EE147 / 247A Midterm Fall 2020

You may spend up to 80 contiguous minutes to take this exam. **Upload within 85 minutes of when you download!**

The exam is open book, open notes. You may view reference materials stored in a single directory on your computer or phone. You may also use a calculator function on these devices. All other use of electronics is prohibited.

Name___________________________

SID_____________________________

Exam start time:______________________

Exam end time:________________________

I didn't cheat and I won't cheat on this exam ___________________________________ (signature)

Problem	Score	Points Possible
1		10
2		10
3		8
4		8
5		10
6		6
7		10
8		8
Total		70

Show your work, and put final answers in the boxes provided. ***Use proper units in all answers.***

1. [10] In the figure below, the structure on the left is the pattern on a mask. The mask is used for a Deep Reactive Ion Etch (DRIE) into a Silicon-on-insulator (SOI) wafer with a top-layer thickness of 10μm, and an oxide thickness of 2μm. Two copies of a cross-section of the device are shown after the DRIE etch and subsequent photoresist removal. The device is then dropped into a hydrofluoric (HF) acid solution with an SiO_2 etch rate of 1um/minute.

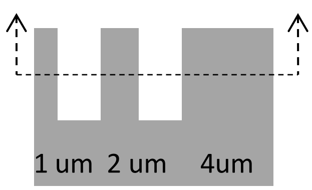
a. Carefully draw the process cross-section after 1 minute in HF.

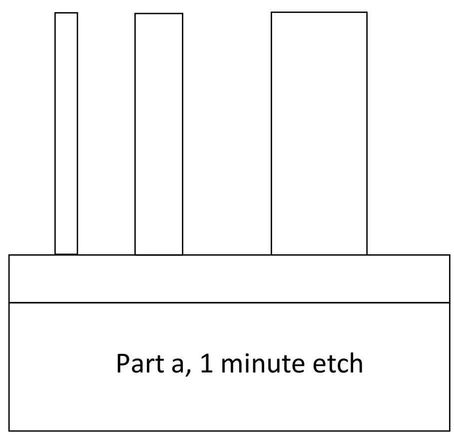
b. Carefully draw the cross-section after 2 minutes in HF.

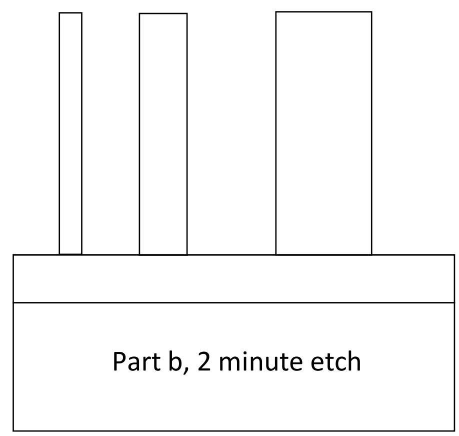
c. An 11 um square piece of silicon has two 2 um square etch holes. On a top-down view of the structures, carefully sketch where there would still be oxide in contact with the SOI layer after a 2 minute etch

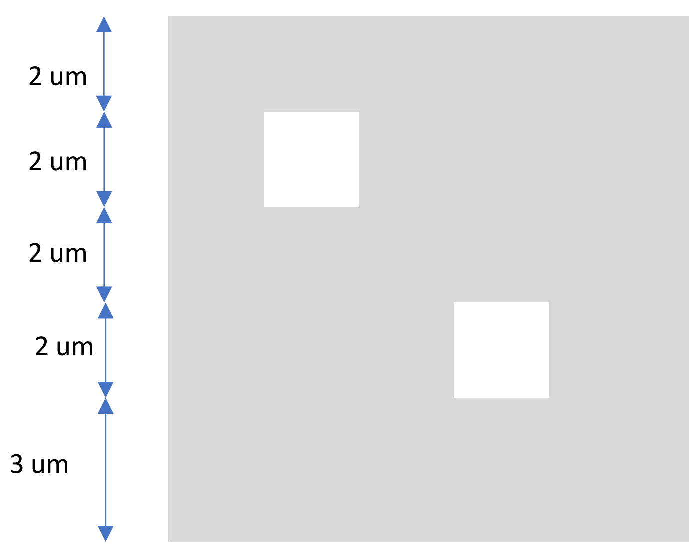
d. What is the diameter of the largest circle that will be released in a 2 minute etch?

e. What is the side of the largest square that will be released in a 2 minute etch?









part c, an 11 um square with 2 etch holes. 2 minute etch.

2. [10] For a silicon cantilevered beam that has a 1x1 um2 square cross-section and a length of 10 um, with a Young's modulus of 170 GPa and a fracture strain of 1%
   a. What is the fracture stress?

   b. What is the axial force that will cause the beam to break?

   c. With a lateral force applied at the tip, where in x and z is the strain the greatest (where x=0 is the distance along the beam from the anchor point, and z is the distance from the neutral axis)

   d. What is the lateral force at the tip that will cause the beam to break?

   e. What is the deflection of the tip when the beam breaks?

3. [8] For a comb drive resonator, if all dimensions scale by a factor S, how do the following parameters scale?

Parameter	Scales as (e.g. S, S^2, sqrt(S), 1, etc.)
mass	
Spring constant	
damping	
Electrostatic force	
Low frequency deflection	
Quality factor Q	
Resonant deflection	

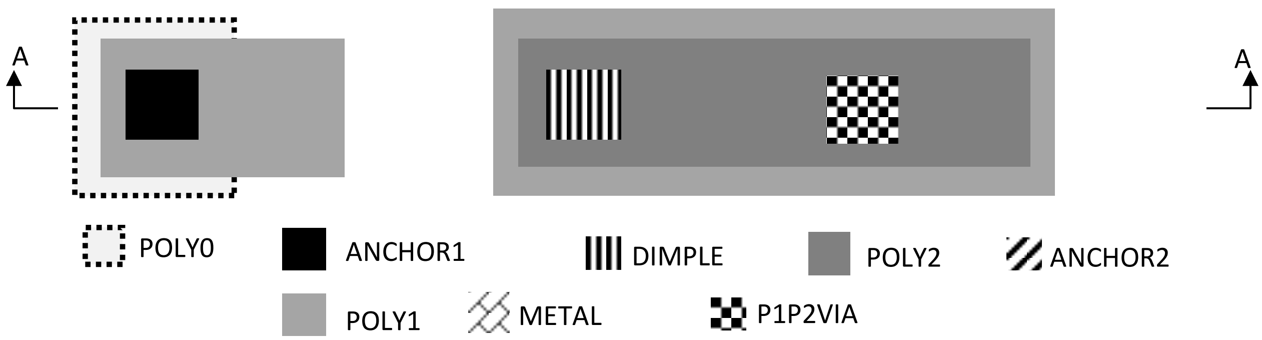
4. [8] In the polyMUMPs process, list the thin film layers that will be present on the substrate (starting at the substrate and working up, in order) before the release etch, in regions with the following masking layers
   a. POLY0, POLY2, METAL

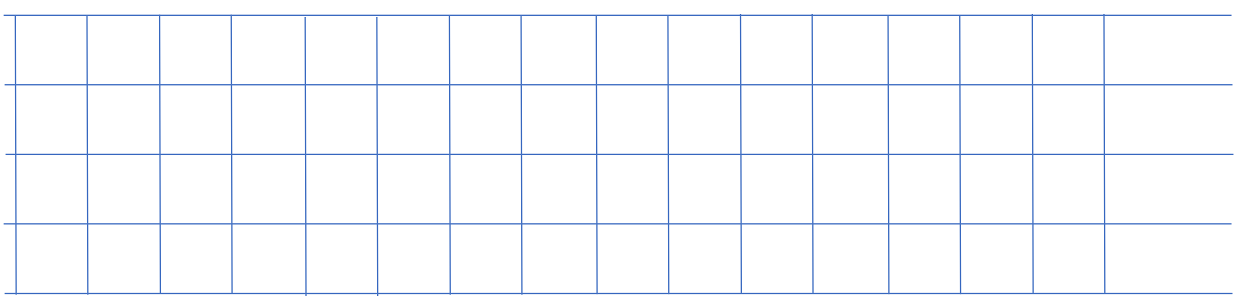
   b. ANCHOR2, POLY2

   c. POLY0, ANCHOR1, POLY1, POLY2

   d. POLY1, PIP2VIA, POLY2

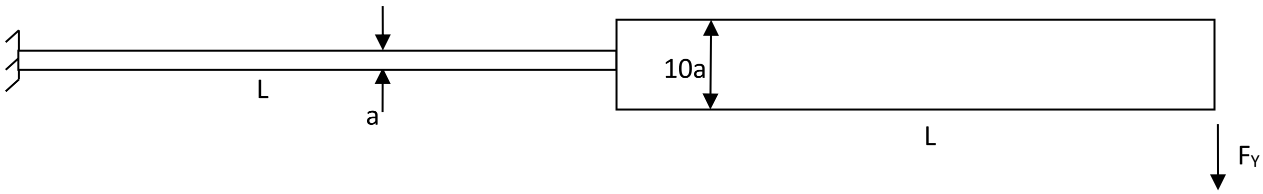
5. [10] The layout below is to be made in the polyMUMPs process. Draw a cross-section through AA of what the structure will look like **before** the final HF etch. Assume that all of the contacts are 2x2um2, and the grid below is also 2um squares.





6. [6] You have a comb drive resonator in an SOI process with a 10 um thick device layer. Your design has 10 comb fingers on each side, with 2 micron gaps. You apply an AC voltage of (15V) sin(ωt) to the comb and a DC 15V to the structure. What forces do you get on the structure? Please give results in Newtons.

7. [10] In the structure below, the smaller beam has a width a, thickness b, and length L. The larger beam attached to it has the same b and L, but is 10 times wider.



   a. If the two beams were separate cantilevers, how much stiffer in lateral deflection would the wider beam be? (I want you to compare the stiffness of two beams of different widths)

   b. Now you may assume that the wider beam is rigid. For the loading condition above, calculate
      i. The end load on the narrow beam, F_0 and M_0.

      ii. The deflection and rotation of the tip of the narrow beam, y_0, θ_0.

      iii. The deflection of the tip of the wider beam, T, in terms of y_0, and θ_0

      iv. The overall spring constant relating the transverse load F_Y to the tip deflection

8. [8] In a comb drive resonator with K = 10 N/m and Q=1,000, you apply a sinusoidal force of 0.1 uN and plot the magnitude and phase of the deflection vs. frequency.
   a. At low frequency, what magnitude and phase do you expect to see?

   b. At resonance, what magnitude and phase do you expect to see?

   c. At 10 times the resonant frequency, what magnitude and phase do you expect to see?