Universidad Carlos III de Madrid

**DEGREE IN AEROSPACE ENGINEERING**
**AEROSPACE MATERIALS I**

**June 22nd, 2017**

**Surnames:** **Name:** **Group:**

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**Information:**
- Read the questions carefully before answering. Use the space given for answering each question.
- You have 2h 30min to complete the exam.
- The marks assigned to each of the questions are given at the beginning of the question.
- To pass the exam you need a minimum mark of 4 over 10.

**1. (0.5 points)** Are the following statements True or False? Justify your answer.

| 1. An ionic compound does not conduct electricity in the solid state but it when dissolved in water the resulting solution conducts electricity. | |
|---|---|
| **T** | |

| 2. Metals form molecular compounds. | |
|---|---|
| **F** | |

| 3. Potassium presents a higher bonding energy than calcium. | |
|---|---|
| **F** | |

| 4. Materials that exhibit high linear coefficient of thermal expansion have a strong atomic bonding and they are useful in applications where the components repeatedly undergo rapid heating and cooling. | |
|---|---|
| **F** | |

**2. (1 point)** For each of the following stacking sequences of crystallographic planes found in FCC metals, explain the type of planar defect that exists and indicate the position(s) of planar defect(s) in the sequence:

a. (0.5p) ...A B C A B C B A C B A...
b. (0.5p) ...A B C A B C B C A B C...

**Solution:**

**a) Twin boundary.**



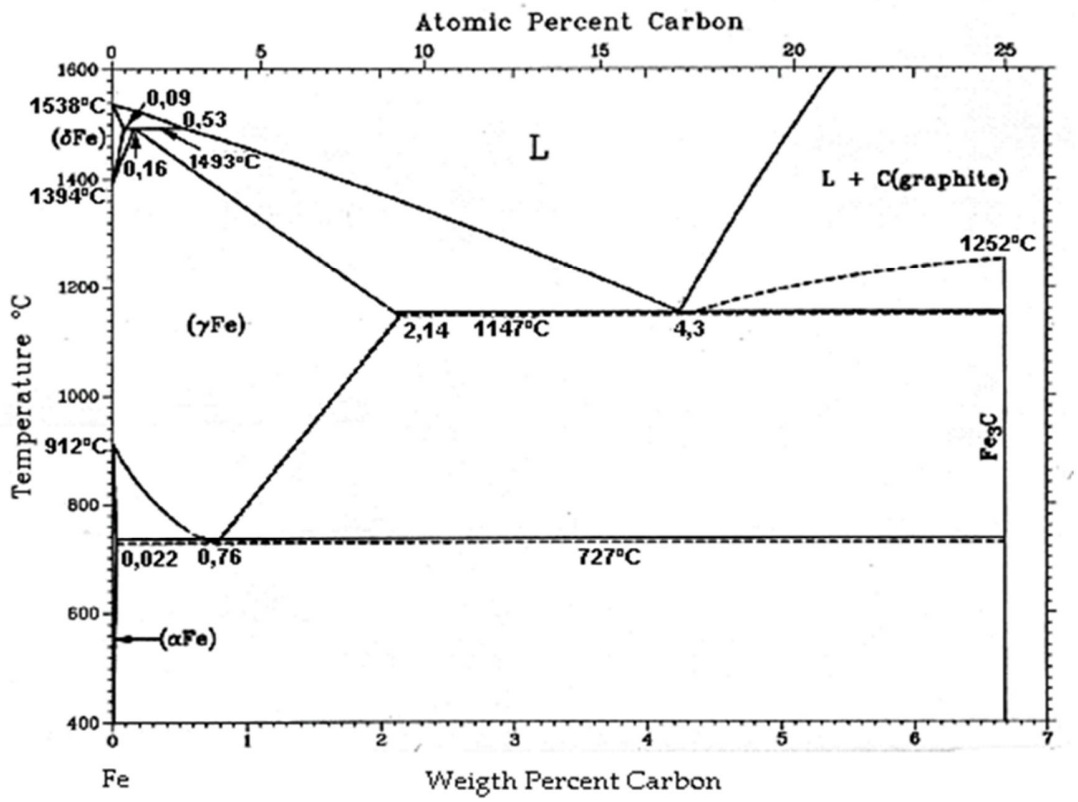

**b) Stacking fault.**




**3. (0.5 points)** Describe two mechanisms of diffusion and give the examples. Which one requires lower activation energy? Why?

**4. (2 points)** Examine closely the phase diagram Fe-C represented in the figure below and answer the following questions:

a. (0.5 p) If there is a 5 kg annealed bar of an alloy with 0.55 wt% C, calculate the quantity (mass expressed in Kg) of pro-eutectoid ferrite, eutectoid ferrite and cementite at 727-$\Delta T$?
b. (0.5 p) Determine the phases and microconstituents in this steel (0.55 wt% C), their composition and their percentage at 600 °C
c. (0.5 p) Calculate the percentage of C in an alloy that has 64.7 wt% of austenite and 35.3 wt% of cementite at 800 °C. What kind of Fe-C alloy is it?
d. (0.5 p) How are the carbon content and temperature at the eutectoid point modified in the diagram if Ni is added? How does this addition modify the steel's microstructure?




**Solution:**

**a) At 727 ºC. pro-eutectoid ferrite = 1.43 kg, eutectoid ferrite = 3.17 kg and cementite = 0.4 kg.**

**b) Microconstituents: α´(pre-eutectoide), pearlite)**

$C_{\alpha'} = 0.022\%C \quad C_{pearlite} = 0.55\%C$

$\chi_{\alpha}(pre) = 0.28$

$\chi_{pearlite} = 1 - \chi_{\alpha}(pre) = 1 - 0.28 = 0.72$

**Phases: ferrite and cementite** $C_{\alpha} = 0\%C \quad C_{Fe3C} = 6.7\%C$

$$\chi_{\alpha}(Total) = \frac{C_{Fe3C} - C_0}{C_{Fe3C} - C_{\alpha}} = \frac{6.7 - 0.55}{6.7 - 0} = 0.92 \quad \chi_{Fe3C}(E) = 0.08$$

**c) At 800 ºC. 3%**

**It is an hypoeutectic cast iron**

**d) Ni: γ stabilizing: eutectoid temperature ↓ ; A3↓ ; A1 ↓ less amount of Fe3C.**

**5. (1 point)** A cylindrical specimen made of brass with a diameter of 10 mm and length of 120 mm is submitted to an uniaxial tensile test:

a. (0.5 p) Calculate the length of the specimen under the load of 11750 N.
b. (0.5 p) Calculate the length of the specimen after the applied load of 23500 N, considering that the deformation just before unloading is $2.2 \cdot 10^{-2}$.

Data: $E = 10^5$ MPa; $\sigma_{0.2} = 250$ MPa; $\sigma_{TS} = 450$ MPa

**Solution:**

**(a) 120.18 mm**

**(b) 122.28 mm**

**6. (0.5 points)** P is added to high purity silicon in order to introduce a concentration of $10^{+23}$ $m^{-3}$ of charge carriers at room temperature.

a. (0.25 p) What type of semiconductor is this material? How does the impurity behave?
b. (0.25 p) What is the conductivity of this semiconductor at room temperature?

Assume that the mobility of the e- in the material is 0.14 $m^2/(V \cdot s)$.

**Solution:**

**b) 22400 $(\Omega m)^{-1}$**

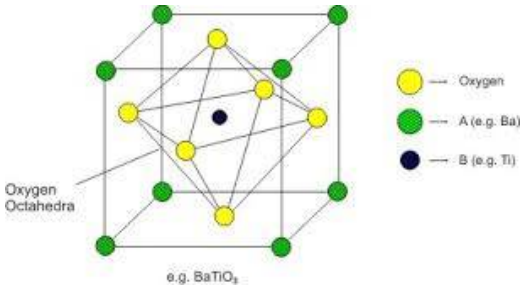
**7. (1.5 points)** The compound $BaTiO_3$ shows perovskite structure.

a. (0.25 p) Describe the structure of cell unit. What are the coordination indexes of the cations?
b. (0.25 p) Determine the lattice parameter in nanometers.
c. (0.5 p) Calculate the planar density in the plane (101) in ions/$nm^2$.
d. (0.5 p) Determine the volumetric density and the packing factor.

Data: $R_{Ti4+} = 0.061$ nm; $R_{O2-} = 0.140$ nm; $R_{Ba2+} = 0.136$ nm; M(Ba) = 137.33 g $mol^{-1}$; M(Ti) = 47.88 g $mol^{-1}$; M(O) = 16 g $mol^{-1}$.

Solution:

a)




Cl(Ti) = 6 and Cl(Ba) = 12.

b) a=0.390 nm

c) 13.92 $ions/nm^2$

d) 6.53 $g/cm^3$ and PF=0.77

**8. (1 point)** A monodisperse polymer with M = 200,000 g/mol is contaminated with 1% (w/w) of an impurity of molecular weight of 1000 g/mol. Calculate the values of $\bar{M}_n$ and $\bar{M}_w$.

**Solution:**

$$\bar{M}_w = 198010\ g/mol$$

$$\bar{M}_n = 66889\ g/mol$$

**9. (2 points)** A continuous and aligned fiber-reinforced composite is to be produced consisting of 30 vol% silicon carbide fibers and 70 vol% of a polycarbonate matrix. This material has a cross-sectional area of 325 $mm^2$ and is subjected to a longitudinal load of 44,600 N.

a. (0.5 p) Calculate the fiber-matrix load ratio.
b. (0.5 p) Justify which phase of the composite supports the vast majority of the applied load.
c. (0.5 p) Compute the magnitude of the stress on each of the fiber and matrix phases.
d. (0.5 p) What strain is experienced by the composite?

Data: $E_{fibers}$ = 400 GPa; $E_{matrix}$ = 2.4 GPa.

**Solution:**

a) 71.43

b) The fiber phase supports the vast majority of the applied load.

a)

$$\sigma_m = 2.71\ MPa$$

$$\sigma_f = 451.1\ MPa$$

b) Isostrain conditions:

$$\varepsilon_m = 1.13 \times 10^{-3}$$