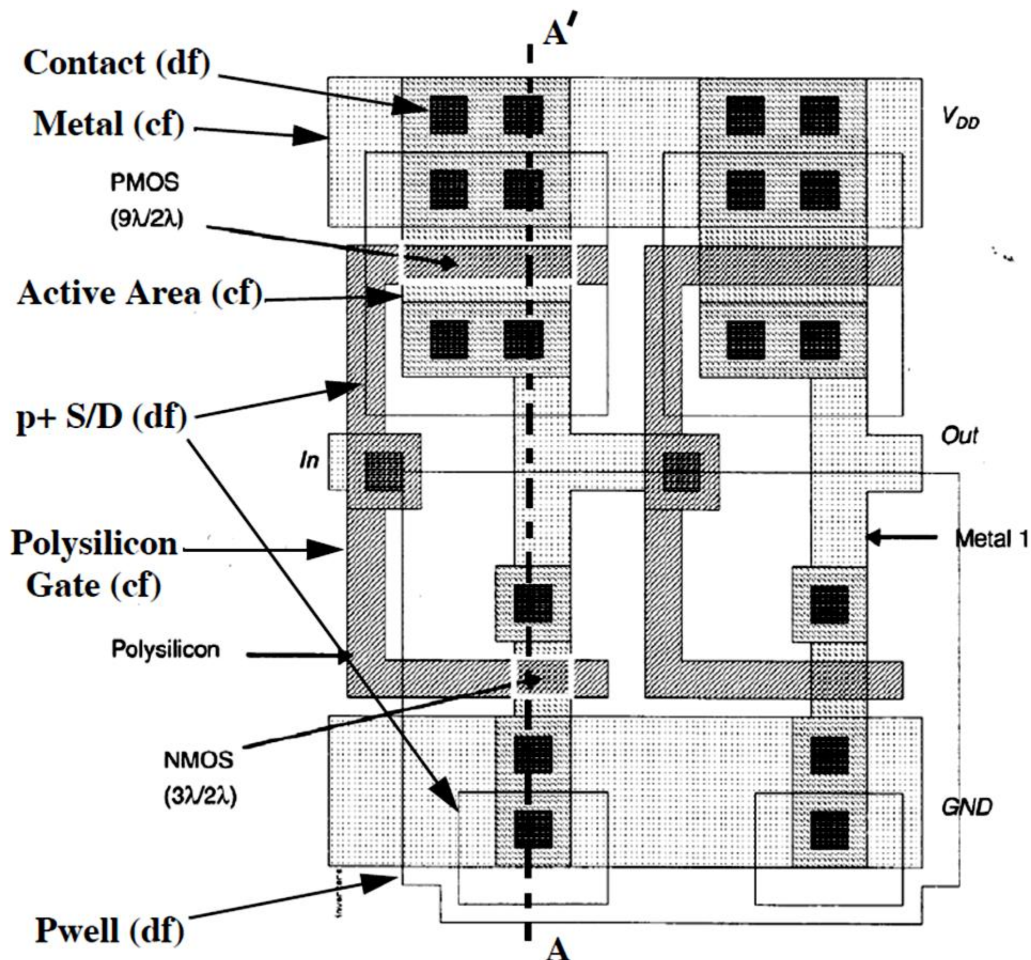
PROBLEM SET #8

Issued: Tuesday, Apr. 6, 2010

Due: Tuesday, Apr. 13, 2010, 7:00 p.m. in the EE 143 homework box in 240 Cory

1. The following pages comprise an actual pwell CMOS process flow with poly-to-poly capacitors. No details are spared in this flow; even equipment names are given, as are diagnostic steps used to verify each step. LPCVD furnace program names 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, implant doses, etc. ...).

   This process flow as applied to the layout below will be the subject of your next few homework assignments. In each of these assignments, you will be asked to answer several questions centered around different points in the process flow.



a) Draw the circuit schematic implemented by the layout and label the device sizes.

b) Draw a qualitative cross-section corresponding to line A-A' in the layout above. Identify layers and try to draw thicknesses to scale. (You should distinguish between CVD oxides and thermally grown oxides—i.e., label them.) Note that although capacitors are not used in this layout, you may need to account for the process steps involved with poly-to-poly capacitor formation to get a sufficiently accurate cross-section. (Note that mask layers are identified in the drawing. Again, 'df' = dark field (i.e., box shows where an opening in the PR will be) and 'cf' = clear field (i.e., box shows the portion to be covered by PR).)

c) What is the LOCOS field oxide thickness?

d) What is the gate oxide thickness?

e) What is the depth of the pwell diffusion at the end of the process?

CMOS Process
2mm, P-well, double poly-Si, single metal

0.0 Starting wafers: 8-12 ohm-cm, n-type, <100>
Control wafers: PWELL (n-type), PCH (n-type)
Scribe lot and wafer number on each wafer, including controls.
Measure bulk resistivity (ohm-cm) of PWELL on Sonogage.

1.0 Initial Oxidation: target = 1000(+/- 5%) A

1.1 TCA clean furnace tube (tylan2).

1.2 Standard clean wafers, include PWELL and PCH.
(Stnd clean: piranha clean, DI rinse, BHF dip, spin-dry. Pls see process module in the lab manual)

1.3 Wet oxidation at 1000 C (SWETOXB*):
5 min dry O2
~9.5 min wet O2
5 min dry O2
20 min dry N2
Measure tox=

2.0 Punch-Through Implant
Blanket implant: Phosphorus, 145 keV, 1.2E12/cm2.
Include PWELL and PCH.

3.0 Well Photo Mask:
Control wafers are not included in any photoresist step.
(PWELL proceeds to Step 4.0, PCH to Step 5.4)

3.1 Standard clean wafers in sink8.
Dehydrate wafers in oven for >30 min. at 120 C.

3.2 Standard I-Line process:
Spin, expose, develop, inspect, descum, hard bake.
No etch. Resist is left on wafers.

4.0 Well Implant: Boron (B11), 3E12/cm2, 80 keV.
Include PWELL.

5.0 Well Drive-In: target xj = ** um, tox = 3500 A

5.1 TCA clean furnace tube (tylan2).

5.2 Etch pattern into oxide in 5/1 BHF.
Strip oxide off of PWELL.

5.3 Remove PR in O2 plasma. Piranha clean wfrs in sink8.

5.4 Stnd clean wfrs in sink6, include PWELL and PCH.

5.5 a) Well drive at 1150 C (WELLDR*):
4 hrs dry O2
5 hrs dry N2
b) Measure oxide thickness on work wafer.
Measure two points on three wafers from different locations on the boat: front, middle and rear.
tox(well)= tox(outside of well)=
c) Strip oxide and measure Rs on PWELL and PCH.
Rs_{PWELL}= Rs_{PCH}=

5.6 TCA clean the furnace tube after well drive-in is done.

6.0 Pad Oxidation/Nitride Deposition:
target = 300 A SiO2 + 1000 A Si3N4

6.1 TCA clean furnace tube (tylan5). Reserve tylan9.

6.2 Etch oxide in 5/1 BHF until wafers dewet.

6.3 Standard clean wafers in sink6, include a Tox monitoring wafer, PWELL and PCH.

6.4 Dry oxidation at 950 C (SGATEOX):
~1 hr. dry O2
20 min dry N2 anneal.
Measure Tox on monitoring wafer. Tox=

6.5 Deposit 1000 A of Si3N4 immediately (SNITC).
Include PWELL and PCH.
approx.time = 23 min., temp.= 800 C.
Measure nitride thickness on 3 work wafers, using tox obtained in 6.4. PWELL and PCH proceed to Step 13.3.

7.0 Active Area Photo Mask:
Standard KTI process. Offset: x = 3.2420, y = 0.6155.

8.0 Nitride Etch:
Plasma etch in lam.
Measure Tox on each work wafer. (1 pnt measurement).
Do not remove PR. Inspect.
Measure PR thickness covering active area. tpr=
PR must be >8 kA. Hard bake again for >2hrs at 120 C.

9.0 P-Field Photo Mask: (basically, the pwell mask)

9.1 Standard KTI process. (Second photo)
Inspect! Inside well, field is open and active areas are covered with Si_3N_4 and PR.

9.2 Measure PR thickness on active area with as200.
Wafers cannot be passed unless PR is >8 kA. tpr=

10.0 P-Field (Channel Stop) Ion implant: B11, 100 keV, 1E13/cm2

11.0 N-Field Photo Mask: (inverse of the pwell mask)

11.1 Remove PR in O2 plasma. Piranha clean wfrs in sink8.
Dehydrate wfrs in oven for >30 min. at 120 C.

11.2 Standard I-Line process.
Well area is covered with PR, active area with Si3N4.

12.0 N-Field (Channel Stop) Ion Implant: Phosphorus, 40keV, 5E12/cm2.

13.0 Locos Oxidation: target = ** A

13.1 TCA clean furnace tube (tylan2).

13.2 Remove PR in O2 plasma. Piranha clean wfrs in sink8.

13.3 Stnd clean wfrs in sink6, include PWELL and PCH.
Dip in 10/1 BHF until field area dewets.

13.4 Wet oxidation at 950 C (SWETOXB*):
5 min dry O2
4 hrs 40 min wet O2
5 min dry O2
20 min N2 anneal
Measure Tox on 3 work wfrs. Tox=

14.0 Nitride Removal

14.1 Dip in 5/1 BHF for 30 sec., include PWELL and PCH.
(To remove thin oxide on top of the nitride)

14.2 Etch nitride off in phosphoric acid at 145 C.

15.0 Sacrificial Oxide: target = 200 (+/- 20) A

15.1 TCA clean furnace tube (tylan5).

15.2 Stnd clean wfrs in sink6, include PWELL and PCH.
Dip in 10:1 BHF until PWELL and PCH dewet.

15.3 Dry oxidation at 950 C (SGATEOX*):
30 min dry O2
20 min N2 anneal
Measure Tox on 3 wfrs. Tox=

16.0 Threshold Implant:
Blanket implant: B11, 30 keV. Doses (/cm2): 9E11.

17.0 Gate Oxidation/Poly-Si Deposition:

17.1 TCA clean furnace tube (tylan5); reserve tylan11.

17.2 Stnd clean wfrs, include PWELL, PCH and, 3 Tox and 1 Tpoly1 monitoring wafers.

17.3 Dip off sacrificial oxide in 10/1 H2O/HF until PWELL and PCH dewet (approx. 1 min).

17.4 Dry oxidation at 950 C (SGATEOX*):
2 hr. dry O2
20 min N2 anneal.
Measure 5 pnts on each of 3 Tox monitoring wfrs. Tox=

17.5 Immediately after oxidation
deposit 4500 A phos.doped poly-Si (SDOPOLYH*).
approx.time = 2 hr. 40 min., temp.= 610 C
Include Tpoly1, PWELL and PCH.
Tpoly1= Measure 5 pnts.
PWELL and PCH proceed to Step 20.2.

18.0 Gate Definition Mask:
Standard I-Line process.

19.0 Plasma etch poly-Si

19.1 Etch poly in Lam4. (CCl4/He/O2 at 300W, 280 mT)

19.2 Measure Tox in S/D area of each work wafer.

19.3 Remove PR in plasma O2. Piranha clean wfrs in sink8.
Measure line width of 2 um gates on each work wafer.
One pnt measurement in 19.2 and 19.3.

20.0 Capacitor formation:
Target = ** A SiO2 on 1st poly + 4500 A 2nd poly

20.1 TCA clean furnace tube (tylan2). Reserve tylan11.

20.2 Standard clean wafers, include PWELL, PCH, Tpoly1and one of gate oxidation monitoring wafers as a 2nd poly monitoring wafer, Tpoly2.
Tpoly2 proceeds to Step 20.4.
From here on: only 10 sec dip in 25/1 H2O/HF after piranha.

20.3 Dry oxidation at 950 C (SDRYOXB*):
55 min dry O2
20 min N2 anneal.
Measure oxide thickness on poly with nanometrix
tox(PWELL) = tox(PCH) =
PWELL proceeds to Step 24. PCH proceeds to Step 25.

20.4 Second poly-Si deposition: immediately after oxidation
deposit 4500 A of phos.doped poly-Si (SDOPOLYH*):
approx.time = 2 hr. 30 min, temp.= 610 C.
Tpoly2=

21.0 Capacitor Photo Mask:
Standard I-Line process.

22.0 Plasma etch poly-Si:

22.1 Etch 2nd poly in Lam4. Inspect.

22.2 Measure Tox in S/D area on each work wafer.

22.3 Remove PR in O2 plasma. Piranha clean wfrs in sink8.
Dehydrate wfrs in oven for > 30 min. at 120 C.

22.4 Measure channel length on nanoline. This measurement can be done at any step before Step 28.

23.0 N+ S/D Photo Mask: (inverse of p+ S/D)
Stnd I-Line process. Do not hard bake.
Inspect. PMOS areas are PR covered. Capacitor areas are not.

24.0 N+ S/D Implant: Arsenic, 160 keV, 5E15/cm2, incl. PWELL.

25.0 N+ S/D Anneal

25.1 TCA clean furnace tube (tylan7).

25.2 Remove PR in O2 plasma and piranha clean wafers in sink8 (no dip here).

25.3 Standard clean wafers in sink6, incl. PWELL and PCH.

25.4 Anneal in N2 at 925 C for 1 hr 15 min (N2ANNEAL*).

26.0 P+ S/D Photo Mask:
Stnd I-Line process.
All areas are covered with PR except PMOS areas.

27.0 P+ S/D Implant: B11 at 30 keV, 5E15/cm2, include PCH.

28.0 PSG Deposition and Densification: target = 7000 (+/-200) A

28.1 Remove PR in O2 plasma and piranha clean wafers in sink8 (no dip).

28.2 Stnd clean wfrs in sink6 (10 sec dip).
Include PWELL, PCH and one PSG monitoring wafer.

28.3 Deposit 7000 A PSG, PH3 flow at 10.3 sccm (SDOLTOD*).
approx.time = 35 min. (check current dep. rate)
temp. = 450 C

28.4 Densify glass in tylan2 at 950 C, immediately after PSG deposition (PSGDENS*). Include PSG control.
5 min dry O2, 20 min wet O2, 5 min dry O2.
Measure tPSG=
Etch oxide on PWELL and PCH, and measure poly sheet resistivity on PWELL and PCH with prometrix.

28.5 Do wet oxidation dummy run afterwards to clean tube:
1 hr wet oxidation at 950 C (SWETOXB*).

29.0 Contact Photo Mask:
Stnd I-Line process.

30.0 Contact Etch:
Plasma etch in Lam2. CHF3/CF4/He, ~800 watts.

31.0 Back side etch

31.1 Remove PR in O2 plasma, piranha clean wfrs in sink8 (no dip).
Dehydrate wafers in oven at 120 C for >30 min.

31.2 Etch backside:
(PWELL and PCH front side etch can be included in c), d) and e), and then proceed to 36.0).
a) Spin PR on front side, do not expose; hard bake.
b) Do a) again.

c) Dip off oxide in 5:1 BHF until backside dewets.
d) Etch poly-Si (poly2 thickness) in lam4.
e) Etch oxide off in 5:1 BHF until backside dewets.
f) Etch poly-Si (poly1 thickness) in lam4.
g) Final dip in 5:1 BHF until back dewets.
h) Remove PR in O2 plasma, piranha clean wfrs in sink8 (no dip).

32.0 Metallization: target = 6000 A
Stnd clean wfrs and do a >=30 sec. 25/1 H2O/HF dip just before metallization.
Sputter Al/2% Si on all wafers in CPA.

33.0 Metal Photo Mask:
Stnd KTI process.
Hard bake for >2 hrs.

34.0 Plasma etch Al in Lam3.
Remove PR in O2 plasma (no piranha!). tAl=
Probe test devices.

35.0 Sintering: 400 C for 20min in forming gas (tylan13).
No ramping, use SINT400 program.

36.0 Testing:
2um NMOS, PMOS devices, capacitors and inverter
Measure the sheet resistivities of PWELL and PCH on prometrix.

End of Process