EE245, Fall 2001

Homework 3 solutions

problem 1.1

For the default case, please see:
http://cuervo.eecs.berkeley.edu/Volcano/sessions//S1001394121/DrawPlot.html

Like the problem statement says, the trench is filled in, but the corners didn't fill in well. After changing the top aperture to 1.1 μm and running the simulation again, this time there is electrical connectivity between the metal on top and the metal in the hole.

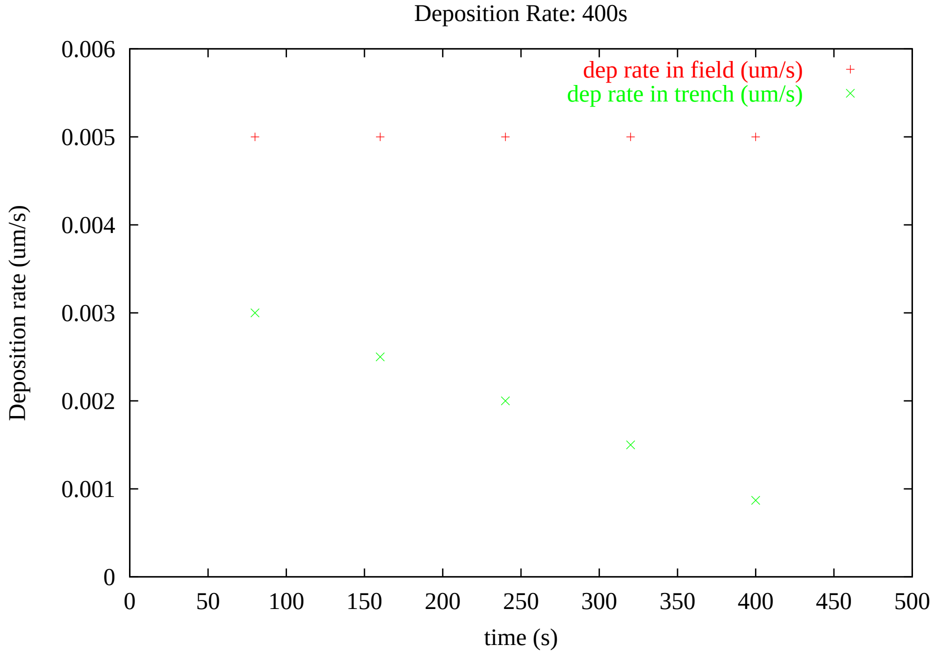
Please see: http://cuervo.eecs.berkeley.edu/Volcano/sessions//S1001394729/DrawPlot.html

After changing the top aperture to 0.9 μm, there is again no electrical continuity. The overhanging edges shadow the bottom of the trench.

Please see: http://cuervo.eecs.berkeley.edu/Volcano/sessions//S1001394887/DrawPlot.html

problem 1.2

From the simulation (400s deposition time, hemispherical source into a square trench) we get these deposition rates:



Please see: http://cuervo.eecs.berkeley.edu/Volcano/sessions//S1001578795/DrawPlot.html

From this graph we can see that the deposition rate in the field does not change with time, whereas deposition rate in the trench decreases as the deposited film gets thicker.

problem 1.3

With a 1 μm square trench, hemispherical deposition with cosine flux, and the positive and negative angles at $\pm 90°$, it takes approximately 450 seconds of deposition before the narrowest part of the keyhole is less than 0.1 μm wide. This corresponds to a film thickness of approximately 2.24 μm in the field.

Please see: http://cuervo.eecs.berkeley.edu/Volcano/sessions//S1001397912/DrawPlot.html

problem 1.4

For a "line" profile, base of the line 0.75 μm wide, top of the line 1 μm wide, 200 second deposition, please see:

http://cuervo.eecs.berkeley.edu/Volcano/sessions//S1001398344/DrawPlot.html

For the same line, 100 second deposition, please see:

http://cuervo.eecs.berkeley.edu/Volcano/sessions//S1001398477/DrawPlot.html

If the "line" were made of photoresist, and the film deposited were gold, the 100 second deposition would likely work. There is a clear separation between the film deposited on the substrate and the film deposited on the photoresist (material removed during the lift-off process). There was a lot of work done to create this kind of overhanging profile. It turns out that if you treat the photoresist by soaking the wafer (after you spin on the photoresist) in chlorobenzene, the chlorobenzene will penetrate into the resist surface. This surface part will develop at a slower rate and thus form the overhanging lip.

problem 1.5

For a hemispherical source, uniform flux, $\pm 90°$ angles, and a line profile (1 μm width on top and bottom), the top can see 180° (all of the "blue sky") and the sides can see 90°. At first glance one might expect that the top will have twice the deposition rate that the sidewalls of the beam will have. As expected, after running the simulation for a 100 second deposition, we see that the deposition rate at the top of the beam is higher than at the side. It is lowest at the lower/inner corners of the beam and has a puckered profile.

Please see: http://cuervo.eecs.berkeley.edu/Volcano/sessions//S1001398884/DrawPlot.html

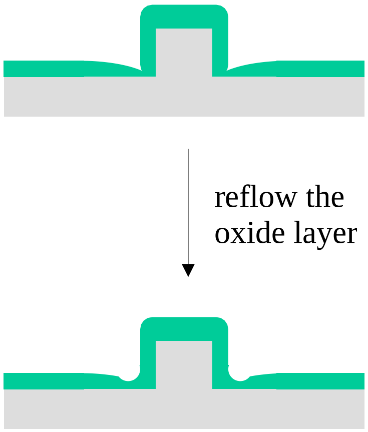
The top of the beam has 0.5 μm film thickness, while the sides have half that, at 0.25 μm film thickness.

For a 200 second deposition, please see:

http://cuervo.eecs.berkeley.edu/Volcano/sessions//S1001399790/DrawPlot.html

Now the top of the beam has 1 μm film thickness, while the sides still have half at 0.5 μm.

Let's say that after film deposition, we do an anneal step (as Professor Pister says, one should always anneal after deposition). From Fundamentals of Microfabrication by Madou, anneal is the "heat process used to remove stress, crystallize or render deposited material more uniform." If we had deposited an oxide film on top of a polysilicon line, this anneal would reflow the oxide and smooth it out a little:



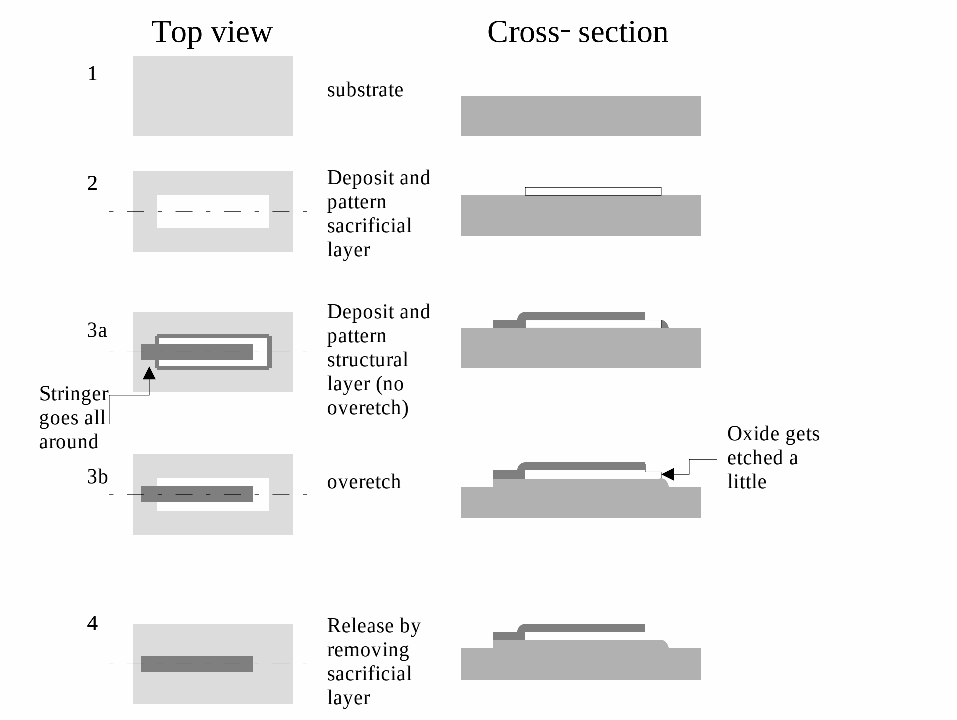
Now instead, let's say that we've reflowed the <u>beam</u>, so that instead of being square in cross-section, it looks more like a semicircle. For example, if the beam was a line of photoresist, and you wanted to deposit a polymer on top of it (photoresist acts as the sacrificial material here), you might reflow it. For a 100 second deposition, please see:

http://cuervo.eecs.berkeley.edu/Volcano/sessions//S1001400128/DrawPlot.html

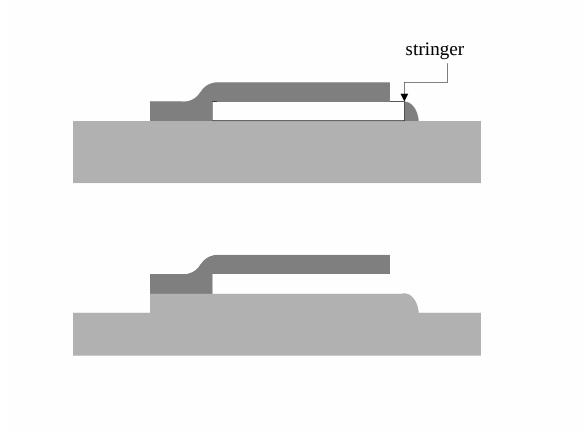
(Reflow profile is somewhat exaggerated.) The deposition rate is much more even across the surface of a rounded beam than a square beam.

problem 2

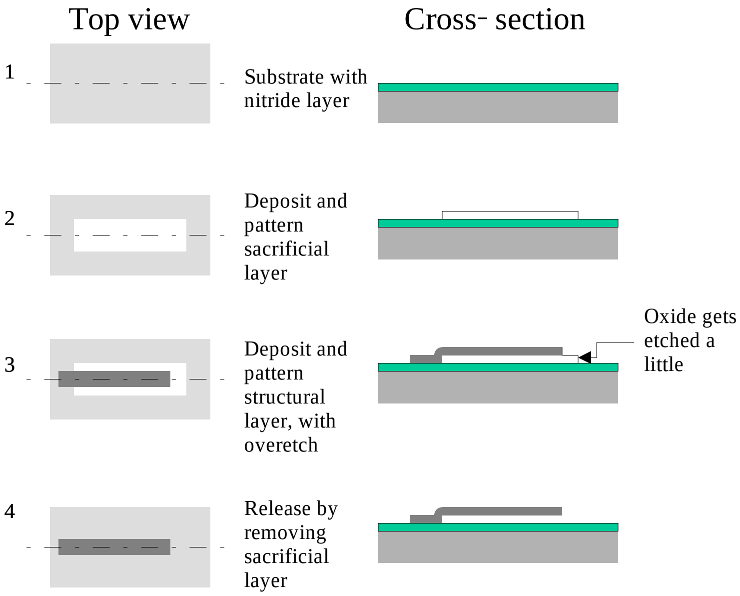
The vertical thickness of the polysilicon where it goes over the edge of the oxide will vary from 2 μm to just less than 4 μm. Based on that thickness, a minimum of 2 μm overetch must be used in the polysilicon etch to avoid leaving any stringers. Assume that you are using the chlorine and helium etch in the Lam Rainbow 4420 etcher from K. Williams' paper, which gives an etchrate of 5700Å/min for n+ poly. This translates to 3.5 minutes overetch. Unfortunately, this overetch will eat into the single-crystal silicon substrate.



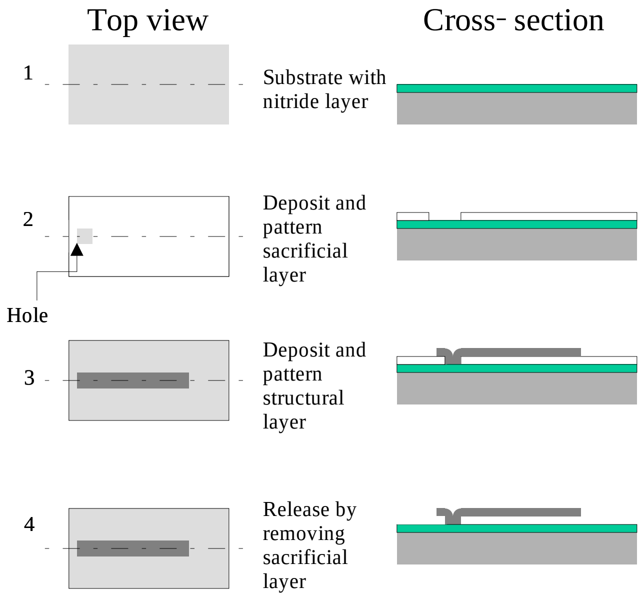
Here is a close-up view of step 3a and 3b:



By adding a uniform 0.5 μm silicon nitride layer before any other processing, the problem of etching into the substrate during the polysilicon etch can be avoided, since the Cl_2 and He etch in the Lam Rainbow 4420 etcher etches low-stress nitride at 530 Å/min. It would take 9.4 minutes to etch through this nitride layer, so a 3.5 minute overetch on the poly should be safe.



If you wanted to change the layout to minimize these problems, you might leave oxide on the entire substrate, and only open a contact hole for the cantilever anchor area. This would avoid the stringer problem since there aren't any extraneous steps for the poly to cover.



problem 3

“Etch selectivity” has to do with how much a given material A and material B are etched in a process. For example, if an etch process will removes film A at 3 μm/min and film B at 0.03 μm/min, then the selectivity of this etch is A:B::100:1. In this case, B makes a good masking material for an etch of A.

Lam 590 (450W, CF_4+CHF_3+He) selectivities:

(etchrates given in Å/min)

LTO:Low-σ nitride $= \frac{4500}{1900} = 2.4$

LTO:silicon (Poly n+) $= \frac{4500}{1900} = 2.4$

These selectivities are low!

Lam 4420 selectivities:

silicon:LTO $= \frac{5700}{60} = 95$

silicon:nitride $= \frac{5700}{530} = 9.7$