EE C245 / ME C218 INTRODUCTION TO MEMS DESIGN FALL 2011

C. Nguyen

PROBLEM SET #5

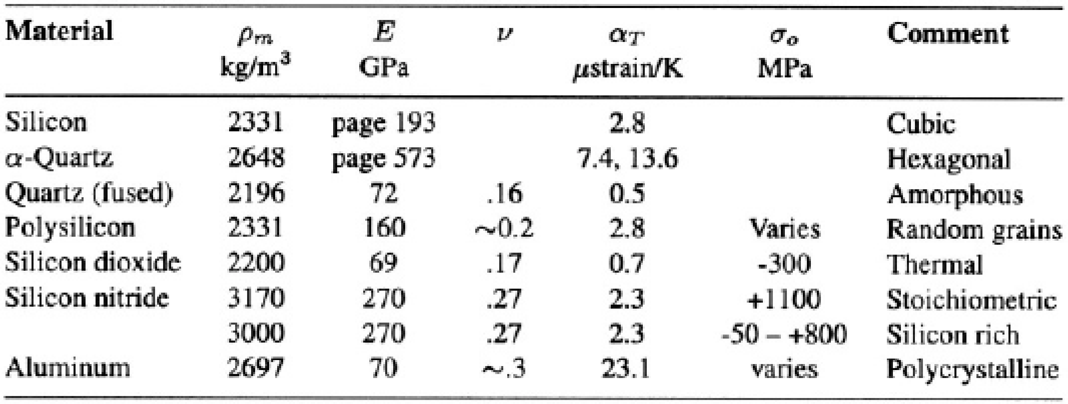
Issued: Tuesday, Oct. 18, 2011,

Due (at 7 p.m.): Tuesday, Oct. 25, 2011, in the EE C245 HW box in 240 Cory.

1. This problem concerns the comb-drive structures made in the following two-mask surface micromachining process:

i) Deposit 2.0 µm of SiGe on a fused quartz (glass) wafer using LPCVD
ii) Lithographically define and then etch anchor openings in SiGe (anisotropic)
iii) Deposit 2.0 µm of polysilicon using LPCVD @ 650°C
iv) Lithographically define and then etch polysilicon structure (anisotropic)
v) Etch SiGe completely using an H_2O_2 etch, releasing structure (isotropic)

(a) Calculate the biaxial strain in the final polysilicon structures due to linear thermal expansion. For all of problem 1 you may assume all materials are isotropic and use the materials properties from *Senturia Table 8.1*, reproduced below.



Material	ρ_m kg/m^3	E GPa	ν	α_T μstrain/K	σ_o MPa	**Comment**
Silicon	2331	page 193		2.8		Cubic
α-Quartz	2648	page 573		7.4, 13.6		Hexagonal
Quartz (fused)	2196	72	.16	0.5		Amorphous
Polysilicon	2331	160	~0.2	2.8	Varies	Random grains
Silicon dioxide	2200	69	.17	0.7	-300	Thermal
Silicon nitride	3170	270	.27	2.3	+1100	Stoichiometric
	3000	270	.27	2.3	-50 – +800	Silicon rich
Aluminum	2697	70	~.3	23.1	varies	Polycrystalline

(b) For the comb-drive resonator structure in Figure 1.1 where L_1 = 100 µm and W = 2 µm, calculate the stress on the flexure beams L_1. Is it compressive or tensile? If the stress is compressive, at what polysilicon deposition temperature would beam buckling occur? Assume the comb-drive shuttle is perfectly rigid.

(c) For the comb-drive resonator structure in Figure 1.2 where L_1 = 100 µm, L_2 = 90 µm, and W = 2 µm, calculate the stress on the flexure beams L_1 and L_2. For each case, indicate whether the stress is compressive or tensile. Assume the comb-drive shuttle and trusses are perfectly rigid.

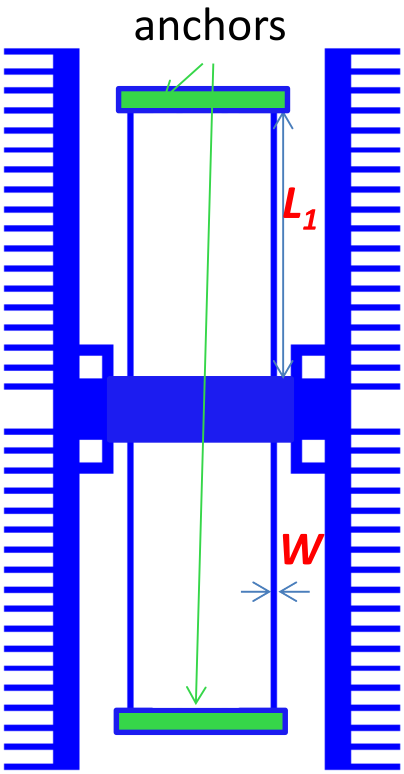


Figure 1.1

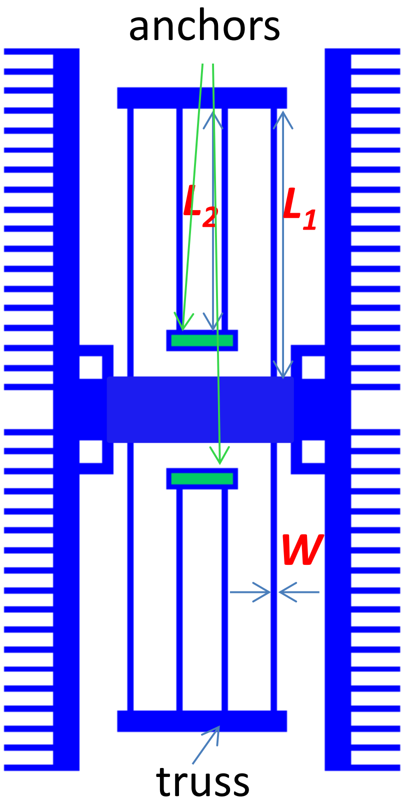


Figure 1.2

(d) Satisfied with the performance of the resonator used for part c, you decide to couple two resonators to make a simple filter as shown in Figure 1.3. For $L_c = 80$ µm and $W_c = 2$ µm, calculate the stress in the coupling beam. Use the same resonators and assumptions as in part (c).

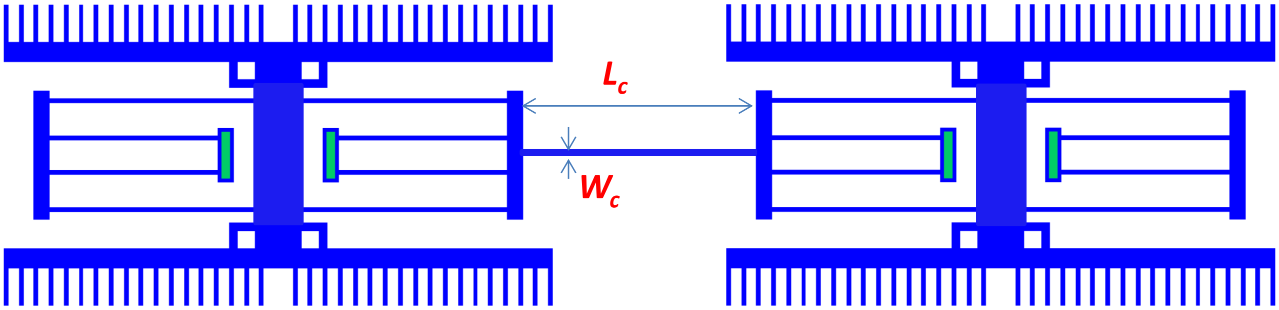
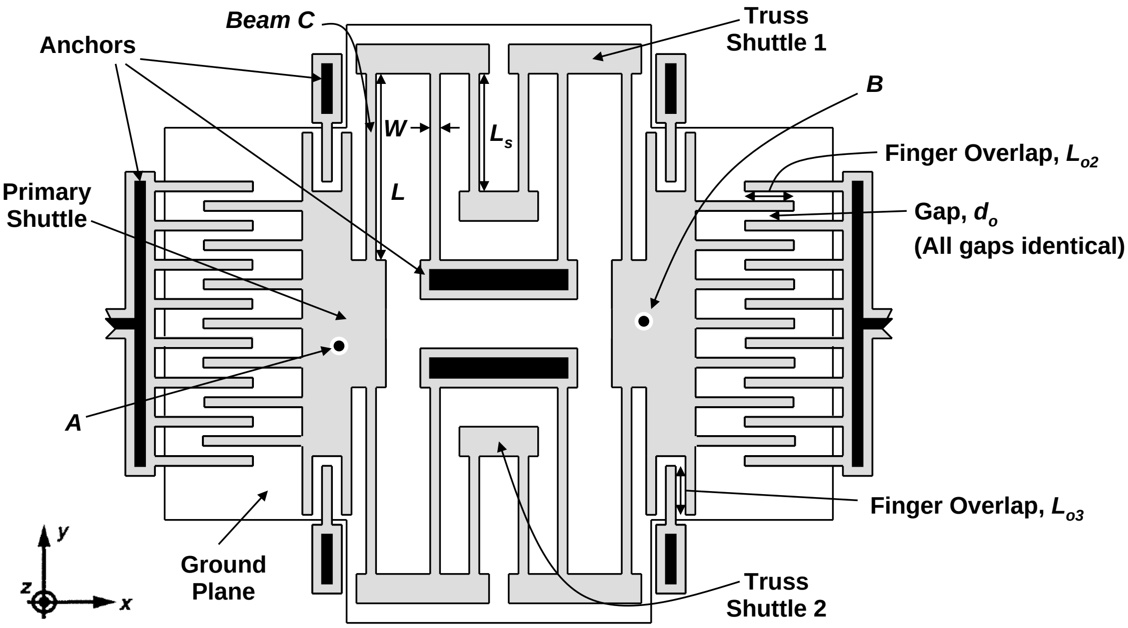


Figure 1.3

2. The figure below presents the top view of a micromechanical device constructed in a 2μm-thick structural layer with numerous ports. Here, everything is suspended 2 μm above the substrate except for the anchoring locations indicated as the darkly shaded regions. Data on the structural material used in this problem and on specific geometric dimensions are given in the box below the figure. Also, assume that all folding trusses and shuttles are rigid in all directions, including the vertical (i.e., *z*) direction. In addition, all suspension beam widths are 2 μm.



Structural Material Properties:
Young's Modulus, E = 150 GPa; Density, ρ = 2,300 kg/m^3
Poisson ratio, ν = 0.226
Geometric Dimensions: (all beams are width W)
L = 50μm; W = 2μm; L_s = 25μm; Thickness, h = 2μm; All Finger Gaps, d_o = 1 μm
All Finger Overlaps, L_o= 10 μm, Truss Shuttle 1 Area = 300 μm^2
Truss Shuttle 2 Area = 100 μm^2, Primary Shuttle Area = 4,000 μm^2

(a) Write an expression for the stiffness of beam C.

(b) Write an expression for the stiffness at point A (assuming no voltages are applied).

(c) If point A moves x_A = 1μm in the x-direction due to a force applied at A, how much does point B move? Provide an expression for x_B in terms of x_A and spring constants, and calculate a numerical value.

(d) Suppose the HF/DI water release etch for this structure was insufficient to release the primary shuttle masses, but long enough to release everything else. Will the remaining released portions of this structure be stuck to the substrate after release and drying? Assume the contact angle of water between the underside of the structure and the substrate is 30°, and the room-temperature surface tension of a water-air interface is 72.75×10^{-3} N/m.