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Exámenes resueltos 2012-2016

2° Materiales Aeroespaciales I

Grado en Ingeniería Aeroespacial

Escuela Politécnica Superior
Universidad Carlos III de Madrid



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Universidad Carlos III de Madrid

EXAM

June 2014

Aerospace Materials I (2nd Year)

Surname: **Name:** **Group:**

Information:

- Read the questions carefully before answering.
- 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. (2 marks) The semiconductor GaAs has a Zinc Blende (ZnS) structure.

a. Describe the structure. What is the coordination index of GaAs?

b. What is the lattice parameter in nanometers for GaAs?

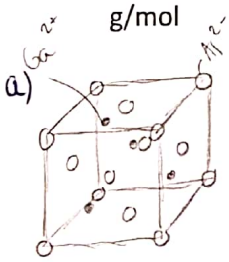
c. Calculate the volumetric density of GaAs expressed in g/ cm^3

d. Determine linear density (ions/mm) in the direction [111] and the planar density (ions/mm^2) in the plane (111)

e. Determine the packing factor

DATA: r_{Ga}=0.126 nm ; r_{As}=0.120 nm ; N_A=6.023x10^{23} at/mol ; M_{Ga}= 69.72 g/mol ; M_{As}= 74.96 g/mol

a)



GaAs

○ As

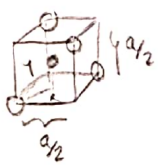
● Ga

Ca^{2+}: 1/2 tetrahedral interstitials

As^{2-}: FCC packing

CI = 4

b)



$x^2 = \frac{a^2}{16} + \frac{a^2}{16}$

$x = \frac{a}{\sqrt{8}}$

$y^2 = x^2 + \frac{a^2}{16} \rightarrow y = \frac{\sqrt{3}}{4}a$

$y = r(Ca^{2+}) + r(As^{2-}) = \frac{\sqrt{3}}{4}a$

$$a = \frac{4 \cdot (0.126 + 0.120)}{\sqrt{3}} = 0.568 \text{ nm}$$

c)

$$\rho = \frac{Z n_i M_i}{N_A V_c} = \frac{74.96 \cdot (\frac{1}{8} \cdot 8 + \frac{1}{2} \cdot 6) + 69.72 \cdot 4}{6.023 \cdot 10^{23} \cdot (0.568 \cdot 10^{-7})^3} = 5.24 \text{ g/cm}^3$$

d)

[111] r_{3a}

$$f_{[111]} = \frac{1 + 2 \cdot 1/2}{\sqrt{3}\, a} = 2.03 \text{ atoms/nm}$$

(111)

$$f_{(111)} = \frac{3 \cdot 1/6 + 3 \cdot 1/2}{\frac{\sqrt{3}}{2} a^2} = 7.16 \text{ atoms/nm}^2$$

$h = \frac{\sqrt{6}}{2}a$

$A = \frac{b \cdot h}{2} = \frac{\sqrt{3}}{2}a^2$

$\sqrt{2a^2 - \frac{2}{4}a^2}$

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e) $PF = \frac{V_{atom}}{V_{cell}} = \frac{4 \cdot \frac{4}{3}\pi \cdot 0.126^3 + 4 \cdot \frac{4}{3}\pi \cdot 0.120^3}{0.568^3} = 0.34$

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2. **(2 marks)** For a continuous and oriented fiber-reinforced composite, the moduli of elasticity of the fibers and matrix are 390 GPa and 3 GPa, respectively. If the volume fraction of fibers is 0.25, determine:
   a) The modulus of elasticity in the longitudinal and transverse directions.
   b) The weight percentage of the fibers and the matrix in the composite.
   c) The average density of the composite.

   A load of 25000 N is applied onto a cylindrical rod of 20 mm in diameter of this composite. Calculate:
   d) The fraction of the load carried by the fibers and matrix phases respectively.
   e) The stress acting on the fibers and matrix, respectively.

   DATA: ρ_m=1.29 g/cm^3, ρ_f=1.79 g/cm^3

a) $E_{c,long} = V_f E_f + V_m E_m = 0.25 \cdot 390 + 0.75 \cdot 3 = 99.75$ GPa

$\frac{1}{E_{c,trans}} = \frac{V_f}{E_f} + \frac{V_m}{E_m} = \frac{0.25}{390} + \frac{0.75}{3} = 0.25 \rightarrow E_{c,trans} = 4$ GPa

b) $W_f = \frac{m_f}{m_c} = \frac{\rho_f V_f}{\rho_f V_f + V_m \rho_m} = \frac{1.79 \cdot 0.25}{1.79 \cdot 0.25 + 1.29 \cdot 0.75} = 0.3$

$W_m = 0.7$

c) $\rho_c = \rho_f V_f + \rho_m V_f = 1.79 \cdot 0.25 + 1.29 \cdot 0.75 = 1.415$ g/cm^3

d) $\frac{F_f}{F_c} = \frac{E_f V_f}{E_c V_c} = \frac{390 \cdot 0.25}{99.75} = \frac{130}{133}$; $\frac{F_m}{F_c} = \frac{E_m V_m}{E_c V_c} = \frac{3 \cdot 0.75}{99.75} = \frac{3}{133}$

$F_f = \frac{130}{133} \cdot 25000N = 24436N$; $F_m = \frac{3}{133} \cdot 25000N = 564N$

e) $\sigma_c = \frac{F_c}{A} = \frac{25000}{\frac{\pi}{4}(20 \cdot 10^{-3})^2} = 8 \cdot 10^7$ Pa $= 80$ MPa

$\frac{\sigma_f}{\sigma_c} = \frac{F_f/A}{F_c/A}$

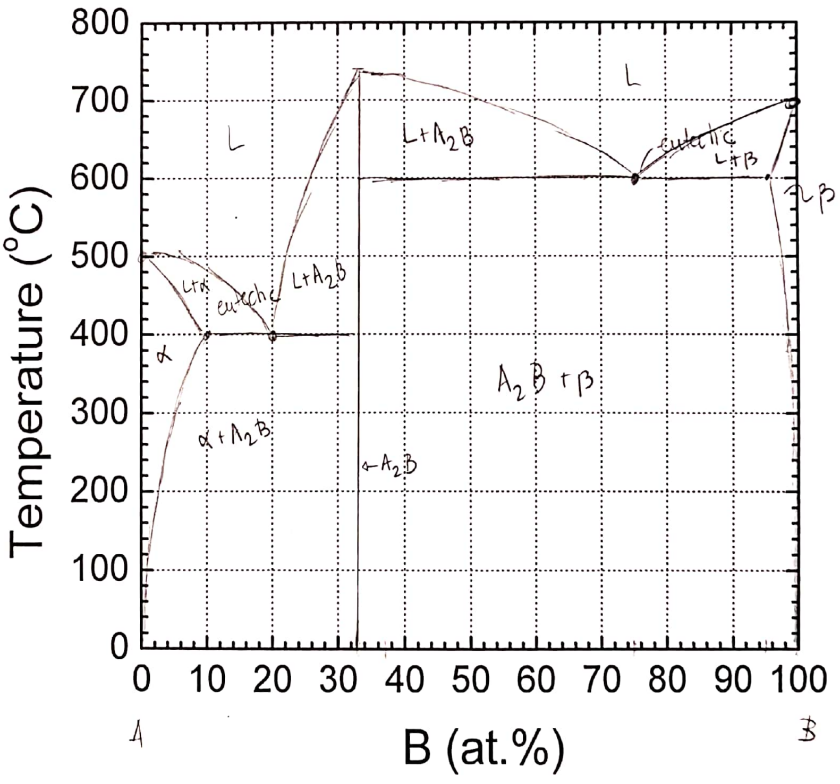
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El **mejor proyector**
relación calidad/precio
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3. (1 mark) Please construct a phase diagram having the following characteristics.
(a) The two components are "A" and "B"
(b) The melting point of A is 500°C, and the melting point of B is 700°C.
(c) The diagram contains only one compound, which is a line compound (exact stoichiometry formula) having the stoichiometry A_2B and a congruent melting point of 750°C.
(d) One eutectic point appears at the component composition 80 at% A and 400°C.
(e) Another eutectic point appears at the component composition 75 at% B and 600°C.
(f) The maximum solubility of B in A occurs at the eutectic temperature and it is 10 at.% (α-phase)
(g) The maximum solubility of A in B occurs at the eutectic temperature and it is 5 at.% (β-phase).
(h) The solubility of A in B and B in A are zero at RT.
Label all the regions on the diagram.



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4. **(1 mark)** Order the following materials in terms of (a) hardness and (b) elastic modulus: Aluminium; Aluminium oxide; Epoxy Resin; Low Density Polyethylene. Justify your answer.

hardness: Aluminium Oxide > Aluminium > Epoxy Resin > Low Density Polyethylene
(ionic) (metal) ↓ ↓
elastic modulus thermoset ↓ρ → ↓ crystallinity →
↓ crosslinking → ↑ hardness → ↓ strength (hardness)

5. **(1 mark)** a) Match the following glass transition temperatures (Tg) to the correct polymer. Explain how can the Tg temperature be increased in each case. Justify your answer.
   Tg: -110 ºC ; 80 ºC ; 140 ºC
   Polymers: Polyethelene (PE) ; Polyvinyl chloride (PVC); epoxy resin
   b) When a bag of semicrystalline plastic deforms (i.e. polyethylene), it will offer greater resistance to deformation. Explain briefly why this behavior occurs.

a) PE $+CH_2 - CH_2+_n$

PE, PVC : thermoplastic → ↑M → ↑Tg → PVC > PE
epoxy: thermoset → ↑cross linking ↑Tg 1° → 140C

Epoxy → 140C
PVC: 80°C PE: -110°C

b) Due to strain hardening (see slides)

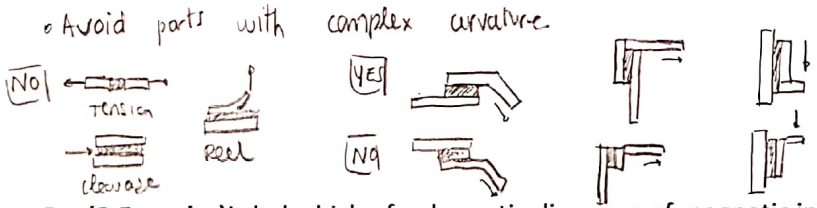
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6. **(1 mark)**

A. **(0.5 marks)**Describe briefly the steps in the production of an adhesive joint. What are the most important considerations in a design of an adhesive joint? Include sketches, where appropriate.

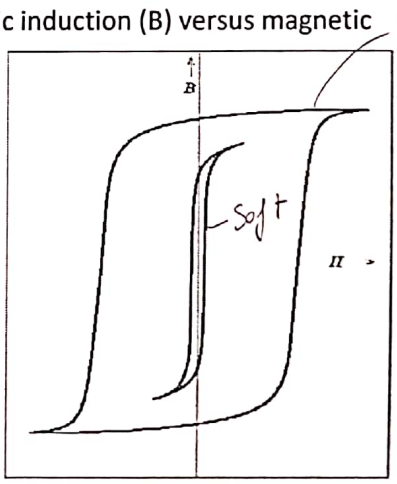
1) Adhesive selection
2) Design of the adhesive joint
3) Adherent preparation /cleaning
4) Adhesive preparation
5) Adhesive application
6) Assembling / joining / system integration
7) Formation of adhesive joint
8) Curing
9) Assesment of joint resistance

- Studying the stress distribution. Adapt design of joint to the advantages of the adhesive
  - Adhesives should ideally be loaded in shear or compressed peel
  - The design should minimize tensile peel and tensile loading
- Large bonding surfaces between the members to be joined are desirable
- Subassemblies designed to minimize adhesive operations
- Avoid parts with complex curvature.



B. **(0.5 marks)**Label which of schematic diagrams of magnetic induction (B) versus magnetic strength (H) is representative of:

a. Hard ferromagnetic material
b. Soft ferromagnetic material



What is an application that requires a soft magnetic material? What is an application that requires a hard magnetic material. Explain briefly how grain size of a material affects the hysteresis cycle of a magnet.

Soft magnetic materials are required for electrical applications (circuits, electric motors, transformers...)

Hard magnetic materials are required for permanent magnets

↑Size of grain → ↑ Mobility of Bloch walls

↑ μ, ↓ H_c, ↓ B_r

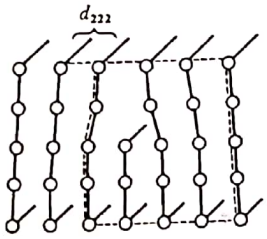
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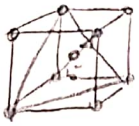
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7. **(1 point)** Suppose we have a BCC structure with a lattice parameter of 4.0 Å, containing the dislocation shown in figure. Determine the direction (Miller indices) and the length of the Burgers vector.



$(222) \equiv (111)$

BCC 

$\vec{b}$ direction = [111] (cube diagonal, $\perp$ (111))

$|\vec{b}| = \frac{\sqrt{3}a}{2} = \frac{\sqrt{3}\cdot 4}{2} = 2\sqrt{3}$ Å

8. **(1 point)**
   a. Name three of the strengthening mechanisms (for metals) discussed in this course.
   b. In general, what is the key objective at the microscopic level for all of these strengthening mechanisms?
   c. For one of the mechanisms listed in part (a), explain how it works. Include sketches, where appropriate

a) Strain hardening — Grain Size Reduction
Solid solution strengthening — Precipitation hardening

b) To increase the restriction towards the movement of dislocations

c) Solid solution strengthening: adding atoms of one element to the crystalline lattice of another element, forming a solid solution

Interstitial

- A vacancy occupied by a solute of smaller radius: atoms solvent submitted to tension
- A vacancy occupied by a solute of greater radius: atoms solvent submitted to compression

→ Lattice distortion → The movement of dislocations becomes difficult → Hardening



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