



9. The process steps in a simple CMOS technology very similar to that examined in Lab 3 are listed below. Both n- and p-channel MOSFETS have n+ poly gates. Calculate the threshold voltage  $V_{Tp}$  of an active p-channel MOSFET fabricated in this technology. (Assume that we are dealing with a long-channel device). Show all relevant steps in your calculation, and state any approximations made.

25 marks

5  $\mu\text{m}$  n-WELL CMOS PROCESS

Starting substrate: 3  $\Omega\text{cm}$  p (100) silicon

A. N- well formation

1. First mask oxidation  $t_{\text{ox}}=200\text{ nm}$   $T=1000^\circ\text{C}$  time=24 min ambient: wet  $\text{O}_2$
2. n-well P.E. and oxide etch PE 1
3. n-well implant phosphorus dose= $7.5 \times 10^{12}\text{ cm}^{-2}$  energy=30 keV
4. Well drive-in  $T=1150^\circ\text{C}$  time=6 hours  $t_{\text{ox}}=50\text{ nm}$  ambient: dilute  $\text{O}_2$  in Ar

B. Device Isolation

1. Blanket oxide etchback
2. Pad oxidation  $t_{\text{ox}}=50\text{ nm}$   $T=1000^\circ\text{C}$  time=40 min ambient: dry  $\text{O}_2$
3. Nitride deposition  $t_{\text{nitride}}=100\text{ nm}$
4. Device well P.E. and nitride etch PE 2
5. p-guard P.E. PE 3
6. p-guard implant boron dose= $7.5 \times 10^{12}\text{ cm}^{-2}$  energy=30 keV
7. Field oxidation  $t_{\text{ox}}=1\text{ }\mu\text{m}$   $T=1000^\circ\text{C}$  time=240 min ambient: wet  $\text{O}_2$

C. Active device formation

1. Blanket nitride and pad oxide etchback
2. Gate oxidation  $t_{\text{ox}}=30\text{ nm}$   $T=1000^\circ\text{C}$  time=20 min ambient=dry  $\text{O}_2$ , with Ar anneal
3. Blanket active device  $V_T$  adjust implant boron dose= $5 \times 10^{11}\text{ cm}^{-2}$  energy=30 keV
4. Gate polysilicon deposition  $t_{\text{poly}}=0.4\text{ }\mu\text{m}$
5. Blanket poly doping implant phosphorus dose= $2 \times 10^{16}\text{ cm}^{-2}$  energy=30 keV
6. Polysilicon gate P.E. and etch PE 4
7. Gate oxide etchback
8. n+ P.E. PE 5
9. n+ implant phosphorus dose= $3 \times 10^{15}\text{ cm}^{-2}$  energy=30 keV
10. p+ P.E. PE 6
11. p+ implant boron dose= $3 \times 10^{15}\text{ cm}^{-2}$  energy=20keV
12. Source/drain implant anneal  $T=1000^\circ\text{C}$  time=5 min ambient: nitrogen

D. Contact and Metallization (simplified)

1. BPSG deposition
2. BPSG flow
3. Contact P.E. and etch PE 7
4. Metal deposition
5. Metal P.E. and etch PE 8