

**Homework Assignment # 12 (Due May 9, Tue 8am)**  
**THIS IS THE LAST HW ASSIGNMENT FOR THE SEMESTER**

**Reading Assignment**

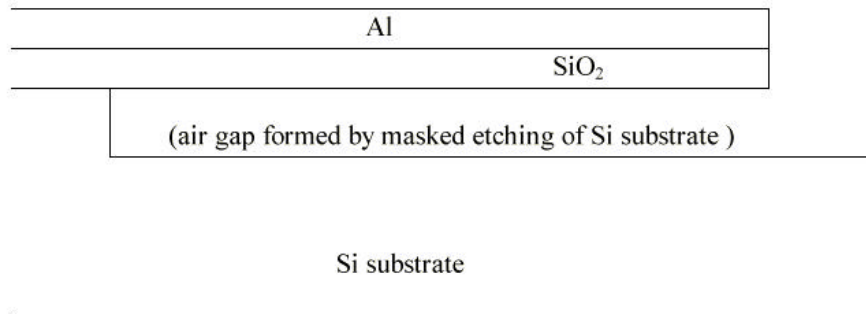
- 1) **Special Handout : “Stress in Thin Films” Reprint.**
- 2) **EE143 Reader , Kovac “Mechanical Transducers” for qualitative understanding of MEMS principles**
- 3) **EE143 Lecture Notes**

**Problem 1 Cantilever beams**

Consider a released cantilever beam consisting of a bilayer of SiO<sub>2</sub> and Al, shown in cross-section below: Prior to release (masked etch of Si substrate, to undercut the beam), the SiO<sub>2</sub> 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 50 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  $\nu = 0.272$  for Si

|    | Thermal Expansion coefficient ( $10^{-6}/^{\circ}\text{C}$ ) | Youngs Modulus ( $10^{11} \text{ N/m}^2$ ) |
|----|--|--|
| Al | 24.6   | 0.7  |
| Si | 2.6  | 1.9  |

- (a) Calculate thermal strain and stress for  $\Delta T = 100^{\circ}\text{C}$ .
- (b) Calculate the radius of curvature of the substrate

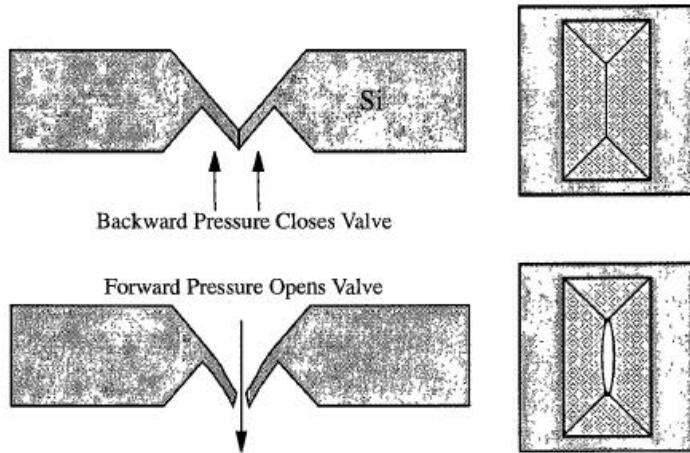
**Problem 3 Cantilever Deflection and Resonate Frequency**

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 ( $g = 9.81 \text{ m/s}^2$  and  $1\text{N} = 1 \text{ Kg m/s}^2$ ).
- 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 2% (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 microfluidic 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.

