ECE 611 / CHE 611 - Electronic Material Processing
Fall 2019
Homework 1
Due at the beginning of class Tuesday October 15th

Question 1 [5 marks]:

a) Like silicon, germanium (Ge) adopts the diamond crystal structure (see Figure 1). The lattice constant of Ge is a = 5.66Å. The mass of Ga atoms are 73 amu. Using Figure 1 Determine the mass density of crystalline germanium. Give your answer in gcm^{-3}. You will need to know that 1 amu = 1.66×10^{-27} kg. [3 marks]

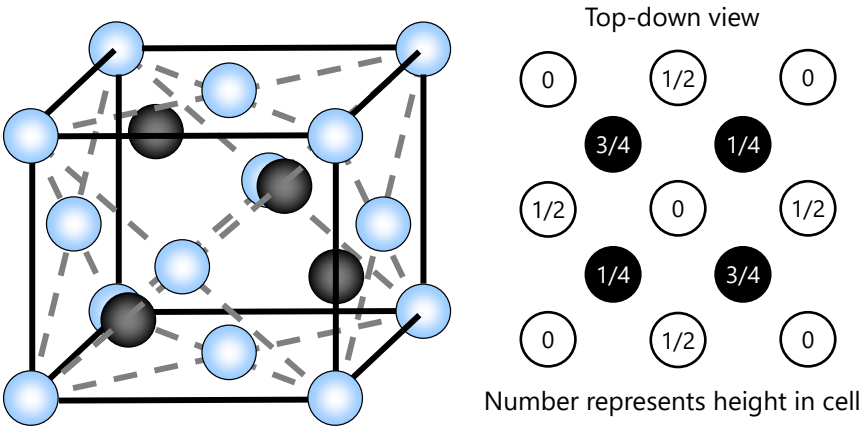


Figure 1: Diamond crystal structure (crystal structure of germanium). All atoms are silicon, despite the differences in color. The difference in color is intended to make the cell easier to visualize.

b) Figure 2 shows planes in a cubic crystal structure. Determine the Miller indices for the two crystal planes shown in Figure 2. The tick marks on the axes are evenly spaced. Quote the miller indices in standard form: with the lowest possible, integer values. For example, the plane (600) should be quoted as (100).[2 marks]

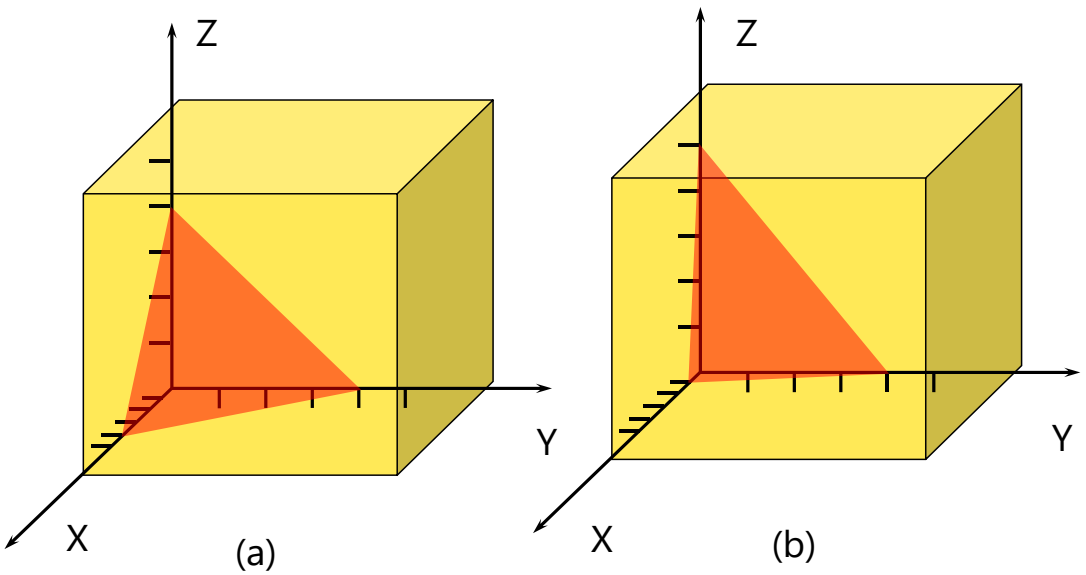


Figure 2: Cubic crystal structures with two different crystal planes located. The tick marks are evenly spaced.

Question 2 [8 marks]:

a) Explain why we require single-crystal (rather than polycrystalline or amorphous) silicon for microelectronics.[2 marks]

b) Figure 3(a) shows a schematic diagram of a silicon boule being withdrawn from a melt. Figure 3(b) shows the measured impurity concentration in this boule as a function of the fraction of the melt solidified. If the impurity concentration in the melt was 10^{19} cm^{-3} before the boule was started to be withdrawn, use the data in Figure 3(b) to determine the segregation coefficient of the impurity element present. [6 marks]

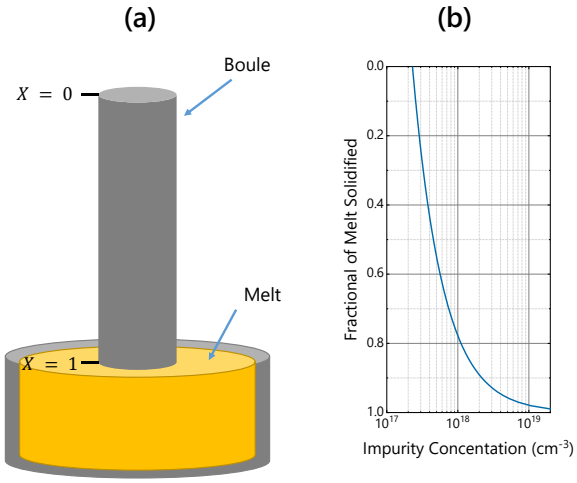


Figure 3: (a) Schematic diagram of boule of silicon withdrawn from melt. (b) Impurity concentration in the silicon boule as a function of the fraction of the melt that has been solidified. This data can be downloaded here.

Question 3 [7 marks]:

a) Figure 4 shows a pipe through which nitrogen gas (N_2) is flowing. The internal diameter of the pipe is 5 cm and the temperature of the gas is 300K. Determine the pressure at which the flow in the chamber makes the transition from viscous to molecular. The molecular diameter of N_2 is 3.16Å. Give your answer in Torr.[2 marks]

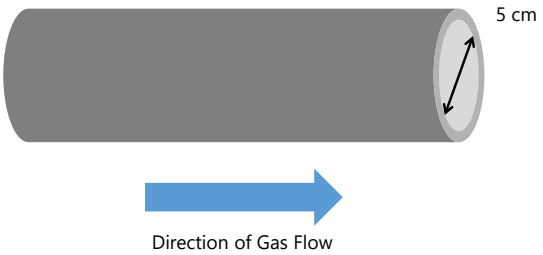
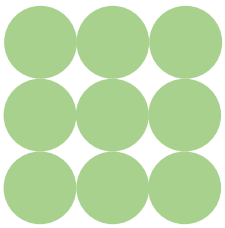


Figure 4: Schematic diagram of pipe through-which N2 gas is flowing. The internal diameter of the pipe is 5 cm.

b) A (111) terminated silicon wafer is placed in a chamber containing O_2, held at 300K for 5 minutes. What type of pump (high vacuum or low vacuum) would be sufficient to ensure a complete monolayer is not formed on the wafer? Approximate O_2 molecules as spheres that form a monolayer in a 2D square array, as shown below. Just guessing the answer (right or wrong) will get you zero marks![3 marks]



You will need to know:

- The molecular diameter of O_2 is 2.96 Å.
- The mass of an O atom is 15.999 amu.
- The sticking coefficient of O_2 on (111) Si is 0.15.
- The Boltzmann constant = 1.38×10^{-23} $m^2kgs^{-2}K^{-1}$.
- 1 atomic mass unit = 1.66×10^{-27} kg.

c) Explain why cryocondensation of hydrogen and helium is not effective in most cryogenic pumps.[2 marks]

Question 4 [5 marks]:

a) Figure 5 an example galvanic cell. The cathode is a cylinder with a diameter of 0.5cm, and 10cm submerged in the solution. If we were to carry out electrodeposition for 10 minutes and need to deposit 100 μm of copper onto the cathode, approximate what constant current would we need to maintain? Give your answer in amps.[3 marks]

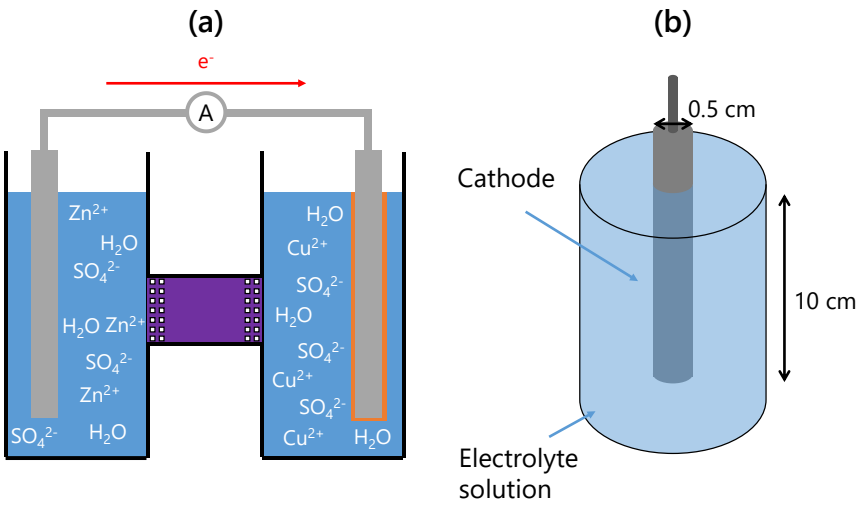


Figure 5: (a) Schematic diagram (side view) of simple galvanic cell. Electrons flow from the anode in electrolyte solution 1 on the left to the cathode in electrolyte solution 2 on the right. The purple region in the middle of the cell is the salt bridge. (b) An oblique view of the cathode in solution 2. The cathode is cylindrical, has a diameter of 0.5 cm and a submerged length of 10 cm.

You will need to know:

- The mass of a copper atom is 63.546 amu.
- The mass density of copper is 8.96 g/cm^3.
- The electrons per half-reaction is 2.
- Faraday Constant, F = 9.65×10^4 C/mol.
- 1 atomic mass unit = 1.66 × 10^{-27} kg.

b) Explain briefly one way organic additive compounds can be used to avoid voids being introduced when depositing metals into trenches via electrochemical deposition.[2 marks]