N.CHEUNG **EE143, F2010**

Homework Assignment # 12 (Due Dec 3 ,Fri 9am)

THIS IS THE LAST HW ASSIGNMENT FOR THE SEMESTER

Reading Assignment

1) **Jaeger Textbook, Chapter 11 on MEMS**
2) **Reprint in Bspace: "Stress in Thin Films" Reprint.**
3) **Reprint Bspace , Sections of Kovac "Mechanical Transducers" -qualitative understanding of MEMS principles**
4) **EE143 Lecture Notes**

Problem 1 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 a Poisson ratio $\nu = 0.272$ for Si

	Thermal Expansion coefficient ($10^{-6}/\,^{o}C$)	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 2 Stress of dual films

A 500 μm -thick bare Si wafer is originally has a radius of curvature of +300 m. After a 300nm-thick oxide deposition, the wafer radius of curvature is measured to be +200 m.

(a) Calculate the stress of the oxide film . Indicate compressive or tensile.

(b) A 600nm nitride film is then deposited on top of the oxide and the wafer radius of curvature becomes +240m.. Calculate the stress of the nitride film alone. Is the nitride stress **compressive** or **tensile**?

(Given: $\nu_{Si}= 0.272$, $E_{Si} = 1.9 \times 10^{11}$Newton/m^2)

RADIUS OF CURVATURE RELATIONSHIP : $\sigma_f = \dfrac{E_s \times t_s^2}{(1-\nu)_s \times 6 \times r \times t_f}$)

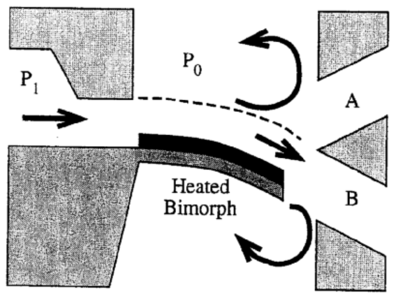
Problem 3 Cantilever Deflection and Resonate Frequency

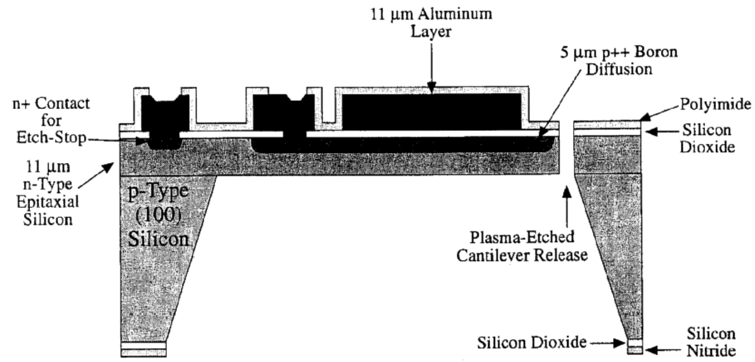
A polysilicon beam is 50 μm wide by 500 μm long and 0.5 μm thick.
a) Determine the deflection of the end caused by gravity ($g = 9.81$ m/s^2 and 1N = 1 Kg m/s^2).
b) Determine the fundamental resonant frequency of the beam.
c) Now assume that one monolayer of chemicals is uniformly adsorpted on both 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 MEMS Processing (Previous Exam question)

The following brief description is taken from a MEMS textbook :

"Doering, et al. demonstrated a thermal bimorph cantilever that combined the use of the Coanda effect with forced convection, to allow a laminar flow to be steered into one of two outlet ports under electrical control (see figure at left). They used an electro-chemical etch-stop and plasma etch edge release to form 11 μm thick n-epitaxial cantilevers that included a p++ boron diffusion for heating resistors and an 11 μm aluminum layer to form the bimorph with silicon (see cross section at right figure)."





Principle of a thermal bimorph cantilever directing fluid flow into one of two outlets

[Background information- The n+ contact for etch stop is an n+ island fabricated on the n-type epitaxial Si. By applying a voltage at the n+ contact during KOH etch of the p-type substrate, etching rate will stop at the pn boundary.]

(a) To aid your understanding of how this device operates, draw a top-view of the device. Label all important boundaries.

(b) When the p++ resistor pattern is heated up by resistive heating, will the cantilever structure curve upward or downward? Briefly explain.

(c) Starting with a p-type Si wafer with an n-type epitaxially grown Si, design a process flow to fabricate the bimorph device. Describe the process steps in the left column and sketch the cross-sections in the right column

PROCESS DESCRIPTION CROSS-SECTIONS

Problem 5 MEMS-before-IC Process

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.