

UNIVERSITY OF CALIFORNIA AT BERKELEY
College of Engineering
Dept. of Electrical Engineering and Computer Sciences

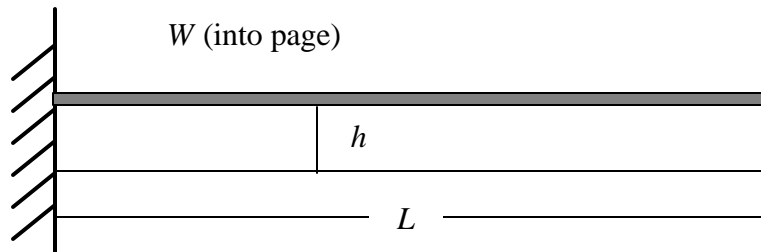
Problem Set #3

Due Thursday, September 25, 2003, 5:00 pm

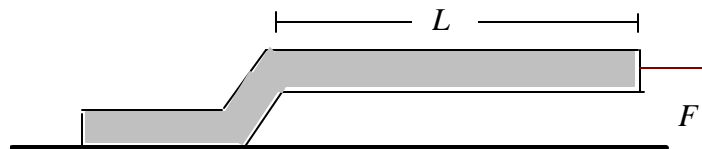
EECS C245 / ME C218

Fall 2003

1. A 100 nm-thick film of low-stress (silicon rich) silicon nitride is deposited on the top surface of a single crystal silicon cantilever having dimensions $L = 1$ cm, $W = 1$ mm, and $h = 200$ μm . The film is deposited at 835 $^{\circ}\text{C}$ by LPCVD. The longitudinal axis of the cantilever is aligned with the $\langle 100 \rangle$ axis of the silicon crystal.



- a) At room temperature, the residual stress in the silicon nitride film is σ_r . Considering the silicon cantilever to be constrained (zero deflection) at this point, find an expression for the built-in bending moment M_z .
 - b) When the cantilever is released, find an expression for the tip deflection at the end of the cantilever.
 - c) If the tip deflection is 1 μm , find the numerical value of the residual stress at room temperature, the thermal stress at room temperature, and the intrinsic stress. Use the material properties given in Table 8.1 of *Microsystem Design*.
2. Axially loaded beams are useful for designing high stiffness springs. The polysilicon beam below is 4 μm wide and 2 μm thick. The beam is suspended 1 μm above the substrate. You can consider that the anchor is perfectly clamped.



- a) Find the length L of this beam needed to obtain a spring constant $k_x = 250$ $\mu\text{N}/\mu\text{m}$.
- b) Find the spring constant of this beam in the y and z directions using first-order linear beam mechanics.
- c) The “step-up” anchor does not clamp the beam perfectly. Estimate the x -axis spring constant for this beam by considering the step as a very stubby beam. If you’re so inclined, you can try to include the effect of shear.

3. In Lecture 7, there is an SEM of the ADXL-05's folded suspension. You are asked by a new startup called Lightweight Xcell, Inc. (not a Berkeley spin-off) to see how a copy of this structure would perform if it was made out of sputtered aluminum, rather than polysilicon. The Lightweight CTO has an answer to your immediate reaction that Al is a lousy MEMS material: the ADXL-05 is a closed-loop accelerometer and so the Al suspension won't move ... much, anyway. The folded suspension has 2 μm -wide and thick beams, with the long leg being 150 μm long and the short leg 130 μm long. The area of the shuttle with comb fingers is 44,000 μm^2 .
- If the aluminum is stress free at room temperature, what is the spring constant along the sensitive axis in N/m?
 - Redesign the folded suspension so that the spring constant is the same as for the polysilicon ADXL-05's.
 - The product has to work over a temperature range of -25 $^{\circ}\text{C}$ to 125 $^{\circ}\text{C}$. Estimate the spring constant at the temperature extremes of the aluminum xcell; you need consider only the effects of thermal stress.
 - Would you invest in Lightweight?

Please post your questions on our newsgroup: ucb.class.ee245