**Department of Electrical and Computer Engineering**
**UNIVERSITY OF BRITISH COLUMBIA**
**EECE 480 MICROELECTRONIC DEVICES**

**MID-TERM EXAM, October 26, 2006**

Time: 1.25 hours
**Full marks can be obtained by answering Questions 1, 2 and 3 correctly.**
No notes, programmable calculators or books allowed.
This exam consists of 2 pages.
Some equations are given on a separate page.

**Information:** For Si: $n_i = 10^{10}\,\mathrm{cm}^{-3}$ and $E_g = 1.12\,\mathrm{eV}$.
For this exam, take: $kT/q = 25\,\mathrm{mV}$ and $\ln(X) = 2\log_{10}(X)$.

**1.**
**(a)** [**3 marks**] In this question, it is permissible to assume that $E_{Fi}$ for Si lies at an energy level that is midway between $E_C$ and $E_V$. Explain, without doing a numerical evaluation, why this is an acceptable assumption.
**(b)** [**8 marks**] Carefully construct an energy band diagram, in the $x$-direction (gate to body), of an N-MOSFET with a heavily doped **p-type** polySi gate, under equilibrium conditions. Show $E_0$, $E_l$, $E_C$, $E_V$, $E_F$, and, in the body and the gate, $E_{Fi}$.
**(c)** [**3 marks**] If the FET in Question 1(b) has an acceptor doping density in the body of $10^{18}\,\mathrm{cm}^{-3}$, how much band bending of $E_C$ is there in the body at the drain end of the device when the FET is at the onset of strong inversion with $V_{DS} = 1.0\,\mathrm{V}$?
**(d)** [**4 marks**] Evaluate the flat-band voltage for this FET.

**2.** [**12 marks**] A West-coast start-up, *480 Semiconductor Inc.*, hires two device engineers, Juliet and Zoe, to design a high-current $n^+$-$p$ diode.
Both designers agree:
- on the doping densities and lengths (essentially infinite) of the $n^+$ "emitter" and the $p$ "base".
- on the forward bias at which the high current must be delivered.
Each designer goes to the lab and fabricates her diode. Juliet is of the opinion that it is necessary to obey strict rules of cleanliness in the processing of the device, but Zoe pays less attention to this. The result is that Juliet's device has an electron minority carrier diffusion length ($L_e = \sqrt{D_e \tau_e}$) that is much longer than the quasi-neutral width of the base $W_B$, whereas Zoe's device has $L_e \ll W_B$.
Which designer's diode becomes the Company's product, and why?

**More questions on the back of this page**

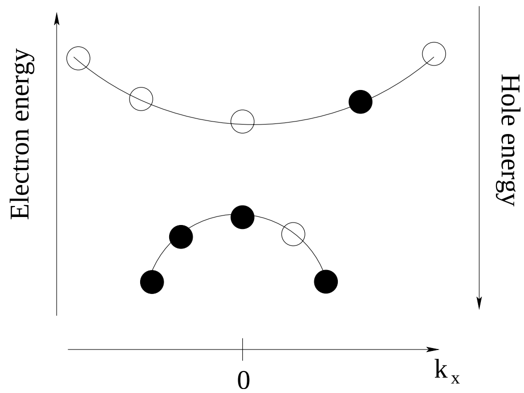


Figure 1: $E$-$k$ relation for a 1-D semiconductor, showing 5 states per band.

**3.** Figure 1 shows 5 states in the conduction band and in the valence band of a 1-D semiconductor.
**(a)** [**3 marks**] The bands appear to be parabolic: generally, is this a useful approximation to the actual $E$-$k$ relationship of a semiconducting material?
**(b)** [**3 marks**] Redraw the Figure on your exam paper and add arrows to it in order to show the movement of the electrons in the conduction band, and of the electrons in the valence band, in response to an electric field in the positive $x$-direction.
**(c)** [**2 marks**] If MOSFETs of channel-length $L$ were made from this semiconducting material to supply a given current at a given overdrive voltage, which type of FET ($n$-channel or $p$-channel) would have the smaller footprint?

**4.** [**Bonus**] Explain why the LEVEL 1 model for the drain current of a MOSFET overestimates the actual current in saturation for modern devices.