"I went on what the movies called a roaring rampage…I roared and I rampaged and I got bloody satisfaction. I've killed a hell of alot of people to get to this point. And I have only one left. The last one."

-Kill Bill, vol. 2

Problem 1 **30 points**

a) Boron etch-stop is a very powerful and precise technology for making a microstructure with a precise thickness. However, it is not exclusively used for making such structures and other techniques are used. Name the single most important reason why this is the case?

3 points

b) Name at least five ways that two silicon wafers can be bonded together?

4 points

c) This question relates to the anodic bonding of silicon and Pyrex glass. Choose the most appropriate statement from the following list (only one answer):

3 points

- The surfaces of the two wafers can be nonplanar.
- The surfaces of the two wafers must be perfectly polished.
- The surfaces of the two wafers can have surface roughness in the range of a few hundred angstroms.

d) This question deals with wafer bonding using eutectic bonding. Choose the most appropriate answer(s) (there may be more than one correct statement):

3 points

a) The surfaces of the two wafers can be nonplanar.
b) Bonding can be done with only Silicon-Gold eutectic.
c) Bonding can be done with several different types of eutectic.
d) Bonding can be performed above the eutectic point of the bonding materials.
e) Bonding can be done at room temperature.

e) The etch rate ratio of silicon in EDP for (100)/(111) and (110)/(111) planes is 40 (both cases), and the etch rate along the [100] direction is 1 μm/minute. A (100) wafer with an oxide mask all around and a square opening on one side (a square whose sides are oriented along the <110> direction) is placed in EDP and is etched until an inverted pyramid is formed. Now the wafer is allowed to sit in EDP for an several hours. Answer the following questions.

5 points

a- The etchant will not undercut the mask opening (circle one):

True False

b- The angle between walls of the inverted pyramid and the surface of the wafer will be (circle one):

A) 54.7^o
B) slightly less than 54.7^o
C) slightly greater than 54.7^o
D) 90°
E) 180°

f) Circle ALL the statements that are correct?

2 points

a- In a negative photoresist, those regions that are exposed will be dissolved away in a developer.

b- In a positive photoresist, those regions that are exposed will be dissolved away in a developer.

g) After a 1 hour oxidation of a silicon wafer at 1000 °C, there is 1 μm of thermal oxide on the surface. If I put the same wafer back in at 1000 °C for 2 more hours, what is the final TOTAL amount of oxide? **3 point**

a. 3 μm
b. 2.3 μm
c. 1.7 μm
d. 1 μm
e. Something else: _____

h) X-rays are used to build high aspect ratio microstructures using electroplating. Why is x-rayused instead of UV radiation, especially since working with x-rays is a lot more difficult? **3 points**

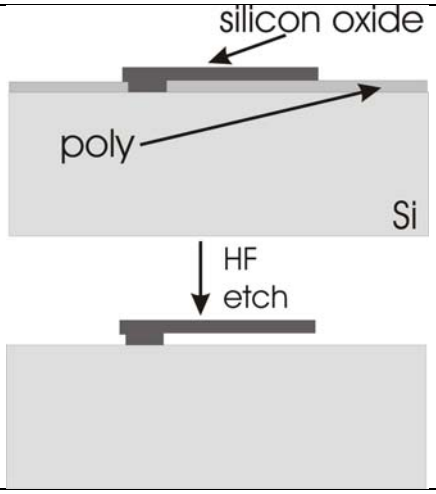
i) It has been said that silicon dioxide cannot be grown to a thickness much larger than about 1-2μm. Briefly explain why? **4 points**

Problem 2 **20 points**

Narrator: *On a long enough timeline, the survival rate for everyone drops to zero.*
-Fight Club

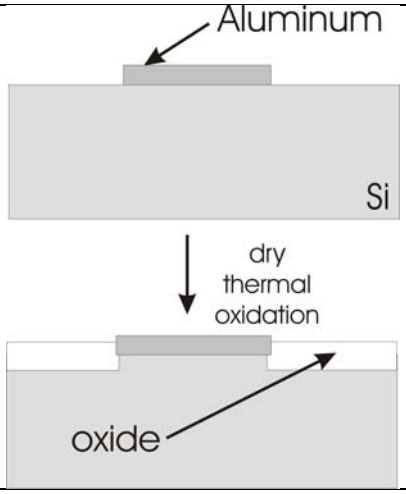
My graduate students are tasked with designing a thermopile sensor on a membrane. Four of them submitted the designs below. Circle which of these designs will get my grad students fired and why (other than because I am a bastard).

A



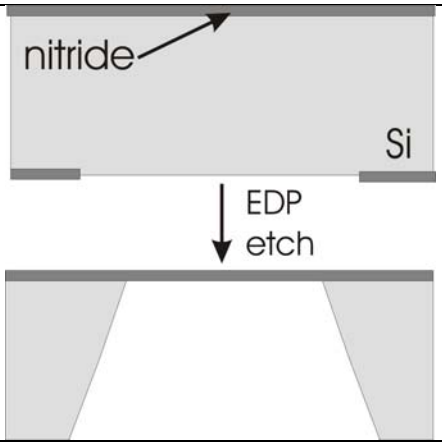
Will this work? **YES** **NO**
Why?

B



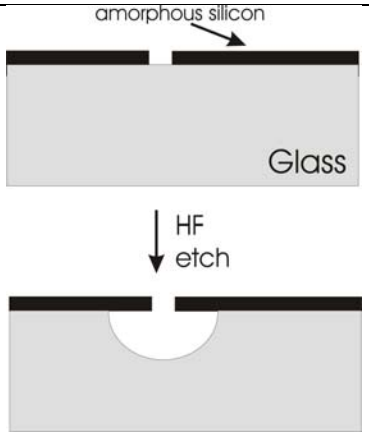
Will this work? **YES** **NO**
Why?

C



Will this work? **YES** **NO**
Why?

D



Will this work? **YES** **NO**
Why?

Problem 3 **30 points**

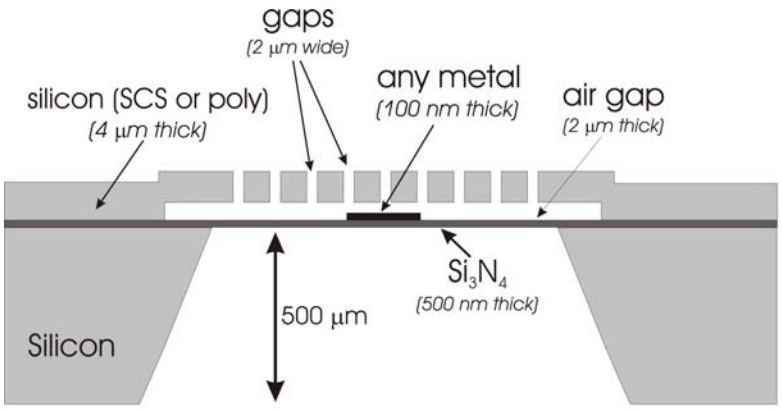
”*Bill: Do you find me sadistic? Yah know, I bet I could fry an egg on your head right now, if I wanted to. Now Kiddo, I'd like to believe that you're aware enough even now to know there's nothing sadistic in my actions, maybe towards those other.....jokers, but not you. No Kiddo, this moment, this me at my most.....masochistic.”*

-Kill Bill, vol. 2

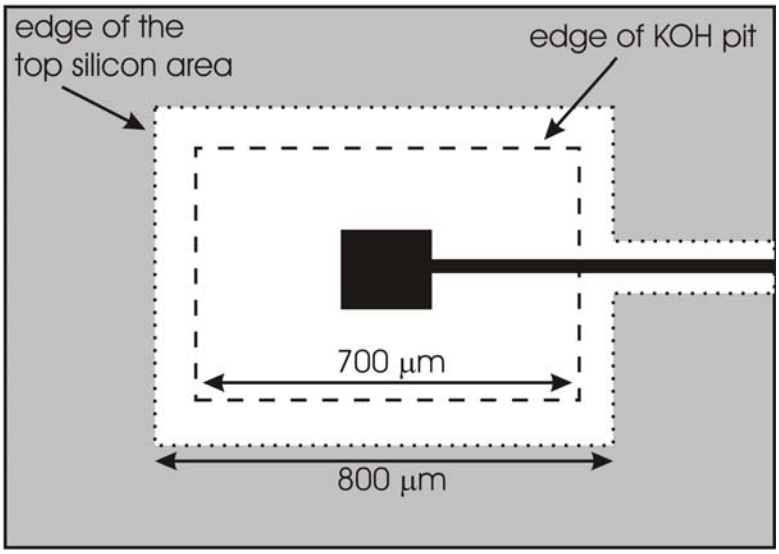
In this problem you are required to fill out a process sequence that will generate the device below.

YOU MUST USE the process sheets in the subsequent pages.
Each step has a space for:
1) that step's process description
2) a mask layout
3) space to draw a cross-section.

A sample is provided on the next page (not related to the problem). **YOU DO NOT HAVE TO PROVIDE ALL THREE COMPONENTS FOR EVERY STEP**.



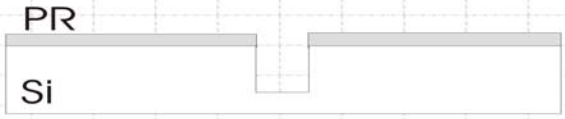
Cross section



Top View

Layout

Cross-section



Description

Lithography with above dark-field mask, then etch of 5 mm of silicon with SF_6. Then strip PR.

Layout

Cross-section

Description

Layout

Cross-section

Description

Layout

Cross-section

Description

Layout

Cross-section

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Cross-section

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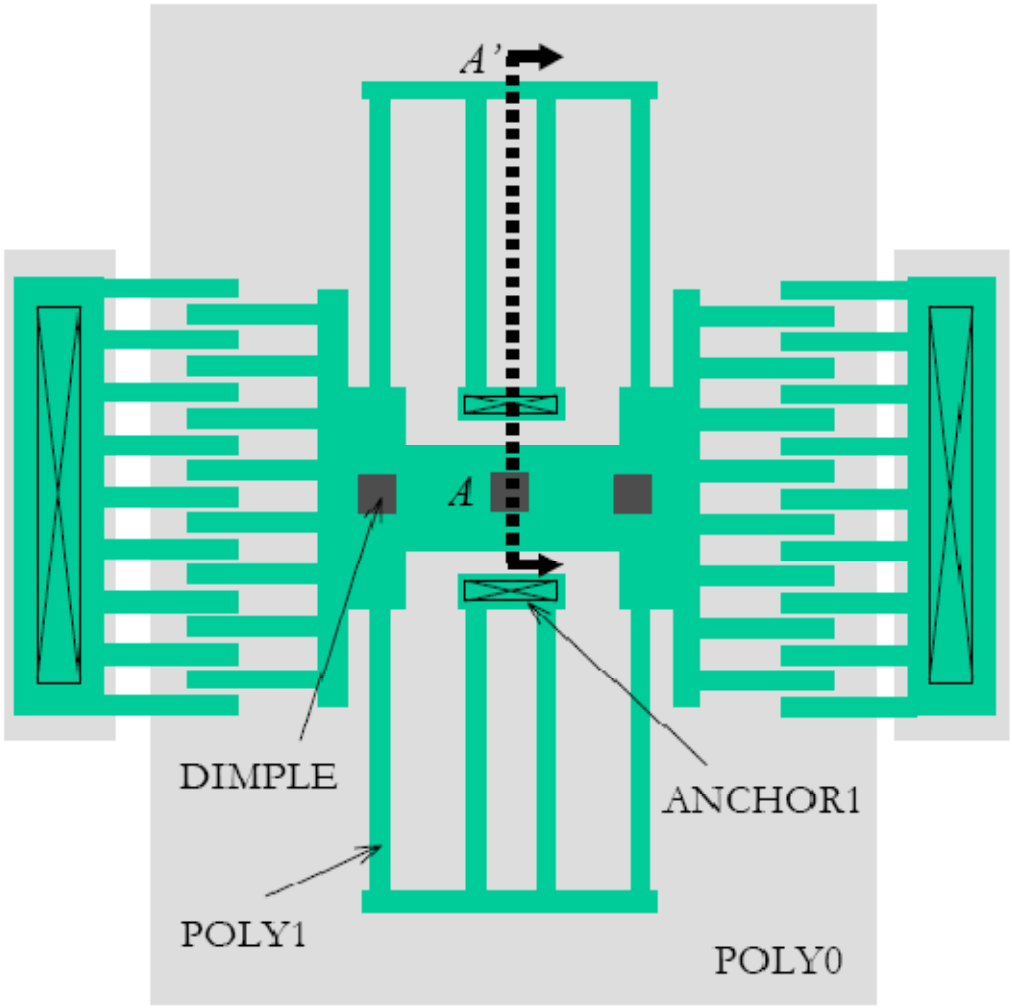
Cross-section

Description

"Paranoia is just life on a finer scale."
-Strange Days

Problem 4 **20 points**

The layout of the lateral resonator shown below is sent to the MUMPS foundry to be fabricated with a surface micromachining process.



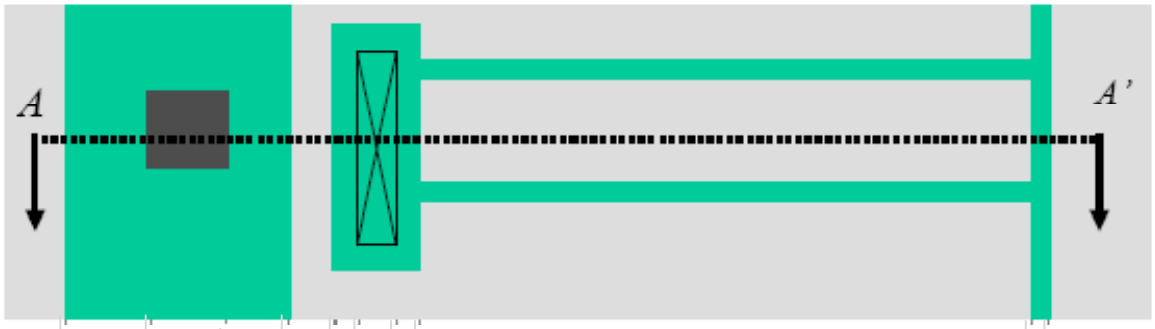
The MUMPS film thicknesses are:

- Silicon nitride 0.6 μm
- POLY0 0.5 μm
- DIMPLE depth 0.75 μm
- Oxide1 2 μm
- POLY1 2 μm

The order in which the masks are used is as follows:

- POLY0
- DIMPLE
- Oxide1
- POLY1

Draw the following cross sections (*A-A'*) on the substrates given below using the provided guide lines:



a) After the process has reached the Oxide1 etching for ANCHOR1 but before photoresist removal:

b) Just before the wafer is put into HF to release the structures: