EECS 130, Fall 1998
Final Exam Solutions
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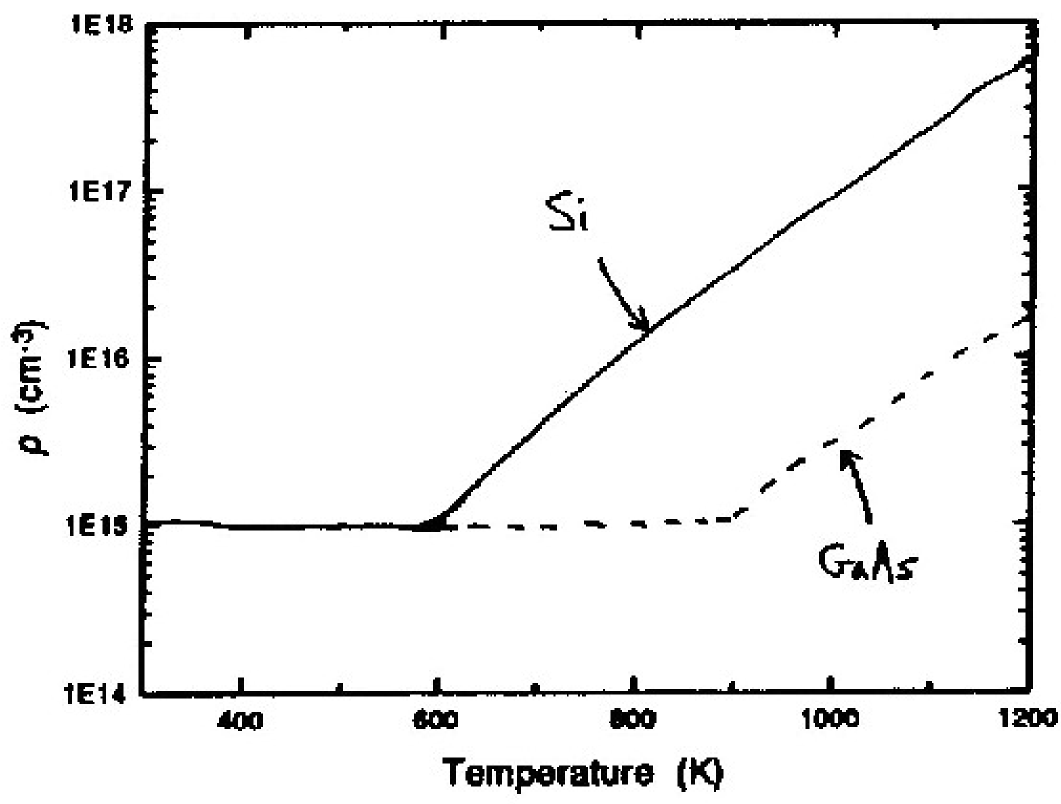
Problem 1

a) At room temperature, the dopants are fully ionized.
Na >> Ni(300K)
p = Na = 10^15 cm^-3
n = (Ni)^2 / p = 10^5 cm^-3

b) (Ni)^2(T) = Nc(T)*Nv(T)*e^(-Eg/kT) , Nc*Nv is proportional to T^3
Ni(600K) = 10^15 cm^-3
p = Na/2 + squareroot of ((Na/2)^2 + (Ni)^2(T)) = 1.62 * 10^15 cm^-3
n = ((Ni)^2(600K)) / p = 6.18 * 10^14 cm^-3

c)



d) See graph in part c)

e) Higher electron mobility or smaller effective mass for GaAs.

f) The hole mobility at 600K is smaller than the hole mobility at 300K. Phonon scattering is increasing with temperature.

g) Holes diffuse from hot to cold. The arrow should be drawn going from cold to hot.

Problem 2

a) LOCOS has Bird's beak, STI does not. STI yields a more planar wafer surface. STI allows tighter transistor packing.

b) 1. Activate implanted dopants
2. Cure implantation damage, i.e. restore crystal structure

c) Growing SiO_2 in water vapor atmosphere.

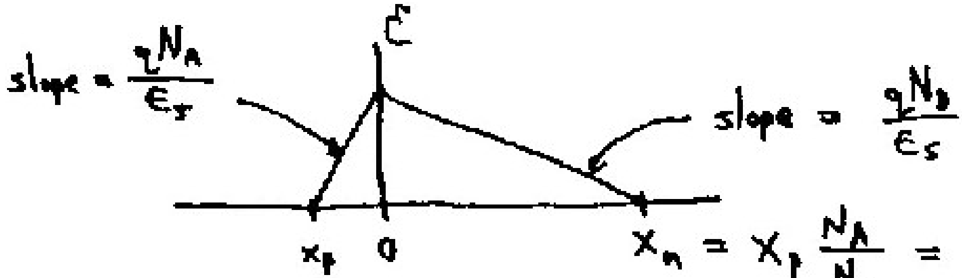
d) Wet oxidation rate is greater than dry oxidation rate.

e) Chemical Vapor Deposition

f) To grow buried subcollector, which is heavily doped to reduce resistance.

Problem 3

$$\phi_{bi} = \frac{kT}{q} \ln \frac{N_A N_D}{n_i^2} = .778 \text{ V}$$



$$x_n = x_p \frac{N_A}{N_D} = 10\, x_p$$

$$.778 \text{ V} = \text{Enclosed Area} = \frac{1}{2}\left(x_p \frac{qN_A}{\epsilon_s}\right)\left(x_p + 10x\right.$$

$$\longrightarrow \quad x_p = .030\ \mu m$$

at x = 0:
p = Ni*e^(-(Ep-Ei)/kT) = 6.6 * 10^15 cm^-3
n = (Ni)^2 / p = 1.5 * 10^4 cm^-3

Problem 4

a) When Xb decreases, emitter efficiency increases.

b) When Xb decreases, base transport factor increases.

c) When Xb decreases (base-width modulation becomes more significant, relatively speaking), early voltage decreases.

d) When Xb decreases, current gain increases.

e) When Xb decreases, base transit time decreases.

f) When Xb decreases, base Gummel number decreases.

g) When Xb decreases, emitter Gummel number remains unchanged.

Problem 5

a) g_msat = (2*Id) / (2*Vg) = (u*Cox*W/L)*(Vg-Vt) = (2*Id) / (Vg-Vt)

b) g_m = Ic / (kT/q)

c) (Vg-Vt) / (2*kT/q)
(Vg-Vt) is about a Volt while (kT/q) is about 26 mV
Therefore g_m (BJT) is larger than g_m (MOS)

d) Vg < Vt: log(Ist) = S(Vg) + Io
g_m (MOS) = (2*Id) / (2*Vg) = (ln 10 /S)*Id
Id = Ic thus the ratio g_m (BJT) / g_m (MOS) = S / ((kT/q)*ln 10) >= 1

Problem 6

a) The substrates are p-type. We know this because Vt > Vfb or increasing Vg depletes the substrate.

b) Xox: B
Vfb: B
Xdmax: A
Nsub: B
Vt: B
