Experiment 8 - Bulk Micromachining to form Diaphragm

**Purpose**
In this experiment, you will perform a bulk micromachining step on the backside of your silicon wafer using an anisotropic wet etchant to form the thin diaphragms required by your MEMS pressure sensor.

**Introduction**
Silicon has a crystal structure and as such certain wet etchants exhibit an orientation dependency during etching. These etchants are “anisotropic” and typically etch the silicon (111) plane the slowest due to its large surface density of atoms. The most popular anisotropic etchants for crystalline silicon are KOH, EDP, hydrazine and TMAH. Thermally-grown silicon dioxide can be used as a convenient protective masking layer for all 4 etchants. By patterning a square openings in the backside of a silicon wafer and carefully monitoring both the silicon and silicon dioxide etch rates, one can precisely form thin silicon diaphragms. For (100) silicon wafers, it is critical to align your square features to the <110> wafer flat to minimize undercutting. In the experiment TMAH is the preferred etchant due to its extremely slow oxide etch rate.

**Equipment and Tools**
- Filmetrics Thin Film Measurement System
- High Power Optical Microscope
- Dektak Profilometer
- TMAH Bench
- BOE Tank
- One-sided wafer holder

**Materials and Supplies:**
- Buffered Oxide Etch 6:1 (BOE 6:1)
- 25% Solution Tetramethyayl Ammonium Hydroxide (TMAH)
- 2Isopropyl Alcohol (IPA)
SOPs
- Filmetrics Thin Film Measurement System
- Silicon Oxide Etch
- Dektak Profilometer

PRE_LAB ASSIGNMENT AND QUESTIONS
(answer questions in your Lab Notebook and then submit a photo-copy to the TA at the start of this Lab)

1. Carefully read the Tetramethyl Ammonium Hydroxide (TMAH) MSDS.

2. Calculate the time necessary to create a 30 micron diaphragm on your silicon wafer using TMAH as the etching solution, assuming a (100) silicon etch rate of 17 microns per hour. Show your work.

3. Assuming the square window openings of the backside bulk-micromachining etch mask are 2 mm on a side, calculate the final lateral dimensions of your MEMS diaphragm after the TMAH etch. Show your work.

LAB PROCEDURES
(make comments and observations in your Lab Notebook)

1. Create a bulk micromachining solution of 25%wt TMAH (5 parts) and 17% vol of IPA (1 part) in the designated TMAH wet bench tank. Fill the tank until the low level sensor alarm turns off. Ensure the temperature probe is inserted into the etch solution.

2. Check the etch parameters on the controller with the TA. These parameters should be preset by cleanroom staff. The bulk micromachining solution will need to be heated to a steady specific temperature for a particular Si etch rate. The desired etch rate is 10-20 µm/hr @ 70C. The magnetic stir bar should be set to 200 rpm.

3. Make sure you measured the thickness of the silicon dioxide layer on your wafer backside as we need to carefully monitor this during the etching process. Measure it in 5 locations.

4. Once the temperature of the etching solution has reached steady state place the wafers in the Teflon wafer carrier. Soak the wafers in running DI water for about a minute to wet the wafer surface. To remove any native oxide in your patterned windows, dip the wafers in BOE for about 3-5 seconds. Then wash them in running DI and check that the windows are hydrophobic. After you are confident there is no oxide inside the patterned windows, (You want to protect the front side of the wafer during the TMAH etching. – Use the special one-sided etching jig which is made out of PEEK material to protect the front side and edges of your wafer. -TA will give you special instructions about placing your wafer on this wafer holder) transfer the wafer carrier to the TMAH etching tank and start your timer.
5. After approximately 1-2 hours of etching, remove your wafers and rinse in running DI. Use the QDR and SRD to further clean and dry your wafers.

6. Measure the thickness of the oxide layer on the backside of your wafer in 5 locations using the Filmetrics system. Calculate an average oxide etch rate.

7. Measure the depth of your silicon etch in 5 locations using both the Dektak Profilometer and High Power Optical Microscope. Calculate an average (100) silicon etch rate.

8. Using the Dektak Profilometer, evaluate the “smoothness” of the bottom of the etched surface in the middle of your wafer by measuring the peak-to-peak roughness of the etched surface.

9. Using the High Power Microscope, measure the lateral undercut of the oxide and use this value to estimate the (111) silicon etch rate.

10. Return the wafers to the TMAH etching solution by repeating step 5. The TA will perform the final etching required to produce 30 um diaphragms.

**POST-LAB ASSIGNMENT AND QUESTIONS**
(Answer questions in your Lab Notebook and then submit a photo-copy to the TA at the start of the next Lab)

1. Complete the Table below:

<table>
<thead>
<tr>
<th>silicon dioxide etch rate (nm/hr)</th>
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<tbody>
<tr>
<td>(100) silicon etch rate (um/hr)</td>
</tr>
<tr>
<td>(111) silicon etch rate (um/hr)</td>
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</tbody>
</table>

2. Draw a plan view (top) and cross-sectional view of your anticipated final etched structure. Provide dimensions.

**PART 1 - Etch Rate and Diaphragm Thickness Calculations**

1. Measure the thickness of your backside silicon dioxide film using the Filmetrics Thin Film Measurement System and calculate your overall Oxide Etch Rate in TMAH. Record this in your lab notebook for future use.

2. Inspect the frontside of your wafer under a high power optical microscope to see if it survived the long TMAH bulk-micromachining etch. Did your frontside oxide fail in spots. If so, note where. Can you make any conclusions?
3. Measure the depth of your TMAH etch using either the Dektak Profilometer or one of the High Power Optical Microscopes. Determine your overall (100) silicon etch rate.

4. Calculate the thickness of your MEMS Diaphragm.

5. Inspect the alignment of your piezoresistive elements with respect to your MEMS diaphragm using the Zeiss Microscope equipped with the IR camera and monitor. Draw a sketch of your result. Are you pleased with your fab?