N.CHEUNG **EE143, Fall 2005**

Homework Assignment # 12 (Due Dec 8 ,Th)

THIS IS THE LAST HW ASSIGNMENT FOR THE SEMESTER

Reading Assignment

1) **Special Handout : "Stress in Thin Films" Reprint.**
2) **EE143 Reader , Kovac "Mechanical Transducers" for qualitative understanding of MEMS principles**
3) **EE143 Lecture Notes**

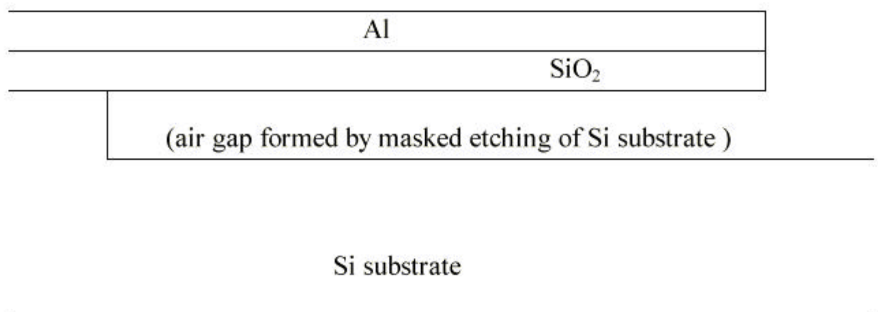
Problem 1 Cantilever beams

Consider a released cantilever beam consisting of a bilayer of SiO2 and Al, shown in cross-section below: Prior to release (masked etch of Si substrate, to undercut the beam), the SiO2 layer is under compressive stress, while the Al layer is under tensile stress.

(a) Would you expect the beam to bend up or down at the tip upon release?

(b) What would you expect to happen as the wafer (beam and Si substrate) is heated up?

Provide a brief explanation of your answers.



Problem 2 Thermal Stress in thin films

A 1 μm thick Al film is deposited without thermal stress on a 100 μm thick Si wafer at a temperature 100°C above ambient temperature. The wafer and film are allowed to cool to the ambient. Using the values provided in the table and assuming Poisson ratio $\nu = 0.272$ for Si

	Thermal Expansion coefficient ($10^{-6}/ {}^oC$)	Youngs Modulus (10^{11} N/m^2)
Al	24.6	0.7
Sl	2.6	1.9

(a) Calculate thermal strain and stress for $\Delta T = 100°C$.

(b) Calculate the radius of curvature of the substrate

Problem 3 Cantilever Deflection and Resonate Frequency

A polysilicon beam is 50 µm wide by 500 µm long and 0.5 µm thick.

a) Determine the deflection of the end caused by gravity ($g = 9.81\ m/s^2$ and $1N = 1\ Kg\ m/s^2$).

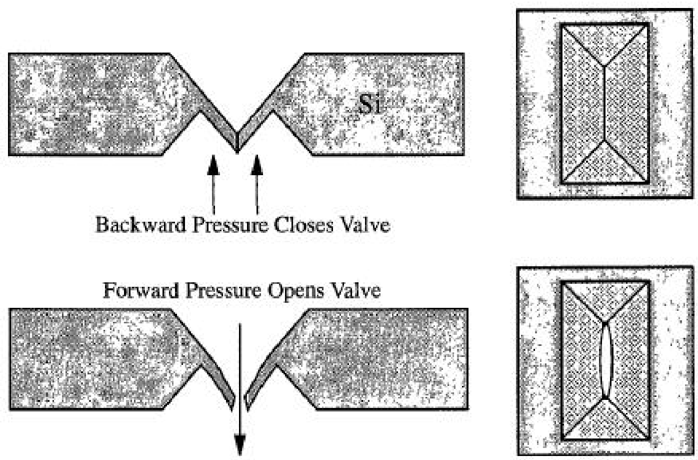
b) Determine the fundamental resonant frequency of the beam.

c) Now assume that one monolayer of chemicals is uniformly adsorpted on both sides of the beam which can be modeled by a mass increase of 1% (but no change in thickness). Find the change in the end deflection in µm and the change in the resonate frequency in cycles/sec.

d) With the results obtained in part c, discuss which method is easier to detect the changes.

Problem 4 Microfluidic Valve

The following figure shows the cross-sections and top-views of a microfludic valve fabricated with a Si wafer. Start with a bulk Si (100) wafer, design a process flow to fabricate this valve structure. Show cross-sections at various process steps. [Hint: When heavily doped Si with boron is etched with KOH, the etch rate will slow down dramatically with increasing boron concentration. ***There is no need for a special process step to form the slit***. A slit will form at the bottom naturally because (1) this part is exposed to the etching solution for the longest time , and (2) this part has the lowest boron concentration with the implant and drive-in process**.**]



Problem 5 Process Integration of MEMS and IC

The following cross-section shows a poly-Si MEMS integrated with CMOS devices. The CMOS uses a p-well inside the n-type epitaxial layer. For simplicity, only the NMOS transistor is shown [the PMOS transistor fabricated on the n-type epi layer is not shown explicitly]. Al is used as Metal-1. Start with the epitaxial layer on Si substrate, design a process flow to fabricate this microsystem. Show cross-sections at major process steps.