

## EXPERIMENT # 3: SILICON ETCHING

Experiment # 4: Etching of silicon. Use of the scanning electron microscope (SEM)

The purpose of this experiment is to study the anisotropic etching of silicon. The etched structures are analyzed with the SEM which provides the necessary depth of field and spatial resolution to observe the details of the etched features.

Reading: handout on silicon etching and Crystallography. For an overview of crystal structures and crystal planes, see "Introduction to Solid State Physics", C. Kittel, 5th edition, Wiley & Sons (not required)

4.1 For this experiment we continue to process the oxidized and patterned wafer used in experiment # 3.

Etch the wafer in KOH at a temperature of approximately 80° C for 6 min.

Agitate gently during the etching.

The KOH mix we use does contain some alcohol to reduce surface tension.

Write down the actual temperature and etch time.

The gold which was sputtered onto the wafer during the previous experiment will start to peel off and should be completely removed after 6 min.

Rinse the wafer in DI water and blow dry.

The etch rate of silicon (100) wafers in KOH is approximately 0.6  $\mu\text{m}/\text{min}$  at 60° C and 8  $\mu\text{m}/\text{min}$  at 100° C.

Measure the depth of the etch based on the 54.7 degree angle (54.7 degree =  $\text{acos}(1/\sqrt{3})$ ) between the (100) and (111) planes.

Take a picture of the 1 mil and 1/2 mil squares, using the highest possible magnification.

For each size, take a picture with the oxide layer in focus and one with the bottom of the etch pit in focus.

Determine the depth of the etch and calculate how much longer needs to be etched to etch 12.5 microns deep into the silicon.

Etch the silicon again.

Check the color of the oxide and compare it to the color before etching.

Measure the thickness of the oxide using the ellipsometer.

4.3 After etching check the depth of the etch (taking the appropriate pictures as evidence). Check the etched pattern and draw carefully and to scale the crosssection between points A and A' and between B and B' as indicated on the mask layout in the handout.

Make sure you also draw the oxide layer.

Take a picture of both areas and attach to your report.

4.4 Find oxide bridges and cantilevers on your wafer.

Indicate their position on the mask layout provided in the handout and add it to your report.

4.5 Measure the flatness of the bottom of the etched regions with the Watson interference microscope.

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Describe the features you see and their height.

Take a picture of the bottom surface with the interference fringes.

Compare the area which was initially covered with gold to the area which was not covered with gold.

How do you explain the difference?

- 4.6 Break off a 1 cm<sup>2</sup> piece for inspection in the Scanning Electron Microscope (SEM).  
Cleave one edge so that it can be used to determine the angle between the (100) and (111) plane.  
To do this use a diamond scribe to scribe the front side of the wafer in a direction which is either parallel or perpendicular to the wafer flat.  
Scribe a line on the wafer so that when cleaving along that direction, the cleave runs through an appropriate etch pit.  
Do not scribe across, but rather adjacent to the etch pit of interest.  
Place the sample vertically into the SEM sample holder, with the cleaved edge facing upwards.
- 4.7 Inspect your etched structure with the SEM and take pictures of the areas A-A' and B-B' indicated on the mask layout.  
Look at the cleaved edge and measure the etch depth and the angle between the (100) and (111) surface.  
Look for the overhanging bridge structures and draw a crosssection of the bridge, indicating the length and thickness of the overhanging oxide, the depth of the edge and the distance between the middle of the bridge and the silicon surface.
- 4.8 Look at thin soap membranes under the microscope and take a picture of the thinnest (darkest) region of the membrane.  
**CAUTION:** Keep a safe distance between the soap film and the objective lens; once you have a soap film on the lens you will get blurry images.  
Form the membranes by dipping a perforated piece of metal (or some specially prepared silicon samples) into a soap solution.  
Look at the soap film and observe how the features move and change color.  
Wait for the structure to settle.  
You now should have black areas as well as several bright colors.  
If you observe primarily pink and green colors and do not get a good focus the soap film is too thick. Repeat the process and hold the metal vertical for a while to thin the membrane.  
Write down the color sequence in order of increasing film thickness. How do these colors differ from those observed with the interference microscope?  
Note that the colors vary in steps rather than continuously. How do you explain this?  
Carefully count the number of steps between the darkest region and the first white region.  
Find out the thickness of the thinnest region.  
Also take a color picture.

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Report # 4: Due Tuesday 3/9/98 - Thursday 3/11/98.

- a) What devices require anisotropic silicon etching? Refer to the corresponding page number in the book. (Chapter 9 and 10)
- b) What was the actual temperature during KOH etching? How long was the total etch time?
- c) Determine the etch depth based on the shape of the etch pits and a 54.7 degree angle between the {100} and {111} planes. Is the total depth close to 12.5  $\mu\text{m}$ ? What is the corresponding etch rate? Paste in the pictures you used to determine the depth, indicating the size of the squares.
- d) Why would one want to reduce the surface tension of the KOH solution?
- e) What was the color of the oxide before and after etching in KOH? What are the corresponding thicknesses? How do those thicknesses compare to those obtained with the ellipsometer. Based on the change in thickness find the etch rate of the  $\text{SiO}_2$  and the etch selectivity between silicon and silicon dioxide.
- f) Draw carefully and to scale the crosssection between point A-A' and between B-B'. Make sure you also draw the oxide. Attach a picture of each region.
- g) Identify some oxide bridges and cantilever structures. Indicate their position on the attached mask layout.
- h) Describe the appearance of the etched silicon surface. What is the height of the surface roughness as measured with the interference microscope? Does the gold affect the surface roughness? If so how do you explain this and how large is the effect?
- i) Attach pictures of areas A-A' and B-B' to your report. Indicate the angle on your picture of the cleaved edge and measure that angle.
- j) Draw a crosssection of an overhanging bridge structure indicating the length and thickness of the overhanging oxide, the depth of the edge and the distance between the middle of the bridge and the silicon surface.
- k) Do the colors of a soapfilm correspond to those observed in the interference microscope? Why do the colors of the soap membrane vary in steps rather than varying continuously? How many steps did you count up to the first white region? What is the thickness corresponding to the first white region? What is the thickness of the thinnest region and how did you obtain this value? (this part is optional)