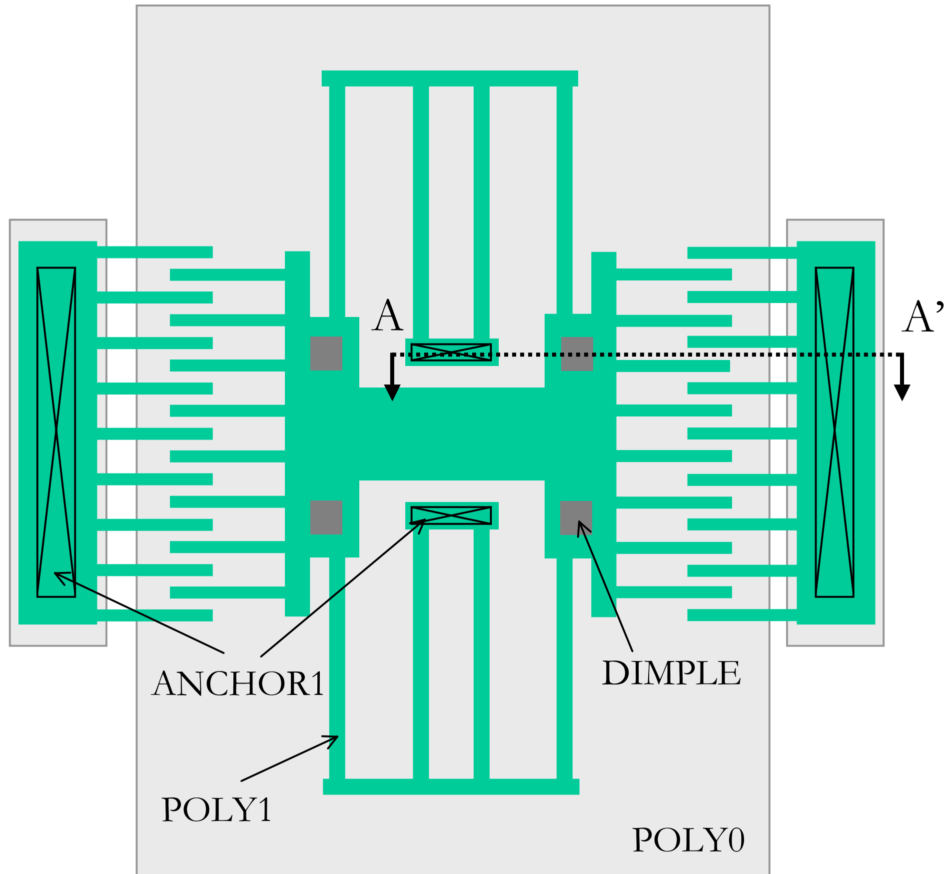
EE 245 Introduction to MEMS Design

Homework 2
Due 9/16/03, 5 pm. (The box is between the corridor and the Moore room on the 2nd floor of Cory Hall.)

1. The layout of the lateral resonator shown below is sent to the MUMPS foundry to be fabricated.



The MUMPS film thicknesses are:

Silicon nitride	0.6 μm
POLY0	0.5 μm
Oxide1	2 μm
DIMPLE depth	0.75 μm
POLY1	2 μm
Oxide2	0.75 μm
POLY2	1.5 μm
METAL	0.5 μm

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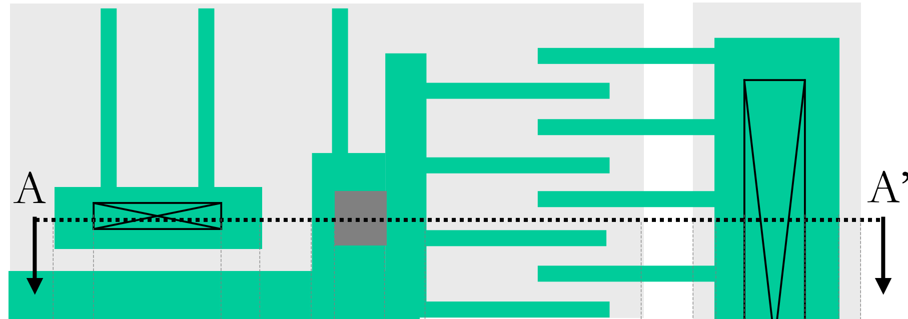
1. Draw the following cross sections (A-A’) on the substrates given below using the provided guide lines:



   a) After the process has reached the photoresist develop for the ANCHOR1 patterning step (but before the Oxide1 etching for ANCHOR1):

Silicon substrate

b) After POLY1 etching and removal of photoresist:

c) After the release step:

2. Upon release of the structure in problem 1, the 200 μm long suspension beams expand 0.15 μm to completely relieve their stress. If the Young's modulus of the POLY1 layer was 190 GPa as-deposited, answer the following:

   a) Was POLY1 under compressive or tensile stress?
   b) What is the value of the residual stress?

3. For the following structural-sacrificial layer combinations, find the etch rates of the layers using the listed release etchants by consulting the etch tables in Kirt Williams' article, "Etch Rates for Micromachining Processing." (Pick the highest etch rate reported for the material and the etchant.) For each case calculate the selectivity of the etchant, the etch rate of the sacrificial material with respect to that of the structural material. For combination(s) that have low etch selectivities (<5), suggest a different etchant.

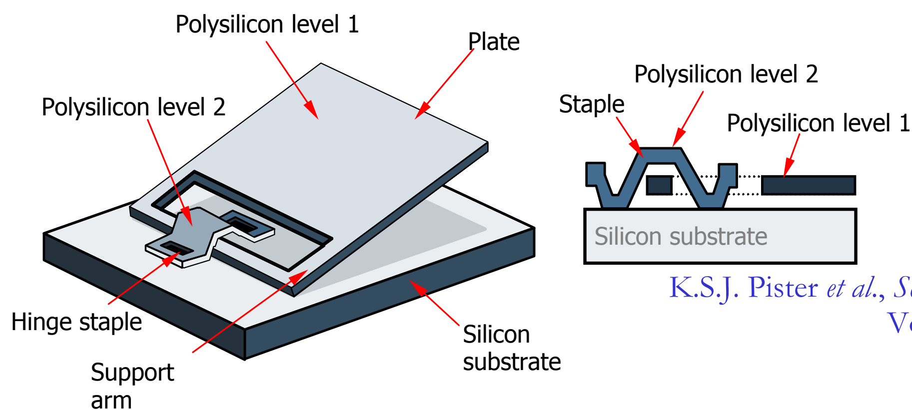
Structural	Sacrificial	Release Etchant
PolySi (n+)	PSG (annealed)	5:1 buffered HF (BHF)
LTO (undoped)	Si (100)	XeF_2 (2.6 torr)
PolySi (undoped)	Nitride (stoichiometric)	SF_6 plasma (25 sccm)
Aluminum/2%Si	Photoresist (OCG 820 PR)	O_2 plasma (400W)

4. Referring to the section on the Digital Micromirror Device (DMD) in Nadim Maluf's *Introduction to Microelectromechanical Systems Engineering* (posted on the website) or pp. 527-528 of the reader, answer the following questions:

   a) What is CMP and why is it used?
   b) How does Texas Instruments achieve low stresses in their metal structural layers?
   c) How are the mirrors released?

5. For the hinge shown below:

   a) Draw the mask layout needed to fabricate it in MUMPS. Mask layers include POLY1, ANCHOR2, and POLY2.
   b) Indicate which masks are light field and which are dark field.



K.S.J. Pister *et al.*, *Sensors and Actuators A*, Vol. A33, p. 249, 1992.