NATIONAL TECHNOLOGICAL UNIVERSITY
Introduction to MEMS
(UC Berkeley EECS 245)

Homework Assignment #3 Solutions

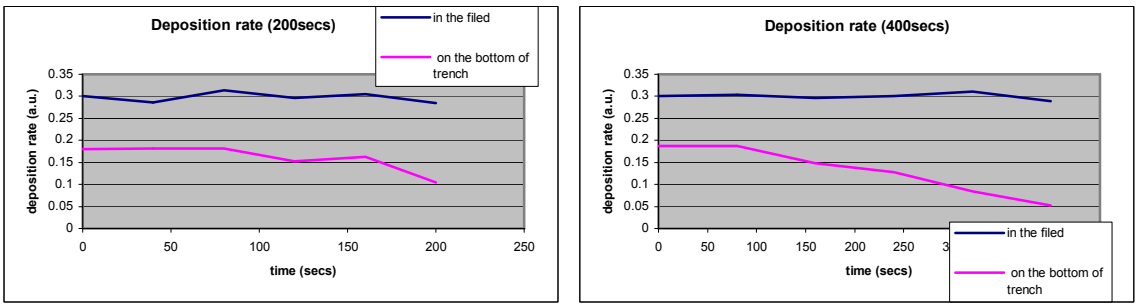
Problem 1: Simulation.

You should see a yellow "substrate" with a 1 micron trench etched into it, and some straight lines above it representing line-of-sight deposition.

1. Don't change any defaults, just press "Submit to Sample2D". You should see that the trench is filled in, but that the corners didn't fill in well. Using one of the red dots on the trench, or the sliders on the side, change the top aperture to 1.1 microns and run the simulation again. Assuming that this is a metal deposition onto an insulator, will there be electrical connectivity between the metal on top and the metal in the hole? Change the top aperture to 0.9 microns and re-run the simulation. Will there be electrical continuity now?

1.1um: yes *0.9um: no*

2. Reset the simulation so that the trench is 1 micron square again, and change the source type to "Hemispherical", and run the simulation. Using the mouse, determine the deposition rate in the field, and in the center of the bottom of the trench. Change the deposition time to 400s and graph the two deposition rates on the same plot. Put the URL for this plot here:



What can you say qualitatively about the deposition rates in the field, at the bottom of the trench, and on the sidewalls?

The deposition rate in the field remains constant all the time, while the rate at the bottom of trench is decreasing with time as the opening of trench is closing.

3.Reset the simulation to a 1 micron square trench, use hemispherical deposition with cosine flux, and set the positive and negative angles to +-90. How long of a deposition is necessary before the top of the keyhole is less than 0.1 microns wide (use the mouse to measure)? What film thickness does this correspond to?

~ 550 sec *2.75um*

4.Reset the simulation to a unidirectional source, and select a "line" profile. Change the base of the line to a width of 0.75 microns, leaving the top at 1micron. Run the simulation twice, once with a 200second deposition, and once with 100 seconds. If the "line" were made of photoresist, and the film deposited were gold, which of these two thicknesses would likely work if the goal were to pattern the metal by liftoff?

100 seconds

5.Reset the simulation to hemispherical source, uniform flux, and +-90 angles, a line profile, and 100s deposition. What fraction of "blue sky" can the top and side of the beam see (in degrees): What deposition rate would you predict for the top and sidewalls of the beam? What are the deposition rates on the top of the beam, on the side of the beam, and in the lower/inner corners of the beam? Does the simulated deposition rate fit with what you predicted? Try the same simulation with longer depositions, and think about how reflow would affect an oxide shaped like this.

"blue sky" for top: 180 side: 90.

predicted deposition rate for top: 5nm/s=0.3um/min side: 5/2nm/s=0.15um/min.

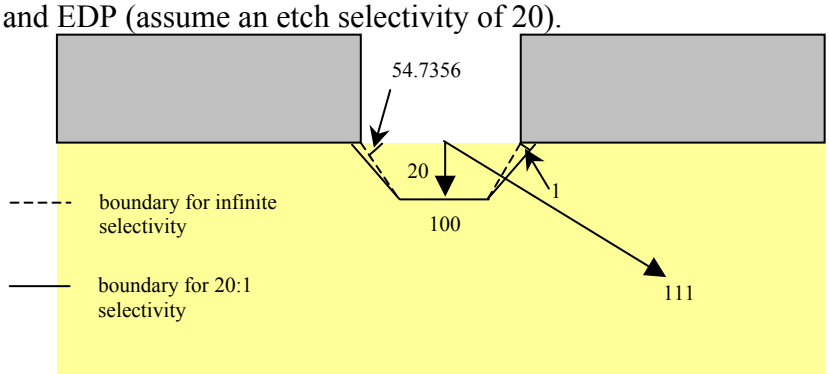
actual deposition rate for top: 0.3um/min side: 0.15um/min lower inner: smaller than side.

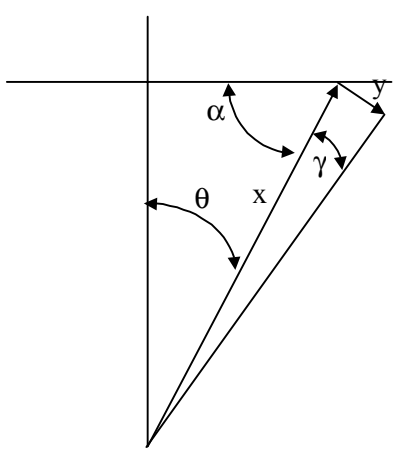
Longer deposition time: there may be a closed key hole existing in the inner corners.

Reflow will flatten out the step.

Problem 3: KOH Etching

The angle between the {100} and {111} crystal planes in a silicon wafer is 54.74 degrees, but a real etchant will not give perfect anisotropy. Calculate the actual angle of the sidewall of a pit etched with KOH (assume the etch selectivity of {100} over {111} is 400) and EDP (assume an etch selectivity of 20).





$\alpha = 54.74$ *y = 1 atomic layer*

$\theta = 90 - 54.74$ *xcosθ = vertical etch distance*

KOH: S=400

$x \cdot \cos\theta = 400$

$\tan\gamma = \frac{y}{x}$

$\alpha - \gamma = 54.62\ ^{\circ}$

EDP: S=20

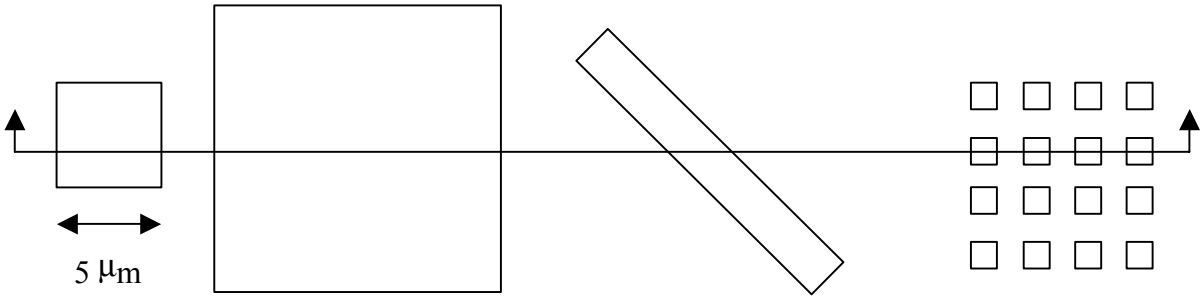
$x \cdot \cos\theta = 20$

$\tan\gamma = \frac{y}{x}$

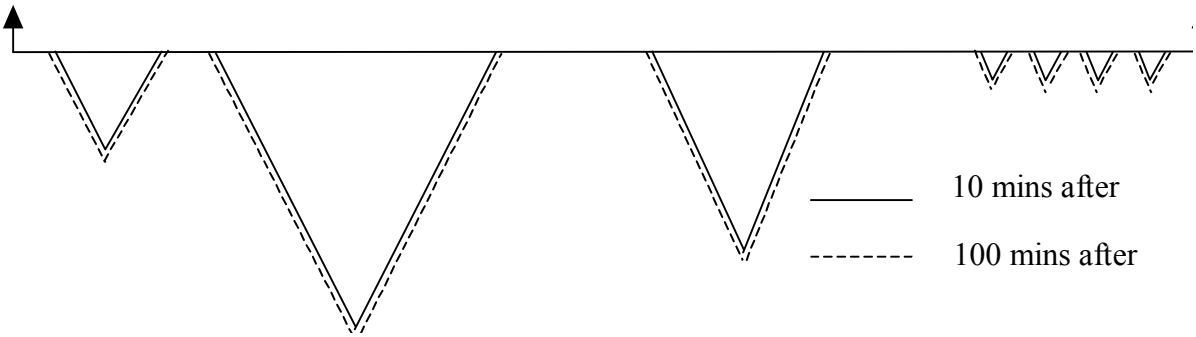
$\alpha - \gamma = 52.4\ ^{\circ}$

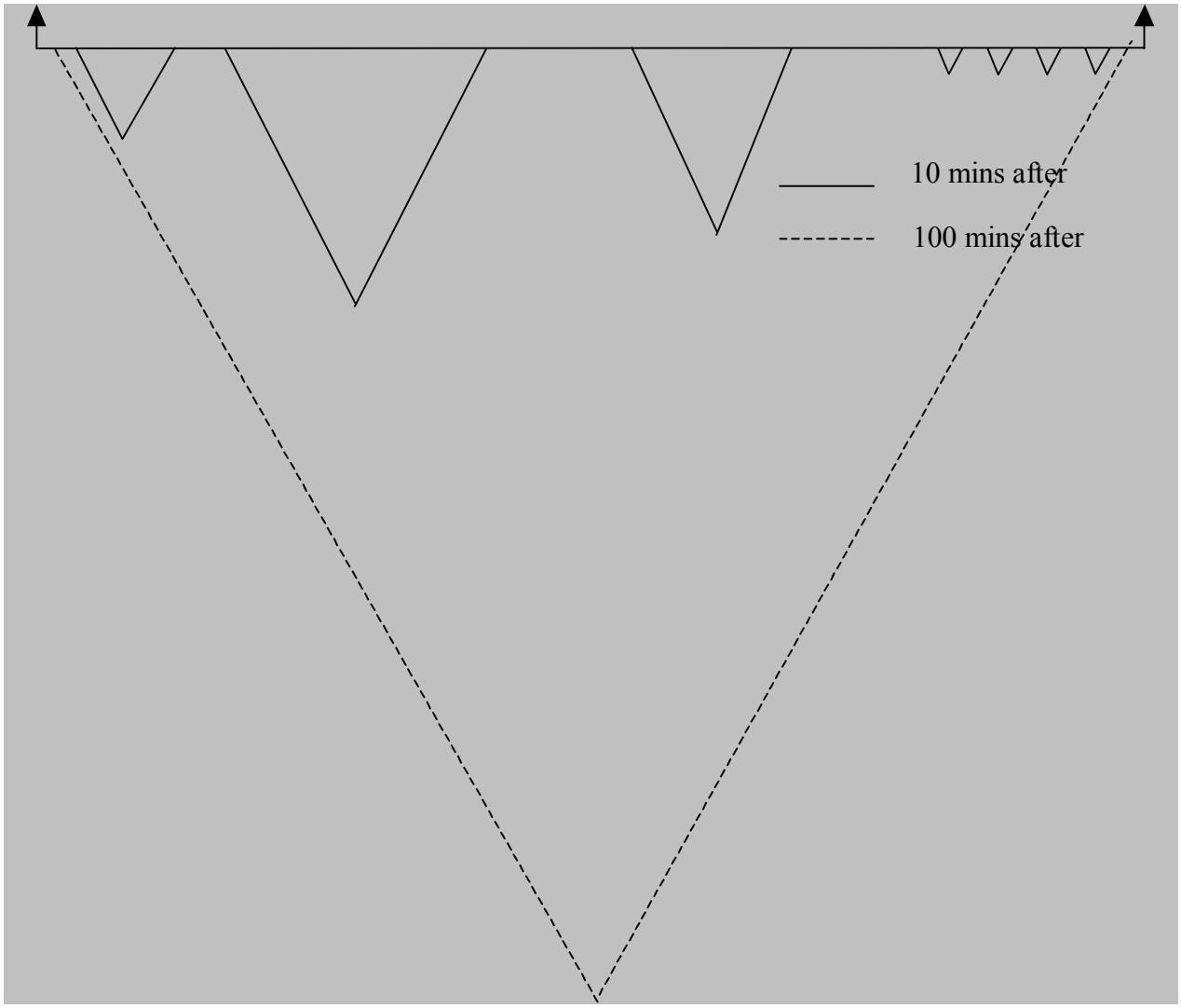
Problem 4: KOH Etching II

A (100) wafer with a nitride mask with the following openings is etched in a KOH solution with an etch rate of 1 micron/minute, and a selectivity of 400. Draw the cross-section after 10 minutes and 100 minutes of etching.



How will the cross-sections change if we use EDP instead of KOH?





Note: this was drawn by hand on the computer, without the aid of angle measurement. Obviously the angles should be about 54°. With EDP the angle should be a little shallower.

Problem 5: Si Crystal

What are all of the possible angles between planes in the {111} family of planes?

From the dot product of the possible vectors in the {111} family, i.e. (a,b,c)·(a,b,c) where a, b, and c could be any combination of 1 and –1: the possible angles are therefore 0, 70.53º, 109.47º, and 180º.