PROBLEM SET #6

Issued: Thursday, Nov. 5, 2009

Due (at 7 p.m.): Tuesday, Nov. 24, 2009, in the EE C245 HW box in 240 Cory.

1. Suppose you would like to fabricate the folded-beam suspended comb-driven structure described by the figures and process flow in the pages that follow. The structure is constructed entirely of doped polysilicon, i.e., the yellow and gray layers are both doped polysilicon, and this particular device features a shuttle mass held 2μm above the substrate by a ratioed folded-beam suspension. Dimensions for the structure are given, except for ones that you will need to determine as part of this assignment. The structure itself (in green) is meant to be 2μm-thick, and the interconnect layers beneath (in yellow) are meant to be in a thin doped polysilicon layer.

(a) Assuming that beam L_2 is 20μm longer than beam L_1, determine the lengths of these beams so that the shuttle displaces 1μm upon application of 50V to the shuttle (through its underlying ground plane) and 30V to the left electrode, with the right electrode grounded.

(b) For the rest of this problem, assume that L_1 = 80μm and L_2 = 100μm. (Note that these are not necessarily the correct answer to part (a).) Use Cadence to generate a layout that achieves the structure of Figs. 1-4 using the process flow outlined in the pages that follow. In addition, add a contact to the substrate ground plane with sufficient area to allow bond wiring to this contact. Also, add interconnect and a bond pad that allows the structure to be biased to a specific voltage during testing. Make sure the spacing for the bond pads are sufficient to allow wire bonding. [Maybe not all masks from the process flow need to be used in this part.]

(c) Calculate the effective dynamic mass on a shuttle location when the structure vibrates at its fundamental resonance frequency.

(d) Calculate the structure's resonance frequency.

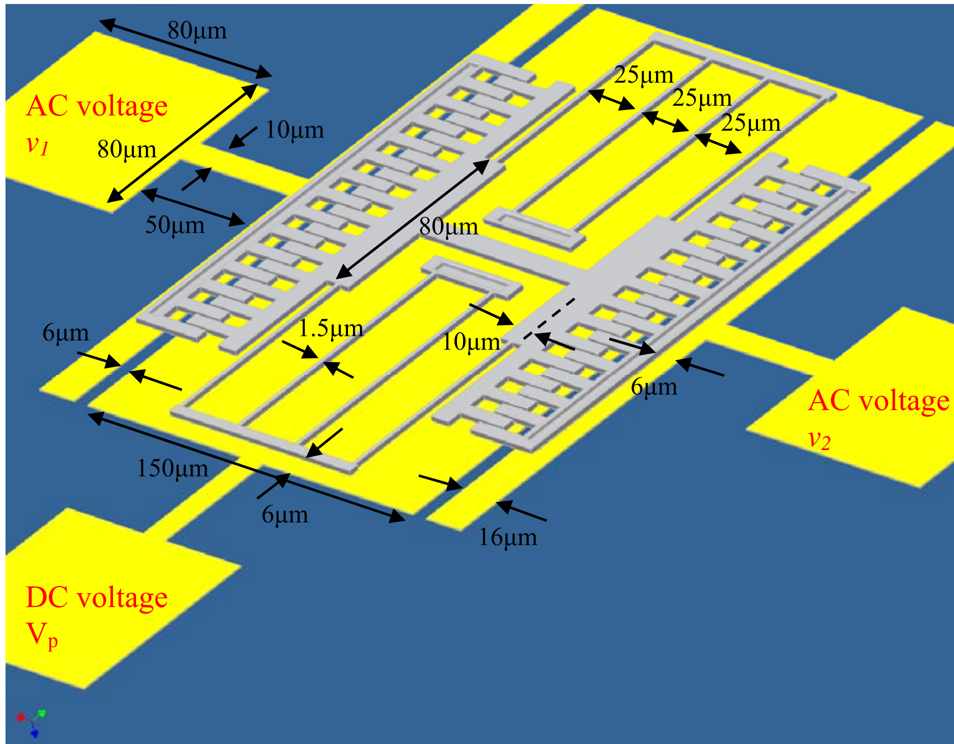

Fig. 1

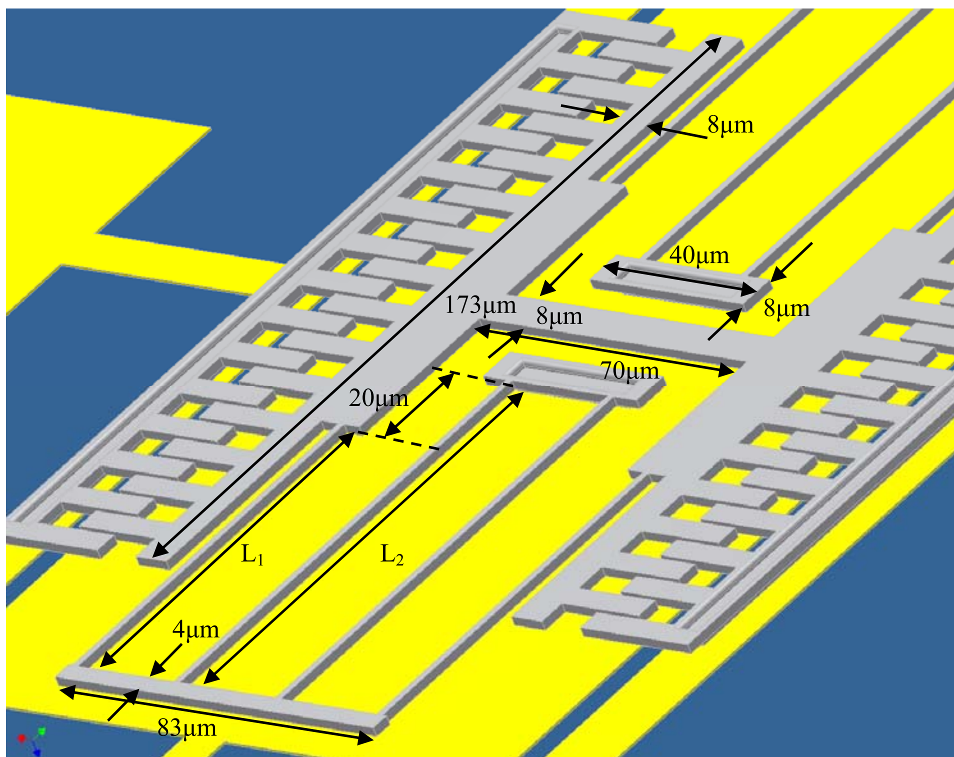

Fig. 2

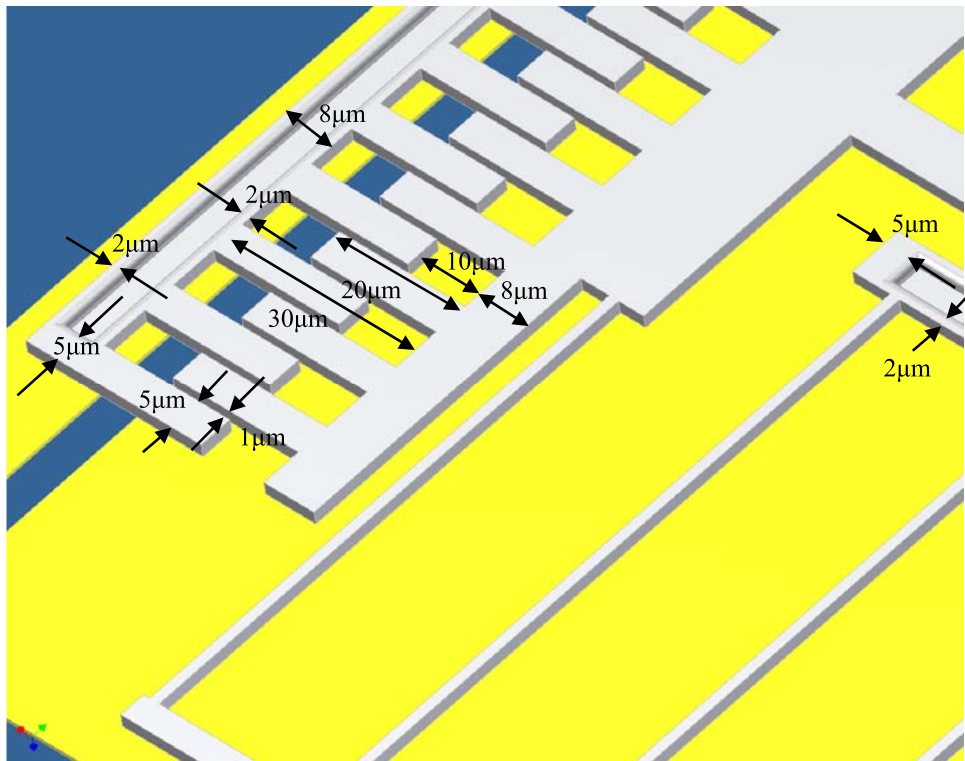

Fig. 3

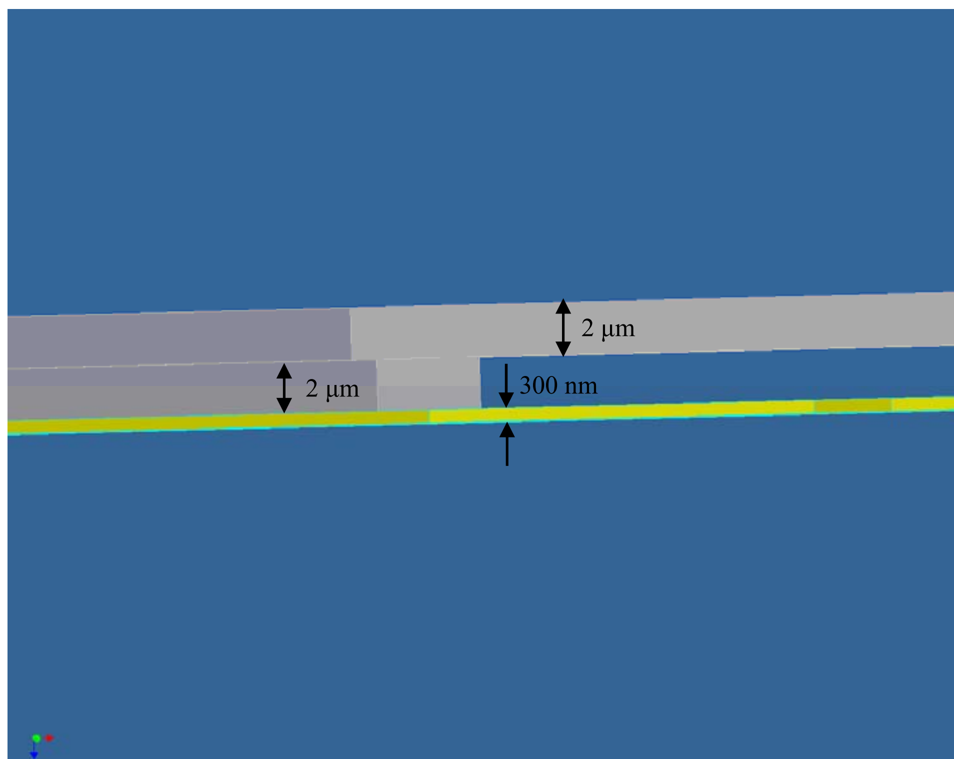

Fig. 4

Folded-Beam Comb-Driven μMechanical Resonator Process

0.0 Starting Wafers: 8-12 ohm-cm, n-type, (100) prime or just n-type test wafers.
Control Wafers: PSGlF, PSGlB (Si)
NITlF, NITlB (Si)
POLYlF, POLYlB (tylanll ctrl.)
PSG2F, PSG2B (Si)
POLY2F, POLY2B (Si)
PSG3F, PSG33 (81)

1.0 $POCl_3$ doping
Tystar13, recipe 13POCL3A
Flows (slm): N_2: 5, $POCl_3$ (in N_2): 1
Time = 1 hour

1.1 Strip oxide
Sink8 BHF, 1 minute

2.0 PSGl Deposition: target = 2 μm
(immediately after n+ diffusion)
Tystar12, recipe 12VDLTOA
Flows (sccm): SiH_4 = 60, PH_3 = 10.3 (entered), O_2 = 90
time (2μm) = 1 hour 40 minutes (-1000 A per 5 min.)
Include etching controls: PSGlF and PSGlB

3.0 Nitride Deposition: target = 300 nm
Deposit stoichiometric nitride:
Tystar17, STDNITA.017
temp. = 800 °C, Flows (sccm): SiH2C12 = 25, NH3 = 75
time = 1 hr. 22 min., (-220 nm per hour)
Include etching controls: NITlF and NITlB

4.0 Substrate Contact Mask: SNC (chrome-df)

4.1 Spin, expose, develop, inspect, descum, hard bake.
PR thickness: 1.6 μm

4.2 Etch nitride in Lam1.
SF_6 = 175 sccm, He = 50 sccm

4.3. Etch in Lam2:
For 2 μm oxide: [press = 2.8 Torr, power = 350 W, gap = 0.38 cm, CHF_3 = 30 sccrn, CF_4 = 90 sccrn, He = 120 sccrn, time = 1 min.],[power = 0, same gases, time = 1 min.] 3X

4.4. Wet dip in 10:1 BHF for 20 s to remove native oxide.

4.5 Remove resist, piranha clean wafers.

5.0 μStructure Polyl Deposition: target = 300 nm
Phosphorus-doped polysilicon deposition: Tystar16, 16VDPLYA
time = 2 hour 30 minutes, temp. = 650 C (~120 nm per hour)
Include etching controls: POLYlF, POLYlB

6.0 μStructure Polyl Definition Mask: SP1 (emulsion-cf)

6.1 Spin, expose, develop, inspect, descum, hard bake.
PR thickness: 1.1 μm

6.2 Plasma etch poly-Si in Lam5 etcher, inspect
(Cl_2/HBr at 300 Watts, 12 mTorr)

6.3 Remove PR, piranha clean wafers along with PSG2F and PSG2B.

7.0 Sacrificial PSG Deposition: target = 2 μm
Tystar12, 12VDLTOA
Flows (sccm) : SiH_4 = 60, PH_3 = 10.3 (entered) , O_2 = 90
time (2μm) = 1 hour 40 minutes (~100 nm per 5 min.)
Include etching controls: PSG2F and PSG2B

8.0 Sacrificial PSG Densification
RTA in Heatpulsel: 30 secs @ 950 C
(also do PSG2 ctrls)

9.0 (optional) Dimple Photo Mask: CD1 (chrome-df)

9.1 spin, expose, develop, descum, hard bake.

9.2 timed wet etch in 5:l BHF. (E.R. ~ 300 nm per min.)

9.3 Remove resist, piranha clean wafers.

10.0 μStructure Anchor Photo Mask: SG1 (chrome-df)

10.1 Spin, expose, develop, descum, hard bake.
PR thickness: 1.1 μm

10.2 Etch in lam2:
For 1 μm oxide: etch as usual.
For 2 μm oxide: [press = 2.8 Torr, power = 350 W, gap = 0.38 cm, CHF_3 = 30 sccrn, CF_4 = 90 sccrn, He = 120 sccrn, time = 1 min.], [power = 0, same gases, time = 1 min.] 3X
For both cases, overetch with 700 W recipe.

10.3 Check contact using IV probe station.

10.4 Wet dip in 5:l BHF for 10 secs.

10.5 Remove resist, piranha clean wafers.

11.0 μStructure Poly2 Deposition: target = 2 μm
Phosphorous-doped polysilicon deposition: Tystar16, 16SDPLYA
time = 16 hours, temp. = 650 C
Include etching controls POLY2F and POLY2B (tylanll cntrls).

12.0 Oxide Mask Deposition: target = 500 nm
Tystar12, 12VDLTOA
Flows (sccrn): SiH_4 = 60, PH_3 = 10.3 (entered), O_2 = 90
time = 25 minutes (~1000 A per 5 rnin.)
Include etching controls: PSG3F and PSG3B

13.0 RTA Anneal
Heatpulsel: 1 min. @ 1100 C in 50 l/sec N2

14.0 μStructure Poly2 Definition Mask: SP2 (emulsion-cf)
Align to μStructure polyl.

14.1 Spin, expose, develop, inspect, descum, hard bake.
PR thickness: 1.6 μm

14.2 Etch oxide mask in lam2.

14.3 (optional) Remove resist:
technics-c, 10 min. 02 plasma B 300 W

14.4 Etch 2nd poly in lam5: [press = 280 mTorr, power = 300 W, gap = 1.5 cm, $CC1_4$ = 130 sccrn, O_2 = 15 sccm, He = 130 sccm, time = 1 rnin.] then [power = 0, same gases, time = 1 rnin.] 5 or 6X, depending upon etch rate (E.R. usually - 4000 A per min.)

14.5 If haven't already removed resist, remove resist.
Technics-c, 10 min. 02 plasma B 300 W

15.0 μStructure Release

15.1 Piranha clean in sink8.

15.2 Wet etch in 5:l BHF (~600 nm per rnin.) in sink8.
(Etch for whatever time is needed to remove all exposed oxide, including oxide underneath structures)
Slowly agitate, rinse.
Spin dry or N2 gun dry.

15.3 Piranha clean in sink8 for 10 min. Follow with standard DI rinses. No HF dip. Spin dry or N2 gun dry.