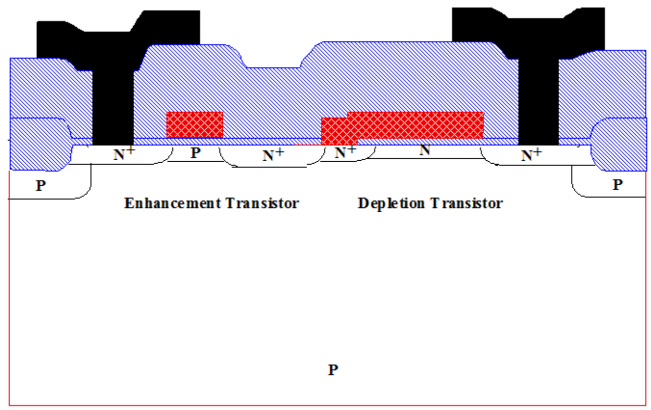
EE486 Integrated Circuit Fabrication, Spring 2017

Homework 1. Due in class on Monday, April 10, 2016.

1. During the 1970s, the dominant logic technology was NMOS as described briefly in Chapter 1. A cross-sectional view of this technology is shown below (see also Figure 1-33). The depletion mode device is identical to the enhancement mode device except that a separate channel implant is done to create a negative threshold voltage. Design a plausible process flow to fabricate such a structure, following the ideas of the CMOS process flow in this chapter. You do not have to include any quantitative process parameters (times, temperatures, doses etc.) Your answer should be given in terms of a series of sketches of the structure after each major process step, like the figures in Chapter 2. Briefly explain your reasoning for each step and the order you choose to do things.



2. For a p-type (boron) diffusion is performed as follows:

Pre-dep: 20 minutes, 900˚C, solid solubility

Drive-in: 30 minutes, 1000˚C

(a) What is the deposited dose (Q)?

(b) If the substrate is doped 10^{16} cm^{-3} phosphorus, what is x_j (junction depth)?

(c) What is the sheet resistance of the diffused layer?

3. Suppose we perform a solid solubility limited predeposition from a doped glass source which introduces a total of Q impurities / cm^2.

(a) If this predeposition was performed for a total of t minutes, how long would it take (total time) to predeposit a total of 2Q impurities/cm^2 into a wafer if the predeposition temperature remained constant.

(b) Derive a simple expression for the $(Dt)_{\text{drive-in}}$ which would be required to drive the initial predep of Q impurities/cm^2 sufficiently deep so that the final surface concentration is equal to 10% of the solid solubility concentration. This can be expressed in terms of $(Dt)_{\text{predep}}$ and the solid solubility C_S.

4. A special twin-well (twin-tub) CMOS technology requires that the wells have the same depth at the substrate concentration of 10^{16} cm^{-3}, with arsenic used for the n-tub and boron used for the p-tub. A shallow implant dose of 10^{14} cm^{-2} is used for both and the slow diffusing arsenic is introduced first and partially driven-in. Then the boron is introduced and the rest of the anneal is performed until both junctions reach 0.5 microns. Calculate drive-in times and temperatures required to achieve these specifications.

5*. (a) What is the total and marginal (change for last atom added) entropy of mixing for 20,000 atoms of element A substitutionally into 980,000 atoms of B (1,000,000 total sites)?

(b) If the equilibrium concentration of neutral interstitials in Si is determined to be 10^{12}cm^{-3} at 1000◦C and 2.6×10^{9}cm^{-3} at 800◦C, what are the enthalpy and entropy of formation of the neutral 110 split interstitial (six possible configurations at each lattice site)?

6*. Given the charge state locations given in Table 3.3 and a total vacancy concentration (over all charge states) of $C_{V^*total} = 10^{11}$cm^{-3} at 1000◦C (use this value rather than value from text):

(a) What is the equilibrium concentration of neutral vacancies?

(b) What is the total vacancy concentration in silicon doped with $N_d^+ = 5\times10^{19}$cm^{-3}.

(c) Sketch the vacancy concentration as a function of n/n_i on a log-log scale.

*EE/MSE 528 problems. Extra credit for EE/MSE 486