PROBLEM SET #3

Issued: Tuesday, Feb. 28, 2017

Due: Thursday, March 9, 2017, 10:00 a.m. in the EE C247B homework box near 125 Cory.

1. In the Berkeley Nanolab, 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. Fig. PS3.1 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 between the wafer surface and a laser beam directed straight down, allowing one to extract the slope of the ensuing θ vs. x curve.

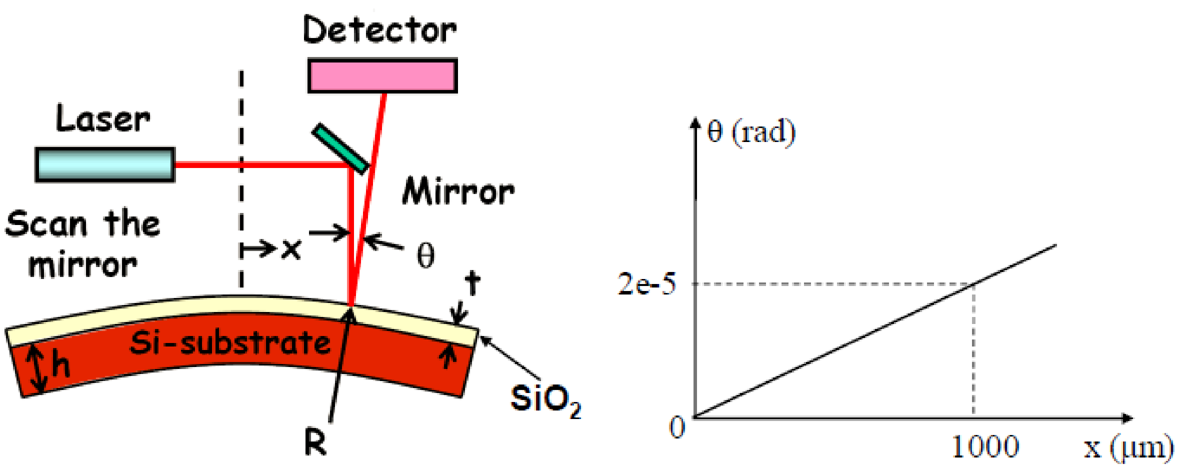


Fig. PS3.1

Suppose the measured curve shown in Fig. PS3.1 is for a 1μm silicon dioxide deposited on a 4″ 525μm-thick bare silicon wafer at 400°C.

(a) What kind of stress does the silicon dioxide have, i.e. tensile or compressive?

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

2. A useful diagnostic structure is the Vernier stress gauge as shown in Fig. PS3.2, which mechanically amplifies the strain caused by residual stress in a film and is capable of measuring both tensile and compressive stress. Here, the residual stress generates a small displacement δ_t in the 'test beam'. This displacement in turn generates an angular deflection along the 'slope beam', which then generates a much larger displacement δ_i at the vernier that can be visually read via optical microscope. By using this structure, the strain in the 'test beam' is effectively amplified to a larger displacement at the vernier site.

Suppose the vernier gauge is constructed from a 2μm-thick polysilicon layer. Answer the following questions.

(a) If the in-plane residual stress in the film is isotropic with a magnitude σ_f, what is the change in the test beam length, δ_t? Derive an expression for the bending profile of the slope beam as a function of δ_t and then as a function of the residual stress, σ_f. (Assume the *y*-direction loading on the slope beam generated from the residual stress in the test beam will not change the slope beam *x*-direction stiffness.)

(b) Write an expression for the displacement at the vernier, δ_i as a function of the residual stress, σ_f in the film. What value of L_c maximizes the vernier displacement, δ_i for a given residual stress, σ_f?

(c) Suppose the 2nd finger from the top on the indicator beam aligns exactly with the 2nd finger from the top on the fixed vernier. Indicate whether the residual stress in the film is tensile or compressive and find its numerical value. (The vernier gauge dimensions are given in Table PS3.1.)

(d) What is the maximum compressive residual stress, σ_{max} that the vernier stress gauge can measure?

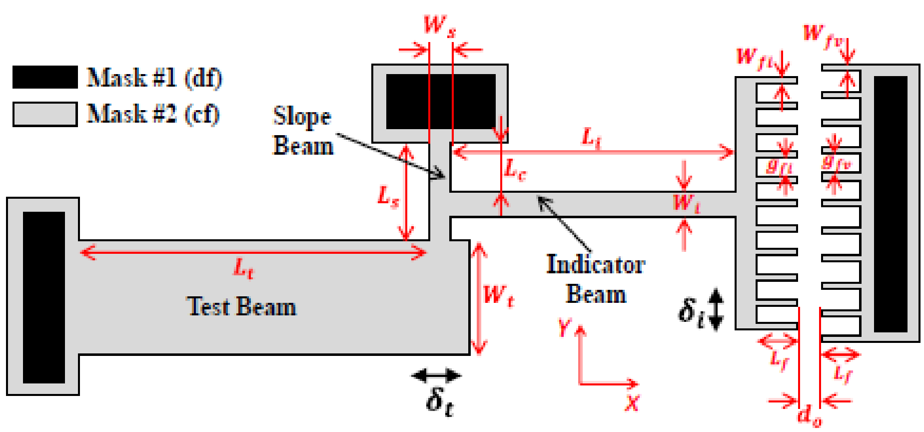


Fig. PS3.2

ρ	E	ν	L_t	W_t	L_s	W_s	L_i	W_i	L_c
2300 kg/m^3	150 GPa	0.2	400 μm	200 μm	20 μm	1 μm	400 μm	2 μm	10 μm

L_f	d_o	W_{fi}	W_{fv}	g_{fi}	g_{fv}
5 μm	2 μm	1 μm	1 μm	2 μm	2.1 μm

Table PS3.1

3. Suppose you have applied the following fabrication process flow to the layout shown below in Fig. PS3.3.

i. Deposit 2μm of low temperature oxide (LTO).

ii. Deposit 2μm of undoped polysilicon.

iii. Ion implant with phosphorous.

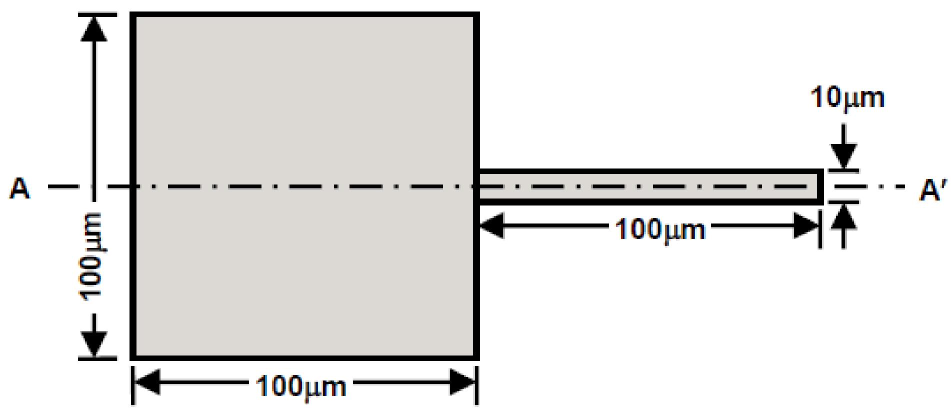
iv. Do lithography: Spin, expose, and develop photoresist (PR) with the single mask layer shown in the figure below.

v. Etch the polysilicon using reactive ion etching (RIE). Assume that the PR sidewalls are perfectly straight and the etch is completely anisotropic with an infinite selectivity pf polysilicon to oxide.

vi. Remove the PR.

vii. Dip the wafer in 5:1 buffered hydrofluoric acid (BHF) for 10min, where the etch rate of LTO in BHF is 700nm/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

Fig. PS3.3

Answer the following questions regarding this problem.

(a) Draw the final cross-section of the structure after release along AA'

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