areas with small patterns.
   Measure the photoresist thickness.

6. Etch field oxide in Buffered Oxide Etch with surfactant.
   The etch rate is ~100 nm/min.
   Etch (agitating gently) to remove all the oxide in the open areas and rinse thoroughly with DI H_2O. Check to see if the wafer is hydrophobic (dewets). Continue the etch and rinse cycles in 1 min increments until the wafer dewets and record the etch time. In order to stop the etching of oxide, the wafer has to be transferred to DI H_2O immediately when the etch time is up.

7. Strip resist
   i) etch in PRS 2000 at 110 °C for 2 min.
   ii) rinse 1 min in acetone.
   iii) rinse 1 min in IPA.
   iv) 90 sec each side of cascade rinser.

8. Dektak oxide step to confirm thickness measurement and to ensure all the oxide is removed in the active areas.

INFORMATION TO BE INCLUDED IN THE LAB REPORT #1

1. Based on the oxide color and Deal-Grove model, estimate the oxide thickness. Does this estimation agree with the thickness obtain from the TSuprem simulation and the ellipsometry measurement? Explain the reasons for different thickness obtained using these 4 different techniques. Which one provides the most accurate thickness?

2. Explain the reasons for pre-bake and post-bake. Explain and draw an estimated cross section of the developed photoresist of the active area before and after post-bake. Emphasize the photoresist profile.

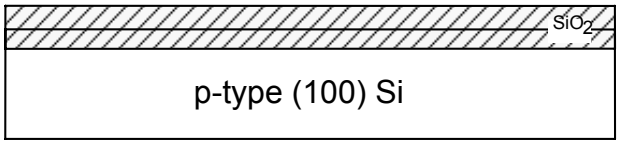
3. Explain how the feature size and profile of the patterned resist would change if the (a) resist thickness, (b) exposure time, and (c) development time is doubled. Sketch cross sections of the developed resist for each of the 3 cases with and without doubling.

4. What does "Buffered" mean in BHF? Explain how the device performance will be affected if the oxide etch time is too long or too short.

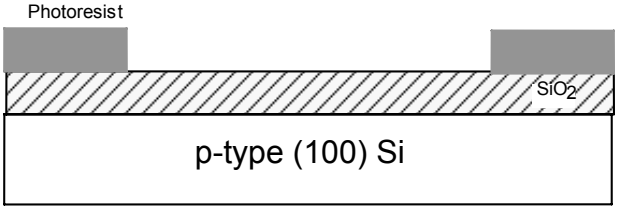
5. Summarize the experimental results:
   Time for Exposure, Development, and Oxide Etch; Step Height for Photoresist and Oxide. Draw top view and cross-sectional view of 1 transistor site on your wafer after Step #6. Pay attention to profiles of photoresist and oxide. (15 points)

*All sketches should be labeled with the materials of the layers and their thicknesses.

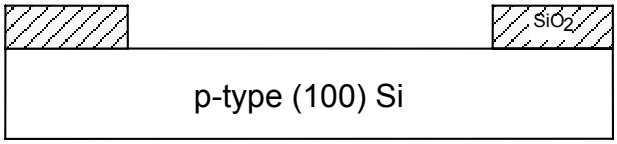
LAB #3 Photolithography and Wet Etching



Field Oxide Grown in Lab#2



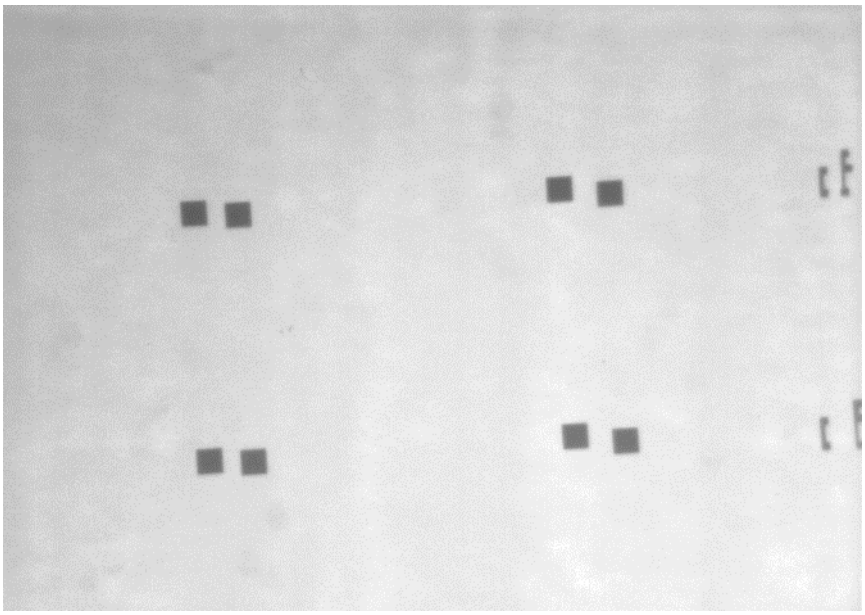
Photolithography to Define Active Device



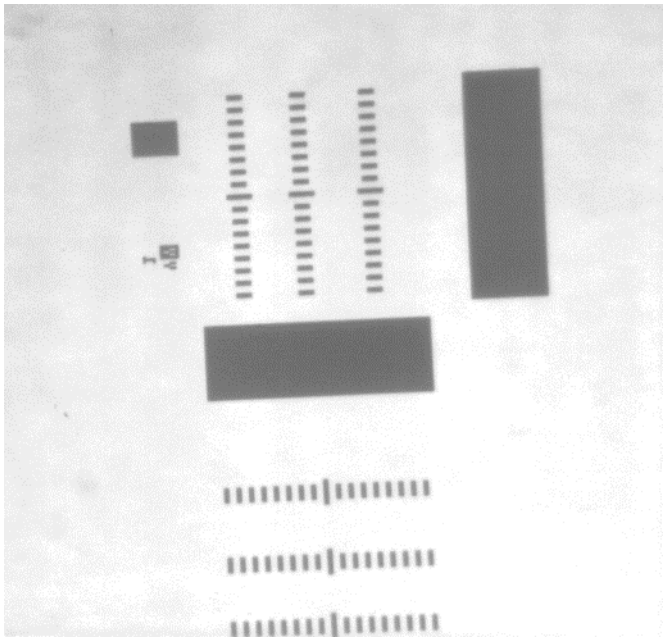
Wet Etching to Remove SiO_2 from Active Region and Prepare for Phosphorus

1) **Profiles for Photoresist and Oxide are not correct in these plots**
2) **Evaluate and Discuss Oxide Thickness**
3) **Explain Effects of Pre-bake and Post-bake**
4) **Explain Effects of Resist Thickness, Exposure Time, and Development time on Feature Size and Photoresist Profile**
5) **Effects of Oxide Etch Time on Device Performance**

Diffusion Mask to define Active Device Areas in Field Oxide



Openings for 8 Transistors



Alignment Marks for Diffusion Mask

KARL SUSS MA 45
OPTICAL LITHOGRAPHY SYSTEM

Standard operating procedure

1. Push the POWER button to turn on the aligner.
2. The lamphouse will move to the right position.
3. Push the START button.
   The lamphouse will move to the left position.
4. Select the exposure mode you would like to use.
   a) Proximity mode - (proximity button illuminated) the substrate is separated from the mask with a small gap.
   b) Contact mode - (proximity button extinguished) the substrate is held in contact with the mask during exposure.
      i) HP - a vacuum is drawn between the mask and the wafer prior to exposure.
      ii) ST - nitrogen pressure is used to press the substrate against the mask.
5. Load the mask.
   a) push the MASK HOLDER button (the light should be extinguished).
   b) slide the mask holder to the left to remove and invert it.
      BE CAREFUL NOT TO HIT THE MICROSCOPE OBJECTIVES
   c) place mask onto the mask holder.
      i) the mask should be clean.
      ii) the Cr side goes up.
      iii) there are no alignment pins, so try to align the mask parallel with the indented part of the mask holder plate. Be sure the pattern is centered on the opening.
   d) flip the GREY TOGGLE switch (mask vacuum) down. this applies vacuum to the mask.
   e) verify that the mask is held securely.
   f) slide the mask holder back into the aligner.
      BE CAREFUL NOT TO HIT THE MICROSCOPE OBJECTIVES
   g) push the MASK HOLDER button (the light should illuminate).
6. Load your wafer onto the wafer chuck.
   a) align the major flat (wafer) to the two pins on the bottom of the wafer chuck.
   b) align the minor flat (wafer) to the one pin on the left side of the wafer chuck.
7. (OPTIONAL) at this time you may push and HOLD the PRE VAC button.
   this applies vacuum to the wafer so that you can use a nitrogen gun to clear your wafer of any loose particles.
8. Push the MANUAL button (the light should illuminate).
9. Press the FOOT PEDAL on the floor.
   a) vacuum is applied to the wafer.
   b) the lamphouse will swing to the right.
   c) the wafer will slide in under the mask.
10. Microscope operation.
    a) turn on the microscope illumination.
       i) this is the box on the left side of the table.
       ii) flip the switch on the front left corner.
       iii) adjust the intensity if needed with the dial located on the back.

b) moving the microscope is done by pressing and holding the buttons on the microscope manipulator handle.
   i) the top button enables X movement.
   ii) the bottom button enables Y movement.
c) adjust the microscope theta.
   i) loosen the theta lock (upper right side of microscope)
   ii) use the adjustment knob under the microscope eyepieces to align the theta.
   iii) retighten the theta lock.

11. Setting the wafer contact pressure (thickness dial setting-front lower left corner of stage) **READ ALL OF STEP 11 BEFORE SETTING CONTACT PRESSURE**.
   a) adjust the focus of the microscope so that the mask is in focus.
   b) while looking at the mask through the microscope, rotate the contact knob located on the left hand side of the stage slowly. You may not be able to rotate it all the way into contact. As you rotate the contact knob, observe what changes in focus occur.
      i) THE MASK IS IN FOCUS, THE WAFER IS NOT - the thickness setting is too low, increase the thickness dial setting.
      ii) THE WAFER IS IN FOCUS, THE MASK IS NOT - if the mask starts to lose its focus, **STOP** rotating the knob. The wafer is pushing on the mask and damage to your wafer or mask is possible - the thickness setting is too high, decrease the thickness dial setting.
      iii) BOTH THE WAFER AND MASK ARE IN FOCUS - the thickness setting is correct.
   c) when the contact pressure is adjusted, you may rotate the contact knob all the way until the contact light is illuminated.
12. Alignment.
   a) push SEPARATION button (right side of aligner). The SEPARATION button will illuminate, the CONTACT button will be extinguished
   b) align the wafer using the X ,Y and theta controls.
      i) you can only align while in separation.
      ii) if the wafer does not move, the separation distance needs to be increased. Rotate separation height dial to the left (black dial in front, lower, center of stage).
      iii) if the wafer shifts going into separation, the separation distance needs to be increased. Rotate separation height dial to the right.
13. Exposure.
   a) check that the alignment is good (in contact only).
   b) set the exposure time.
      i) the outer dial reading is the scale for the timer.
      ii) the inner dial reading is the multiplier factor, align with arrow.
   c) push EXPOSURE button.
      i) you must be out of separation (separation button extinguished).
      ii) you must be in contact (contact button illuminated) (except when using proximity mode).
14. After exposure is complete, push the MANUAL button.
   The light will extinguish, and the wafer chuck will slide out.
15. Unload the wafer.
16. Remove the mask.
   a) push the MASK HOLDER button.
   b) slide out the mask holder and invert.
   c) flip GREY TOGGLE switch to turn off mask vacuum.

d) remove the mask.
e) replace the mask holder.
f) push mask holder button.

17. Turn off the microscope.
18. Push the POWER button to turn off the power to the aligner.