PROBLEM SET #3

Issued: Sunday, Sept. 28, 2008

Due (at 5 p.m.): Tuesday, Oct. 7, 2008

1. The following pages comprise a surface micromachining process flow for a folded-beam comb-driven micromechanical resonator with layout shown below. No details are spared in this flow; even equipment names are given, as are diagnostic steps used to verify select process steps. Furnace program names (for equipment in the UC Berkeley Microlab) are also given. These details are included to present a more realistic situation. In doing this problem, you must sift through the extraneous information and concentrate on the recipe information (i.e., temperatures, times, doses, etc.).

For etch steps, if the etch uses a plasma or RIE process, assume perfect anisotropy. Also, assume that any etch time is determined by first calculating the time needed to etch through the nominal film thickness based on the nominal etch rate, then adding a 30% overetch to remove any small remaining spots of material. Assume that after you develop your photoresist, it has a sidewall angle of 60°. Also assume that the photoresist will have the given thickness in the field regions, and have a perfectly flat upper surface.

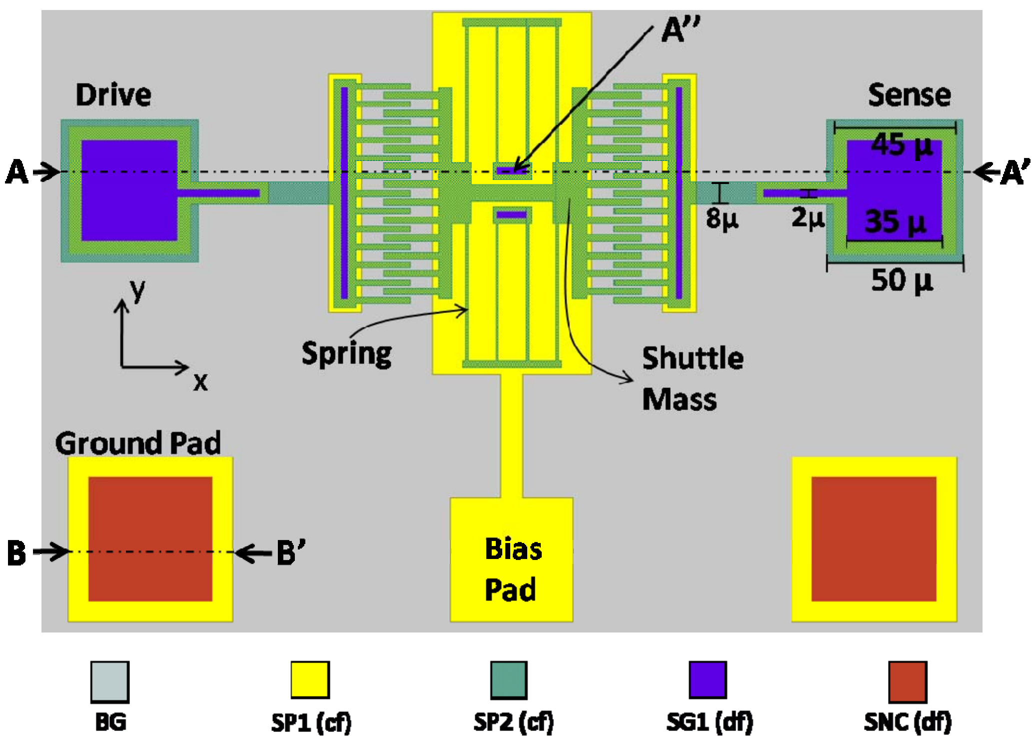

Figure 1: Full layout view.

The gray color BG is the background color of the layout editor. (This is "field" for all masks.) Also, note that the line A-A' passes through the anchor for the flexures, but not through the comb fingers.

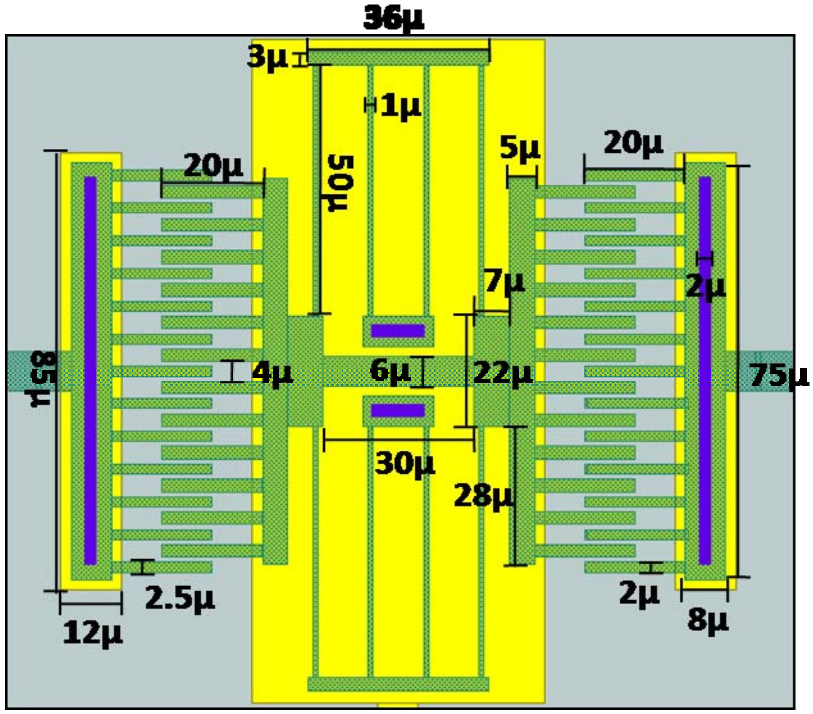

Figure 2: Close-up view of the comb-drive folded-beam resonator, with dimensions.

When considering etches in this problem, assume the following selectivities (estimated from Kirt Williams, "Etch Rates for Micromachinig Processing"). As a reminder, the definition of selectivity is $S_{A/B} = ER_A/ER_B$.

Etchant	Layer A	Layer B	Selectivity $S_{A/B}$
SF_6 + He	Nitride	Photoresist	1:1
		Oxide	2:1
		Silicon	1:3
CF_4 + CHF_3 + He	Oxide	Photoresist	3:1
		Nitride	4:1
		Silicon	4:1
Cl_2 + HBr	Silicon	Photoresist	1:1
		Oxide	100:1
		Nitride	1:2
HF (release)	Oxide	Stoichiometric nitride	250:1

(a) Draw the cross-section of the structures along the A-A' and B-B' lines in the layout: (i) after step 14.2 of the process; and (ii) at the end of the process. Here, you should get the thickness dimensions correct (to within 100 nm or 20%, whichever is finer). Draw the length (horizontal) dimensions, use a compressed scale. If there are angles in the cross-section, show either the angle or its tangent, approximately. If any structures completely detach from the wafer, please show this clearly in the final sketch.

(b) Suppose you made a mistake in lithography, so that mask SP2 is misaligned to mask SG1 by 4 µm in the *x*-direction. Draw the cross-section along line A''-A' at the end of the process. How will this affect the device?

(c) If the wafer is immersed in HF too long, something very bad happens. What is this? What is the longest time that the wafer can be immersed in HF before this happens? Is this enough to completely release the structure?

(d) Suppose the amount of time available in HF under the restriction of part (c) were 5 minutes, which is insufficient to release the structure. Propose a design change would allow complete release with only this much time in HF.

(e) If the springs supporting the shuttle mass provide a total restoring stiffness of 2 N/m, and the contact angle of water underneath the shuttle during drying is 30^{o}, will the shuttle be stuck down after drying in air? To simplify this problem, ignore the effect of surface tension on the springs and folding-trusses themselves; i.e., only consider the shuttle mass and fingers when determining sticking forces. Also, assume that the room-temperature surface tension of a water-air interface is 72.75×10^{-3} N/m.

(f) Assuming the contact angle and surface tension numbers of part (e), what is the minimum sacrificial oxide thickness that you can use and still end up with a structure that is not stuck to the substrate after release?

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.

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.
