Name: Email: ID#

UNIVERSITY OF CALIFORNIA
Department of Electrical Engineering and Computer Sciences
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Test #1

1) Consider the following elements:

   Zn: Atomic number: 30, Atomic weight: 65
   O: Atomic number: 8, Atomic weight: 16

   a) Write the electronic configurations ($1s_2$, $2s_2$, …) for both elements

      i) Zn: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2$
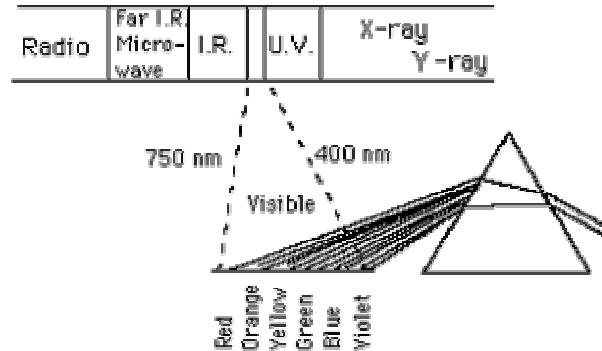
2 pts

      ii) O: $1s^2\ 2s^2 2p^4$

   b) Two Zinc Oxides are known to exist. ZnO and ZnO_2. Which material is likely to be a semiconductor? Why?

1 pt

ZnO is likely to be a semiconductor. ZnO will form a silicon-like II-VI structure. ZnO_2 should be comparatively unstable due to the partially filled O shells.

   c) The portion of the electromagnetic spectrum around visible light is shown below.

| Frequencies: 4 - 7.5 x 10^14 Hz |
| Wavelengths: 750 - 400 nm |
| Quantum energies: 1.65 - 3.1 eV |

The Zinc Oxide semiconductor from above is known to be almost entirely transparent to visible light, yet, also forms a decent semiconductor at room temperature. Suggest a likely bandgap for the material. Give reasons for your answer.

2 pts

The bandgap must be larger than 3.1eV to prevent absorption of visible light. It should be as small as possible to prevent the material from being too insulating. Therefore, an E_G of slightly more than 3.1eV is likely.

2) Consider a block of silicon that is doped into three zones, each 1cm long with phosphorus concentrations of 1E16, 1E17, and 1E18 cm^{-3} respectively.

E_C

E_F

E_V

Zone 1   Zone 2   Zone 3
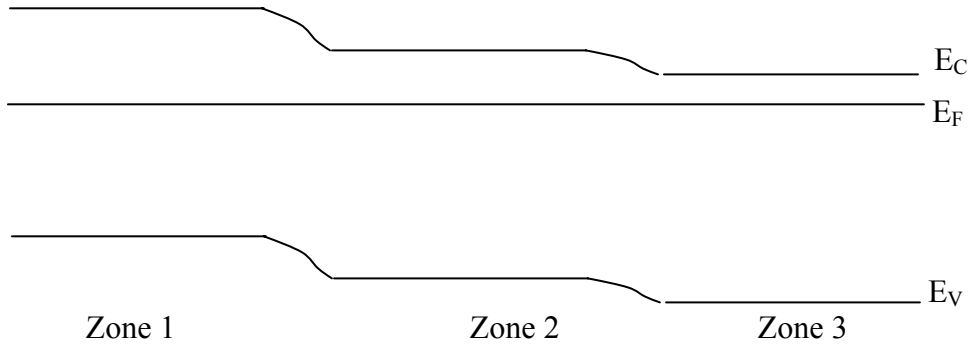
a) Based on the band diagram above, determine which doping level corresponds to each zone

    i) Zone 1: *1E16cm^{-3}*

    ii) Zone 2: *1E17cm^{-3}*

1.5 pts

    iii) Zone 3: *1E18cm^{-3}*

b) What is the voltage applied across the piece of silicon above? Give reasons.

1 pt

*The voltage is 0. We know this since the Fermi level is flat.*

c) Estimate the resistances of the three zones, assuming the cross-sectional area is 1cm×1cm. Ignore the curved regions on the band diagram above:

    i) Zone 1: *R ~ 0.5ohms*

    ii) Zone 2: *R ~ 0.08ohms*

1.5 pts

    iii) Zone 3: *R ~0.02ohms*

d) Suppose I apply 0.6V across the block, with the anode connected on the left. Sketch the resulting band diagram, indicating the approximate voltage drop across each region.

4 pts

E_C

0.02V

0.08V

E_V

0.5V

E_F
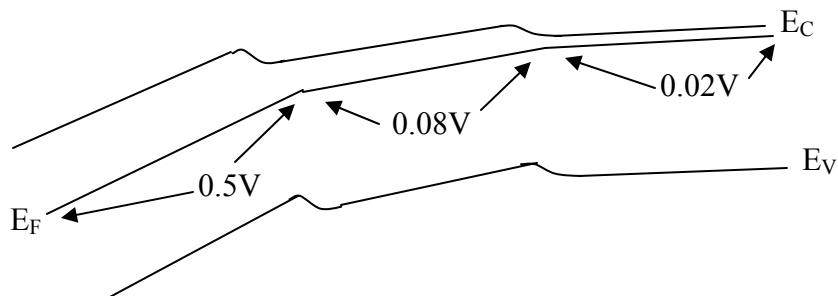
3) Suppose I take a block of silicon and dope it with 1E17cm^{-3} Arsenic.

    a) What is the concentration of electronics and holes at room temperature?

1 pt

$n=N_D=10^{17}cm^{-3}$. $p=n_i^2/n=10^3cm^{-3}$.

    b) Now, suppose I add 1E18cm^{-3} Indium to this block. Will the resulting material be N-type, intrinsic, or P-type. Give reasons.

2 pts

The resulting material will be p-type. Indium is an acceptor, and, given the order of magnitude excess, should completely counterdope the material.

   c) Which dopant will be more completely ionized. Why?

2 pts

The As will be more completely ionized. (1) it has a smaller activation energy (2) E_F will be further away from E_{As} than from $E_{In.}$

    d) Now, suppose I add an additional 1E19cm^{-3} of Indium. Will the %ionization of Indium Increase or decrease. Sketch a plot of the Fermi function in the two cases to illustrate your answer.

3 pts

The %ionization of In will decrease. The E_F will move closer to E_{In}, reducing the probability of ionization as shown below:
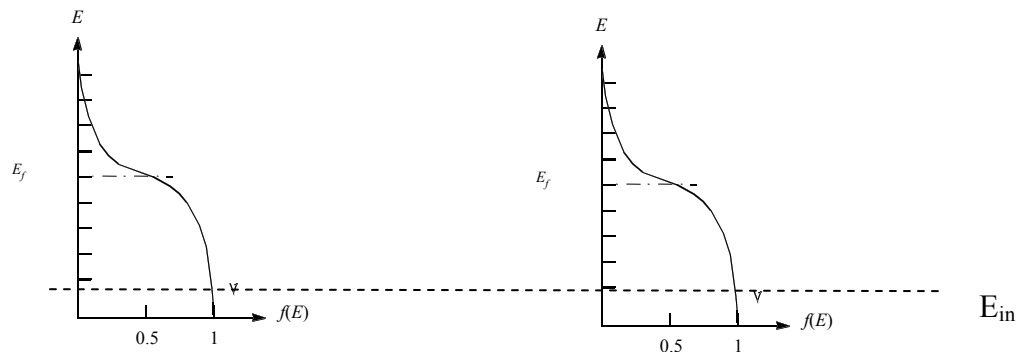
    e) Suppose I were to have used Boron instead of Indium in parts (b) and (d) above. Would the resistance of the block increase, decrease, or stay the same. Give reasons for your answer.

2 pts

The resistance will decrease, since Boron is more easily activated due to its lower ionization energy

    f) Compare the hole mobility of two identical blocks of silicon at room temperature. Block "A" is moderately doped (~1E17 or so) with Boron, while Block "B" is doped with an identical amount of Indium. Give reasons for your answer.

2 pts

The mobility in block A will be lower due to the higher coulombic scattering caused by the increased dopant activation in Boron.