

Name:

Email:

ID#

UNIVERSITY OF CALIFORNIA
Department of Electrical Engineering and Computer Sciences
EE130 Fall 2004

Prof. Subramanian

Test #1

1) Consider the following elements:

Fe: Atomic number: 26, Atomic weight: 56

S: Atomic number: 16, Atomic weight: 32

a) Write the electronic configurations ($1s^2, 2s^2, \dots$) for both elements

i) Fe: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$

ii) S: $1s^2 2s^2 2p^6 3s^2 3p^4$

1 pt

b) Iron is among the most abundant materials on the planet. Would you expect the following iron-based materials to be semiconductors? Give reasons.

i) Iron Pyrites (FeS_2 , also known as “Fool’s Gold”):

Based on non-hybridized model above, you wouldn’t expect this to be a semiconductor. However, it turns out that this actually is a semiconductor due to hybridization.

ii) Ferric Chloride (FeCl_3):

This will be strongly ionic, and therefore is not a semiconductor.

3 pts

iii) Ferrous Chloride (FeCl_2):

This will be strongly ionic, and therefore is not a semiconductor.

c) TiO_2 is in fact a semiconductor. Why? Give your answer in terms of the expected orbital configurations.

Ti is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$, while O is $1s^2 2s^2 2p^4$. To form a “group-IV-like” configuration, based on what we have learned in class (the reality is a little more complicated), Ti could contribute the 4s and 3d electrons to the two O atoms to form a fully stable configuration

1 pt

d) TiO_2 has a bandgap of approximately 3eV. All else, being equal, would you expect it to be more or less conductive at room temperature than (give reasons):

i) Silicon

Probably less conductive, since it should have less intrinsic electrons and holes due to the larger bandgap

2 pts

ii) Diamond

Probably more conductive, since it should have more intrinsic carriers due to the smaller E_G

Name:

Email:

ID#

3) In this question, we are going to investigate the effect of temperature on various material and device parameters.

a) Suppose I take a piece of silicon doped with 10^{17} cm^{-3} Phosphorus, and heat it from 300K to 400K. Which carrier concentration shows the greater % change – electrons or holes? Why?

The minority carrier always shows the greater change in carrier concentrations as temperature is increased, due to greater intrinsic carrier generation. In other words, holes will show the larger increase.

1 pt

b) What is the effect of the above increase in temperature on carrier mobility, i.e., does it increase or decrease? Why?

Mobility will decrease due to increased phonon scattering.

1 pt

c) Based on your analysis above, would you generally expect the carrier lifetime to increase or decrease? Give reasons.

Since there is greater vibration, we would generally expect a smaller carrier lifetime due to more frequent scattering.

1 pt

d) What will be the impact on diffusion coefficient? Again, give reasons.

From the graphs in the notes, mobility decreases from $\sim 700 \text{ cm}^2/\text{V-s}$ to ~ 400 , while T increases by a smaller fraction. Therefore, we would generally expect D to decrease slightly in this case.

1 pt

You are given a random piece of silicon with a resistivity of $>10^4 \text{ ohm-cm}$ and an electron mobility of $\sim 300 \text{ cm}^2/\text{V-s}$.

a) Is the material n-type, p-type or essentially intrinsic? Why?

1 pt

The material is essentially intrinsic, as evidenced by the large resistivity.

b) What is the concentration of donors and acceptors? Give reasons for your answers.

2 pts

The total doping is probably $\sim 10^{18}$ (from the mobility vs. doping plot). Since the material is intrinsic, the donor and acceptor concentration are equal, and in that ballpark.

c) Suppose I were to cool the silicon down to 150K. Would the mobility increase or decrease? Why?

1 pt

From the mobility vs. temperature curve, for a doping of 10^{18} , the mobility would actually decrease going down to 150K due to increased impurity scattering.

Name:

Email:

ID#

3) Consider the following equation:
$$\frac{d^2 \Delta p}{dx^2} = \frac{\Delta p}{D_p \tau_p} = \frac{\Delta p}{L_p^2}$$

a) Would this equation be valid if $\Delta p = 10^{17} \text{cm}^{-3}$? Why / why not?

1 pt

This equation would probably not be valid, since this large excess carrier concentration will result in the minority carrier concentration being large enough that drift cannot be ignored.

b) What major approximations / assumptions do we make to go from the general continuity equation to the simple form above?

2 pts

We assume the absence of drift, the absence of any generation/recombination beyond the normal thermal means, and we assume steady state.

c) Suppose I were to take a piece of silicon and somehow alloy it with Ge to increase its mobility by 2X. What would happen to L_p ? Why?

1 pt

L_p would increase, since an increase in mobility must be accompanied by an increase in D (and therefore L) from Einstein's equation.

d) Suppose the alloying also increased the defects in the material by over an order of magnitude. What would happen to L_p ? Why?

1 pt

An order of magnitude increase in defects would likely dramatically decrease carrier lifetime, resulting in a strong decrease in τ . This would likely outweigh the increase in D , resulting in a net decrease in L .

e) Suppose I were to increase the temperature of the silicon from 300K to 400K. What would happen to L_p ? Why?

1 pt

Mobility would decrease, accompanied by a decrease in D , and therefore in L .

f) Suppose I were to shine light ($E < 0.5 \text{eV}$) on the Si. What would happen to (give reasons):

i) L_p : *Would probably have no impact, since D and τ aren't dependent on excess carrier concentration*

2 pts

ii) Δp : *Would probably have no impact, since this light isn't absorbed.*

g) Suppose I were to decrease the wavelength by 3X. What would happen to (give reasons):

i) L_p : *Would probably have no impact, since D and τ aren't dependent on excess carrier concentration*

2 pts

ii) Δp : *Would probably increase, since the energy would now exceed the bandgap, increasing generation and therefore the concentration of excess carriers.*