

151-Tutorial Assignment #2 (Fall 2009)

Bonds, Bands, and Doping: How Do LEDs Work?

Name Master
Last first

Chem ID _____

(4)1. For the four elements: sulfur, germanium, gallium, and phosphorous.

Which has the widest band gap? Enter your choice in the box.

sulfur

Which has the narrowest band gap? Enter your choice in the box.

germanium

Which has no band gap? Enter your choice in the box.

gallium

(8)2. Circle **all** the correct statement(s) of the following. (Two points will be deducted for each incorrect response.)

a. A LED chip is approximately 50 mm in diameter.

50 mm is the diameter of the plastic capsule of the LED, the size of the chip is much smaller.

b. The valence orbitals of metal atoms overlap with their neighbors to form covalent bonds.

c. An atom in crystalline sodium is weakly bonded to 12 neighboring sodium atoms.

According to the tutorial reading, many metals adopt the closest pack crystalline structure and an atom in a closest pack structure has 12 closest neighbors. Hence, each atom is weakly bonded to 12 neighboring atoms. Unfortunately, I had picked an exceptional example in this question because the crystalline structures of sodium and other alkali metals are body-centered cube having only 8 closest neighbors. Therefore, I will accept both answers (circled or non-circled answers).

d. Atoms in metallic crystals have fewer nearest neighbors than atoms in non-metal crystals.

Atoms in metallic crystals have more nearest neighbors than atoms in non-metal crystals.

e. The valence bands in non-metals are empty.

The valence bands are filled.

f. A semimetal can become a conductor of electricity with moderate input of thermal energy.

g. The conductivity of semimetals can be enhanced by doping with impurities that have the same number of valence electrons as the semimetals.

The impurities must have different number of valence electrons of the semiconductor

h. The band gap of a LED emitting red light is wider than the band gap of a LED emitting blue light.

Since blue light is more energetic than red light, the band gap of a LED emitting blue light is wider than the band gap of a LED emitting red light.

(8)3. A diode is constructed by silicon doped with phosphorus in contact with silicon doped with aluminum.

a. Which semiconductor is the p-type junction? Circle your answer.

(silicon doped with phosphorus / silicon doped with aluminum)

b. Which semiconductor has partially filled conduction bands? Circle your answer.

(silicon doped with phosphorus / silicon doped with aluminum)

c. Which semiconductor has partially filled valence bands? Circle your answer.

(silicon doped with phosphorus / silicon doped with aluminum)

d. Which semiconductor should be connected to the negative electrode of a battery? Circle your answer.

(silicon doped with phosphorus / silicon doped with aluminum)

e. Another diode is constructed by germanium doped with arsenic in contact with germanium doped with gallium. When connected to a battery, which LED will emit light of shorter wavelength? Circle your answer.

(the LED with the silicon diode / the LED with the germanium diode)

LEDs made of semiconductors with a wider band gap should emit electromagnetic wave of greater energy (shorter wavelength). Since a more electronegative element would have wider band gap, one should pick a more electronegative semiconductor of the two semimetals, silicon or germanium. If one follows the periodic trends of electronegativity, he/she would pick the silicon diode because silicon is above germanium in the periodic chart and should be more electronegative according to the trend. However, according to the Pauling scale of electronegativity from the Table in the lab manual, $\chi_{\text{Si}} = 1.90$ but $\chi_{\text{Ge}} = 2.01$. Therefore, those who had looked up for the values of electronegativities would pick the germanium diode over silicon. I have used another exceptional situation in here. I will accept both answers.

Two points were deducted for each incorrect answer not to exceed the total points of each question.