Department of Electrical and Computer Engineering
UNIVERSITY OF BRITISH COLUMBIA

EECE 480 MICROELECTRONIC DEVICES

FINAL EXAM, December 4, 2003

Time: 2.5 hours
ANSWER ALL QUESTIONS.
All questions carry equal weight.
No notes, programmable calculators or books allowed.
Some equations are given on the next page.
This exam consists of 2 pages.

1.
(a) Explain the phenomenon of deep depletion.
(b) Sketch a cross-sectional view of a DRAM element. How and why does the drain differ from that of a regular MOSFET?
(c) Explain the operations of writing and storing '1's' and '0's', and of refreshing, in a DRAM.
(d) Why is deep depletion not an issue in the switching of regular MOSFETs?

2.
(a) What is the short-channel effect in MOSFETs?
(b) Discuss the importance of the source/drain junction depth, and the source-drain voltage, in determining the extent of the short-channel effect.
(c) How is the short-channel effect controlled (reduced) in (*i*) regular MOSFETs, and (*ii*) dual-gate MOSFETs?
(d) As the channel length has shortened, the mobility has decreased. Why is this, and how might this trend be halted?

3.
(a) Discuss the various factors that must be considered when choosing N_{SUB}, L, T_{OX}, and V_{DD} in designing a MOSFET suited to high-speed logic applications.
(b) What are the reasons for incorporating HBTs into a CMOS process?
(c) Compare and contrast CMOS logic and ECL.

4. Refer to the Figure overleaf, and consider building an HBT on an InP substrate, using InAlAs and InGaAs epi-layers.
(a) Which of the two epi-layers should be used as the emitter, and why?
(b) Choose, giving reasons for your choice, suitable mole fractions of In for *(i)* the emitter, and *(ii)* the base.
(c) Draw an equilibrium energy band diagram, showing E_{vac}, E_C, E_V and E_F roughly to scale, for an *npn* version of your HBT. The electron affinity can be assumed to be the same for all the materials used.

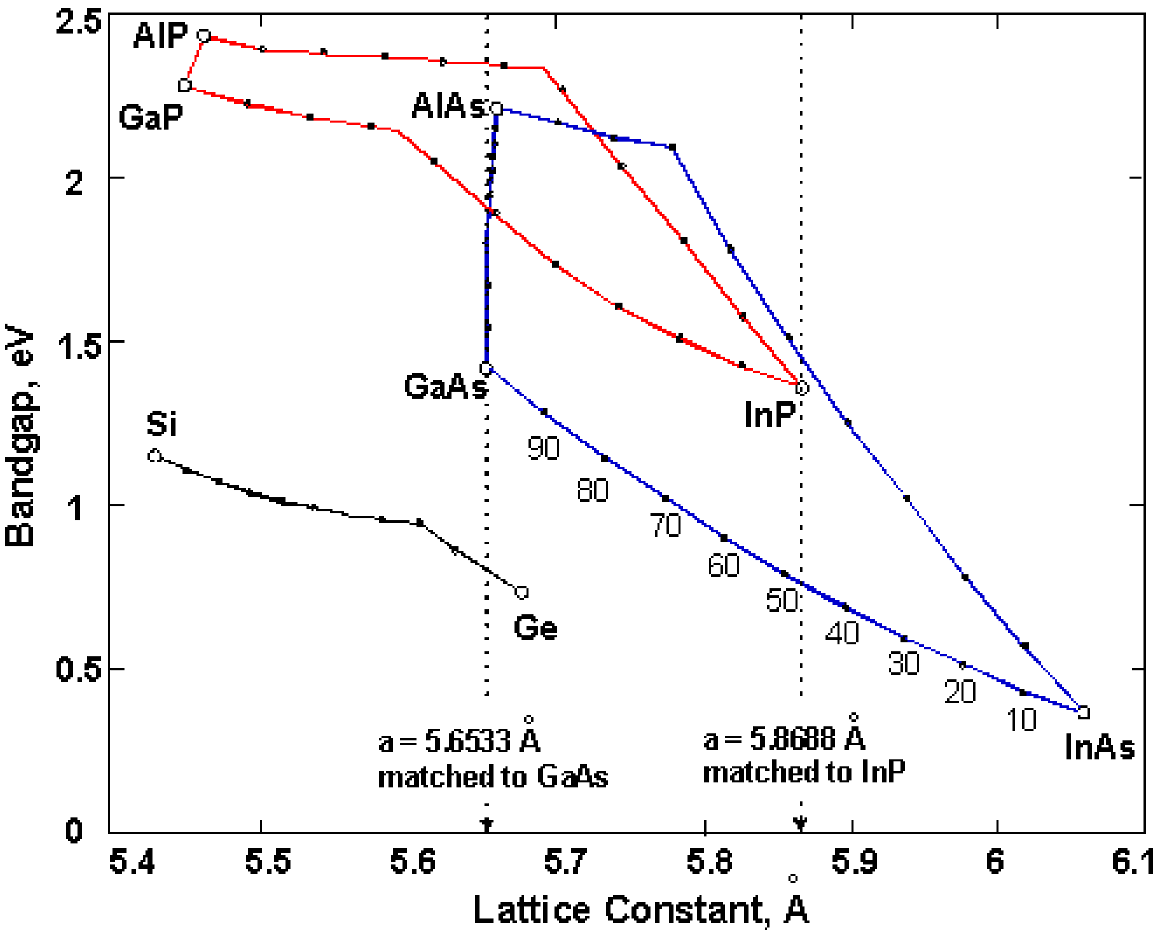

Figure 1: Bandgap *vs.* Lattice Constant.

SOME EQUATIONS

$p_0 n_0 = n_i^2;$ $n = n_i \exp[(E_{Fn} - E_{Fi})/kT];$ $n = N_C \exp[(E_{Fn} - E_C)/kT];$

$n_i(\text{Si}) = 10^{10}\,\text{cm}^{-3};$ $kT/q = 0.026\,\text{V at 300K};$ $E_g(\text{Si}) = 1.12\,\text{eV}$

$f(E) = 1/[1 + \exp((E - E_F)/kT)];$

$\frac{\partial^2\psi}{\partial x^2} + \frac{2m}{\hbar}[E - U(x)]\psi = 0;$ $\hbar^2 k^2 = 2mE$

$-q\psi = E_{Fi} - E_F;$ $-q\phi_n = E_{Fn} - E_F$

$V_T = \frac{1}{C_{ox}}\sqrt{2\epsilon_s q N_{SUB}(2\phi_B + V_{SB})} + 2\phi_B + V_{FB};$ $\phi_B = \frac{kT}{q}\ln\frac{N_{SUB}}{n_i}$

$v = \mu\frac{E_y}{1 + E_y/E_{crit}};$ $D/\mu = kT/q$

$I_{Dsat} = C_{ox} Z v_{sat}(V_{GS} - V_T);$ $I_C = I_S \exp qV_{BE}/kT$

$(2\pi f_T)^{-1} = \frac{C_\pi + C_\mu}{g_m} + C_\mu(R_E + R_C);$ $f_{max} = \sqrt{\frac{f_T}{8\pi C_\mu R_B}}$