PROBLEM SET #4

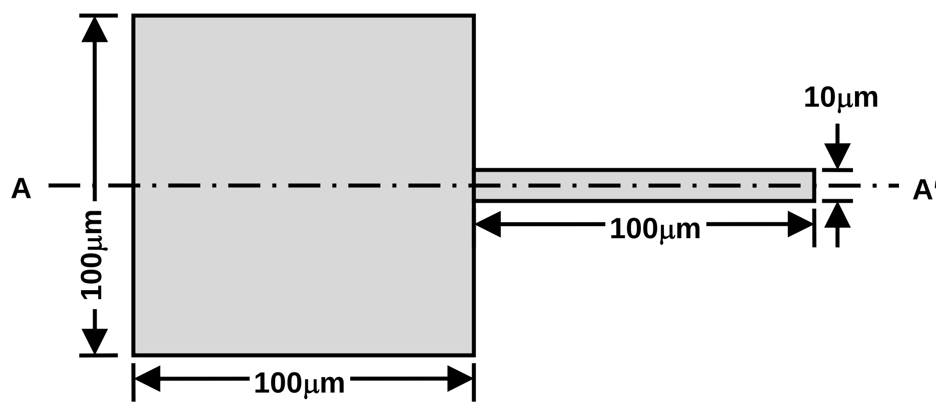
Issued: Thursday, Oct. 15, 2009

Due (at 7 p.m.): Thursday, Oct. 22, 2009, in the EE C245 HW box in 240 Cory

1. Suppose you applied the following fabrication process flow to the layout shown below:

1. Deposit 2 μm of LTO.
2. Deposit 2 μm of undoped polysilicon.
3. Ion implant with phosphorous.
4. Do lithography: Spin and expose resist with the single mask layer shown below.
5. Etch the polysilicon using reactive ion etching (RIE). Assume that the photoresist sidewalls are perfectly straight and the etch is completely anisotropic with an infinite selectivity of polysilicon to oxide.
6. Remove photoresist.
7. Dip the wafer in 5:1 buffered hydrofluoric acid (BHF) for 10 minutes, where the etch rate of LTO in BHF is 700 nm/min.

Assume for this problem that the undoped polysilicon film is completely stress free after deposition and before the ion implantation. Also assume that there is no stiction.



Polysilicon Material Properties:
Young's Modulus, E = 150 GPa; Density, ρ = 2,300 kg/m^3; Poisson ratio, ν = 0.226

Answer the following questions regarding this problem.

(a) Draw the final cross-section of the structure after release along A-A′.

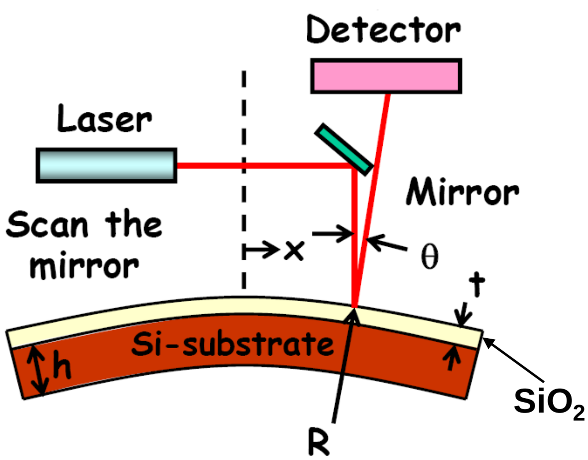
(b) If the implanted phosphorous is 10 nm deep with a uniform axial compressive stress of 400 MPa, how far above the surface of the wafer will the tip of the beam be once the structure is released?

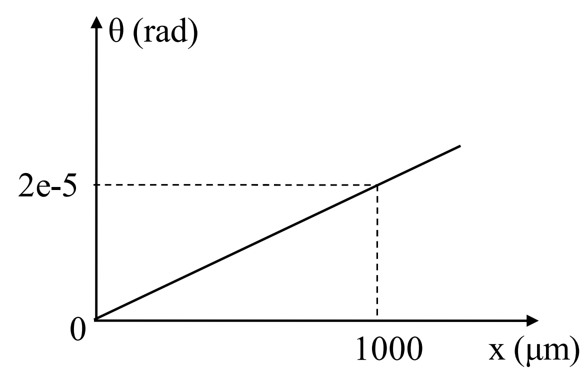
2. In the Berkeley Microlab, a tool called the Flexus can be used to determine the stress on a thin film deposited on a silicon wafer by measuring the wafer curvature. The figure below presents a schematic illustration of the Flexus and its measurement mechanism, together with a typical measured result. As shown, the Flexus simply measures the angle θ between the wafer surface and a laser beam directed straight down, allowing one to extract the slope of the ensuing θ vs. *x* curve.

Suppose the measured curve shown below is that for a 1 μm silicon dioxide layer deposited on a 4″ 525μm-thick bare silicon wafer at 400°C.

(a) What kind of stress does the silicon oxide have (tensile or compressive)?

(b) Determine the maximum stress in the silicon oxide film.



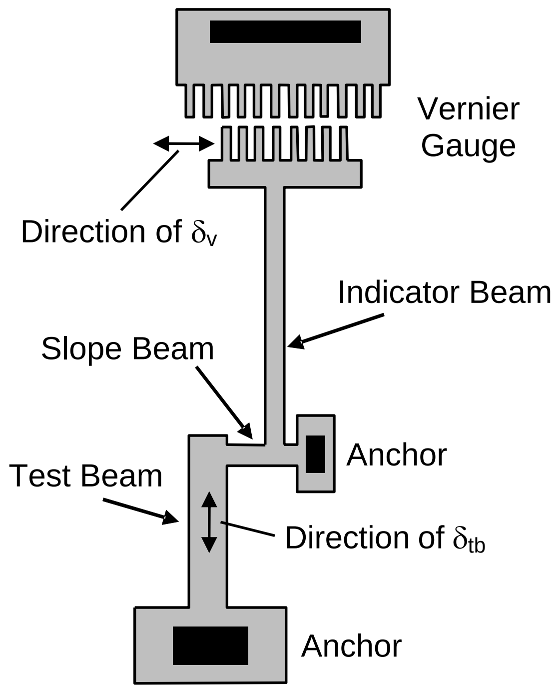


3. The figure below presents a passive micro strain gauge (invented by UC Berkeley Prof. Liwei Lin) that utilizes a lever arm structure to mechanically amplify strains caused by stress. Here, residual stress, either tensile or compressive, generates a small displacement δ_{tb} in the "test beam". This displacement in turn generates an angular deflection along the "slope beam", which then generates a much larger displacement δ_v at the vernier that can be read visually via optical microscope. Via this structure, the strain in the "test beam" is effectively amplified to a larger displacement at the vernier site.

(a) Write an expression for the mechanical gain factor (δ_v/δ_{tb}) provided by this structure. [Hint: You might find it useful to look up the appropriate literature on this structure.]

(b) Use the table provided to calculate a numerical value for the mechanical gain factor.

(c) Suppose the strain gauge is constructed from a polysilicon layer with a thickness of 2μm. If the measured movement δ_v is 18μm to the left side, find the strain and indicate whether the stress on the film is tensile or compressive.



Symbol	Element	Value (μm)
L_{tb}	Length of the test beam	500
L_{sb}	Length of the slope beam	20
L_{ib}	Length of the indicator beam	500
W_{tb}	Width of the test beam	30
W_{sb}	Width of the slope beam	1.2
W_{ib}	Width of the indicator beam	2
h	Thickness of thin film	2
L_v	Length of the Vernier finger	1
W_v	Width of the Vernier finger	4
	Center to center distance of the Vernier fingers	3
	Gap between top and bottom Vernier fingers	2