Universidad Carlos III de Madrid

DEGREE IN AEROSPACE ENGINEERING
AEROSPACE MATERIALS I

June 17th, 2016

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

Information:
- Read the questions carefully before answering. Use the space given for answering each question.
- You have **2h 30min** to complete the exam.
- To pass the exam you need a minimum mark of 5 over 10.

1. (0.5 points) Explain briefly the following questions:

a. (0.25 p) How the bonding strength in materials affects the linear coefficients of thermal expansion.

b. (0.25 p) Based on atomic bonding, why are metals usually more ductile than ionic or covalent bonded materials?

2. (1 point) Consider boron diffusion into an intrinsic Si wafer (pure Si, no boron inside)at 1200 °C. If the diffusivity of boron in Si at 1200 °C is $D = 3.6 \times 10^{-16}$ m^2/s and the boron surface concentration is kept constant at 3×10^{24} atoms/m^3,what will be the boron concentration in atoms/m^3 at 1.0 μm below the surface after 3 hours? For full credit show your linear interpolation of the error function table.

z	erf (z)	z	erf (z)
0.00	0.0000	0.70	0.6778
0.01	0.0113	0.75	0.7112
0.02	0.0226	0.80	0.7421
0.03	0.0338	0.85	0.7707
0.04	0.0451	0.90	0.7969
0.05	0.0564	0.95	0.8209
0.10	0.1125	1.00	0.8427
0.15	0.1680	1.10	0.8802
0.20	0.2227	1.20	0.9103
0.25	0.2763	1.30	0.9340
0.30	0.3286	1.40	0.9523
0.35	0.3794	1.50	0.9661
0.40	0.4284	1.60	0.9763
0.45	0.4755	1.70	0.9838
0.50	0.5205	1.80	0.9891
0.55	0.5633	1.90	0.9928
0.60	0.6039	2.00	0.9953
0.65	0.6420		

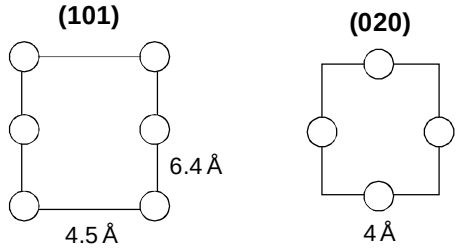
Solution:
2.16×10^{24} atoms/m^3

3. (2 points) Two distinct crystallographic planes in the unit cell of a hypothetic metal are shown below. The circles represent atoms.

a. (0.5 p) Identify the type of crystalline structure and the packing factor.
b. (0.5 p) Calculate the planar density for the plane (111) in atoms/cm^2.
c. (0.5 p) Given that the density of the material is ρ = 6.85 g/cm^3, calculate the molecular weight of the metal.

At a certain temperature a polymorphic change takes place and crystalline structure is transformed to a FCC structure.

d. (0.5 p) Determine the change in the volume of the metal after that transformation (expressed in %).



Solution:

a) 0.76

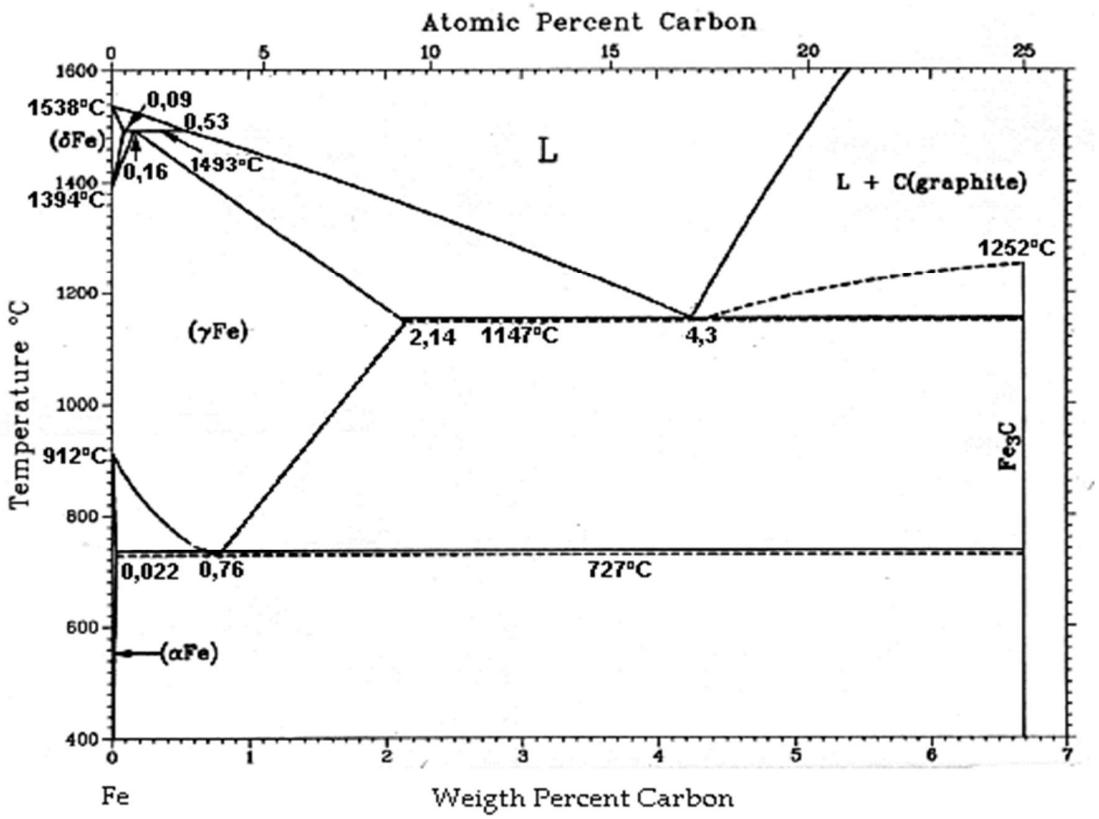
b) $1.14 \cdot 10^{15}\ atoms/cm^2$

c) 92.9 g/mol

d) Increases ~3%

4. (1 point) There are two different alloys A and B in the Fe-Fe_3C phase diagram shown below:

a. (0.5 p) Alloy A: For a 5 kg bar with the composition 0.55 % C, determine the quantity (in kg) of the proeutectoid ferrite, eutectoid ferrite, and cementite at (727-ΔT) °C.
b. (0.5 p) Alloy B: The microstructure of alloy B contains 63.3% of the proeutectoid ferrite. Calculate the carbon content of this steel.



Solution:

a)

m α(p) = 1.42 kg

mFe_3C = 0.4 kg

mα(e) = 3.18 kg

b)

C_0 = 0.29

5. (0.5 points) In a Ge semiconductor dopped with P the temperature limit for extrinsic behaviour is 100 °C. The extrinsic conductivity is 60 $(\Omega.m)^{-1}$:

a. (0.25 p) What type of semiconductor is it? Why?
b. (0.25 p) At what temperature the intrinsic conductivity would be 60 $(\Omega.m)^{-1}$.

Data: E_g = 0.66 eV; $\sigma_0 = 7.11 \times 10^{-5}$ $(\Omega m)^{-1}$, K = 8.62×10^{-5} eV/K.

Solution:

b) T= 408K=135ºC.

6. (1 point) Two bars with square cross sections were mechanically tested. One is made of a material A having E = 200 GPa and ν = 0.30, and other one of material B having E = 89 GPa and ν = 0.25. When the same force F is applied to both bars the maximum elastic deformation produced is identical and equal to 1.25×10^{-3}. Considering that for the material A change in lateral dimension is 3.75×10^{-3} mm and elongation is 0.125 mm under the force F and that for the material B elongation produced by the same force F is 50% of the elongation of material A, calculate:

a. (0.5 p) Initial dimensions of both bars and the applied load F.
b. (0.5 p) When a bar of material A is submitted to a tensile test, the elongation at fracture is 8.120mm. After the test, the measured deformation was 8%. Calculate the elastic deformation at the moment of fracture.

Solution:

a) $l_{0_A} = 10\,\text{mm}$; $l_{0_B} = 15\,\text{mm}$ and F=25000 N

b) $\varepsilon_{elastic} = 1.2 \cdot 10^{-3}$

7. (1 point) Answer and explain briefly the following questions:

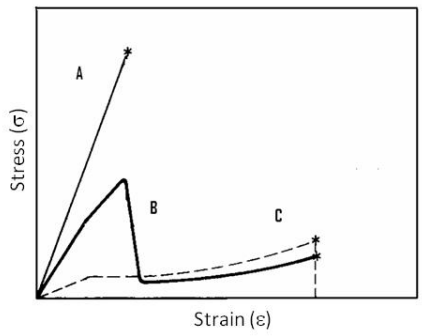
a. (0.5 p) How can the thermal shock mechanism be produced in ceramic materials?
b (0.5 p) What are the two limiting factors of the packing density in ceramics?

8. (1 point) Answer and explain briefly the following questions:

a. (0.5 p) Why does crosslinking influence the value of Tg?
b. (0.5 p) What is the reason for the fact that polymers cannot be entirely in a crystalline state?

9. (1 point) On the figure shown below, stress-strain curves of the composite, reinforcement fibers, and polymer matrix are plotted.

a. (0.5 p) Identify the behavior of the composite material, fibers, and matrix with the curves A, B, and C.
b. (0.5 p) Explain briefly why the fracture stress on C curve is higher than that of B curve.



10. (1 point) Name and describe the failure modes of an adhesive. Draw sketches if necessary.