Universidad Carlos III de Madrid

DEGREE IN AEROSPACE ENGINEERING
AEROSPACE MATERIALS I

January 23rd, 2017

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.
- The marks assigned to each of the questions are given at the beginning of the question.
- To pass the final exam you need a minimum mark of 4 over 10.

1. (1 points) 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 = 3.6×10^{-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.

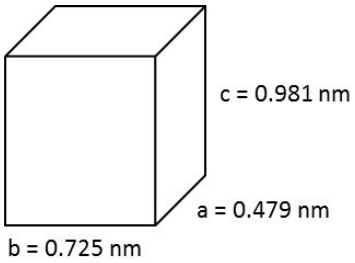
Solution: 2.16×10^{24} atoms/m^3

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		

2. (0.5 points) (a) (0.25 p) Explain why hydrogen fluoride (HF) has a higher boiling temperature than hydrogen chloride (HCl), even though HF has a lower molecular weight.; (b) (0.25 p) Explain with an example, how strength of a pure metal may be increased.

3. (1.5 points) Iodine has a base centered orthorhombic crystal structure for which the lattice parameters are shown below.

a. (0.5 p) If the atomic packing factor is 0.547, determine the number of atoms in each unit cell.
b. (0.25 p) The atomic weight of iodine is 126.91 g/mol; compute its theroretical density.
c. (0.25 p) Calculate the planar density in the plane (110) in atoms/cm^2.
d. (0.5 p) Determine the activation energy for vacancy formation in iodine, given that the equilibrium number of vacancies at 650 °C is 7.68×10^{18} vacancies/cm^3.
Data: R = 8.314 J/mol K.



Solution:

a) 4.3 atoms

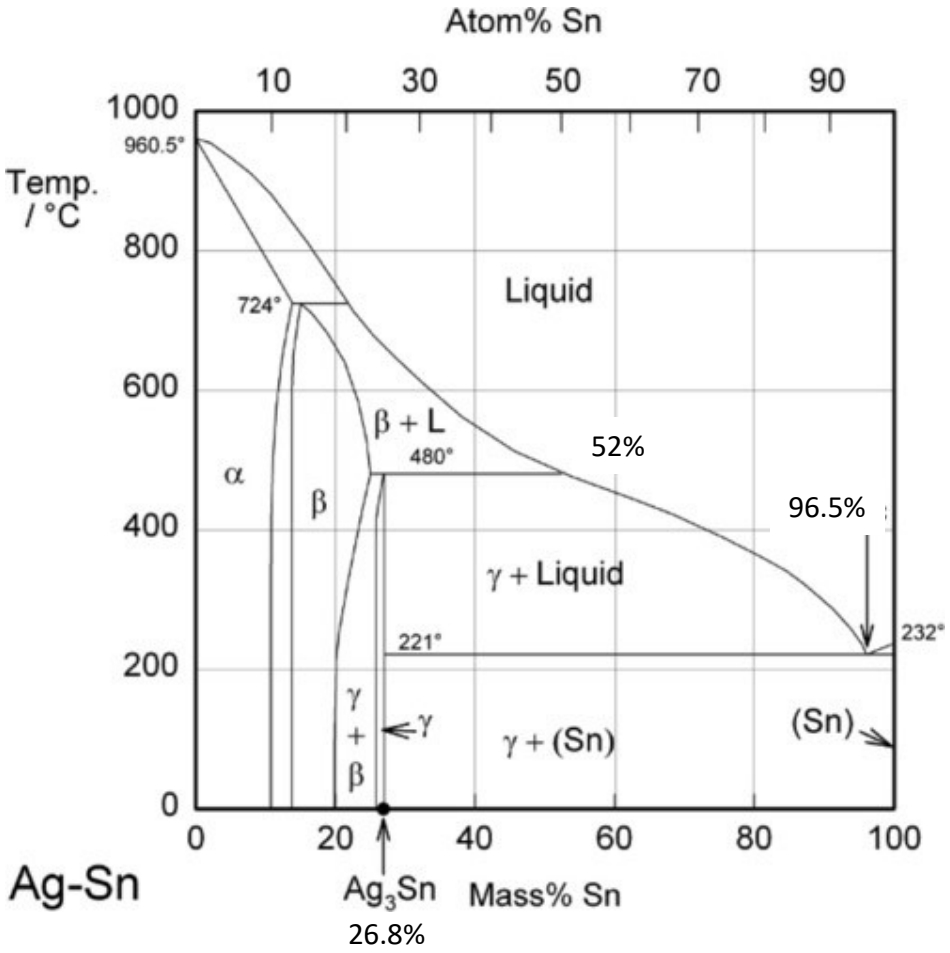
b) $2.66\ g/cm^3$

c) $2.35 \times 10^{14}\ \frac{atoms}{cm^2}$

d) $56.81\ kJ/mol$

4. (2 points) Use the following Ag-Sn phase (wt.%) to answer the questions:

a. (0.5 p) Write the invariant reactions, including: name, temperature, and mass percentage of involved phases.
b. (0.5 p) For the alloy Ag-30% of Sn, indicate the phases present, composition, and percentage of phases at 480-ΔT°C.
c. (0.5 p) Indicate the micro-constituents and their fractions at 221-ΔT°C for the alloy Ag-60% de Sn.
d. (0.5 p) Indicate which intermetallic compounds melt congruently. What is the maximum solubility of Sn in Ag and at what temperature is it observed?



Solution:

a) 724: peritectic: L (22%Sn) + alpha (16%Sn) ⇒ beta (18%Sn)
480ºC: Peritectic: L (52%Sn) + beta (25%Sn) ⇒ Gamma (26.8%Sn)
221ºC: Eutectic: L (96.5%Sn) ⇒ gamma (26.8%Sn) + Sn (100%Sn)

b) Phases present gamma and Liquid:

V_f(L)=(30-26.8)/(52-26.8)*100= 12.7%
V_f(gamma) 1- 12.7= 87.3%

c) Primary gamma and eutectic; C_L = 52%Sn and C_γ = 26.8%Sn.

wt%E = (60-26.8)/(96.5-26.8)*100= 47.6 %
wt% gamma (primary)=100 – 47.6= 52.4%

d) None of them. Max solubility of Sn in Ag is 16at% at 724 ºC

5. (1 point) A titanium bar with 10 mm diameter and 204 mm long has a yield strength of 345 MPa, a modulus of elasticity of 110 GPa, and a Poisson´s ratio of 0.30.

a. (0.5p) Determine whether the bar will plastically deform when 22 KN load is applied.
b. (0.5p) Calculate the length and diameter of the bar when 22 KN load is applied.

Solution:

a) It will not deform plastically

b) L = 204.52 mm; d = 9.9925 mm.

6. (0.5 points) What is the residual resistivity? What does it depend on? How?

7. (1 point) Are the following statements True or False? Justify your answer.

1. The fluorite structure (CaF_2) is FCC, where Ca^{2+} ions are located in the FCC lattice sites and the F^- ions occupy half of the tetrahedral sites	
F	

2. Hardness of ceramic materials with covalent bonds is higher than those with ionic ones.	
T	

3. For fabrication of ceramic layers, slip casting process involves the casting the slurry onto a flat moving carrier surface.	
F	

4. Sintering a ceramic material involves heating the part to an elevated temperature above the melting point in a controlled environment.	
F	

8. (1 point) (a) (0.5 p) If we look at the following series, a strong rise of the glass transition temperatures can be seen. Explain the differences.

PE (-CH_2-CH_2-)	T_g = -120 °C
PP (-CH_2-$CHCH_3$-)	T_g = -15 °C
PVC (-CH_2-CHCl-)	T_g = 90 °C

(b) (0.5 p) Detail the different ways of classification of polymers according to behavior with temperature.

9. (1 point) (a) (0.5 p) Determine the density of 1 m^3 of a composite composed of an epoxy matrix reinforced with 10% in volume of unidirectional carbon fiber. (b) (0.5 p) Calculate the modulus of elasticity of this composite in the perpendicular direction.

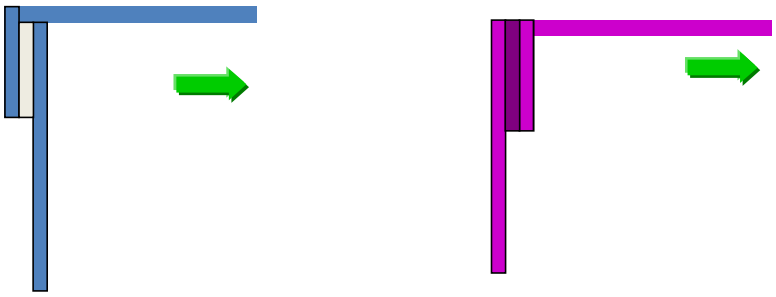
Data: ρ_{fiber} = 1.79 g/cm^3; ρ_{matrix} = 1.20 g/cm^3; E_{fiber} = 350 GPa; E_{matrix} = 3.1 GPa.

Solution:

a) $1.259 \frac{g}{cm^3}$

b) **3.44 GPa**

10. (0.5 points) Which design of the adhesive joint is correct? Why? Which stresses should be maximized and which ones minimized in an adhesive joint?



The left one is correct.