Materials science and engineering

Academic Year: (2019 / 2020) **Review date: 15-05-2020**

Department assigned to the subject: Materials Science and Engineering and Chemical Engineering Department

Coordinating teacher: BASELGA LLIDO, JUAN

Type: Compulsory ECTS Credits : 6.0

Year : 2 Semester : 2

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Chemistry

OBJECTIVES

To understand the main principles of materials science and engineering: relationship between structure, chemical bonding, properties, processing and applications.
To know the general properties of the main groups of materials: ceramics, metal, polymers and composites
During the course students will work on the following capabilities:
- Capability to solve complex problems
- Capability to find, understand and discriminate the relevant information to make a proper decission
- Capability to apply multidisciplinary knowledge to solve a given problem
- Capability for team work: to accept tasks and to distribute tasks among classmates to face complex problems

A collaborative attitude will be developed along the course to obtain from other agents skills and knowledge necessary for specific objectives.

DESCRIPTION OF CONTENTS: PROGRAMME

1. Families of materials, applications and selection criteria. History of materials. Materials science and engineering. Classification of materials. General properties of materials: metals, ceramics, polymers, composites. Structure, properties and processing: examples. Selection of materials: practical examples. Ashby plots. Evolution and competition between materials.
2. Bonding. Ionic bonding: ionic radii, interionic force and energy for an ionic pair, lattice energy: NaCl. Born-Haber cycle. Properties that depend on lattice energy: melting, hardness, thermal expansion. Covalent bond, a review: polar molecules, polarization capacity and polarizability. Metallic bond: introduction to band theory, s and p atomic orbital overlap, valence and conduction band. Intermolecular forces: an overview. Bonding and properties of materials.
3. Structure of materials. Long and short range order. Unit cell, spatial lattice. Crystalline systems. Bravais lattices. Main metallic structures BCC, FCC, HCP: coordination, atomic packing factor, tetrahedral and octahedral sites. Solubility of C in Fe. Structures in ionic ceramics: packing of ions, CsCl, NaCl, Zn blende, CaF2, corundum. Polymorphism and allotropy: carbon, iron, zirconia. Amorphous materials: ceramic glasses- the glass transition- polymers. Crystalline structure of polymers. Atomic positions, directions and planes in cubic cells: Miller indices. Planes in hexagonal cells. Distance between planes. Linear, planar and volumetric density
4. Crystalline defects and solid solutions. Imperfections in real crystals: thermodynamic justification. Classification of defects. Point defects: vacancy, interstitial, Schotky and Frenkel defects in ionic structures. Order-disorder in solid solutions. Dislocations: types, Burger¿s vector. Dislocation movement. Slip planes and slip systems. Plastic deformation: slipping of dislocations. Planar defects: grain boundaries, Hall-Petch relation, grain size number, stacking faults, twin boundaries. Solid solutions: types, Hume-Rothery rules.
5. Diffusion. Mechanism of diffusion: self-diffusion, vacancy diffusion, activation energy, interstitial diffusion. Steady state diffusion: Fick¿s law, examples. Non-steady state diffusion: Fick¿s second law. Cementation. Factors that influence diffusivity. Transport of gases and vapours through polymer films. Mechanisms: filtration, permeation. Permeability and permselectivity.
6. Equilibrium phase diagrams. Basic concepts: component, phase, microcomponent. Gibbs phase rule. Binary isomorphous phase diagrams: tie line and lever rule. Non equilibrium solidification: microsegregation. Binary eutectic systems: eutectic reaction and microstructure. Hypo and hyper eutectic compositions and microstructure. Other invariant reactions: monotectic, peritectic, eutectoid,

peritectoid. Intermetallics. Incongruent melting. The Fe-C system: invariant reactions. Eutectoid steels: pearlite, growth and transformations. Hypo and hyper eutectoid steels. Effect of alloying elements in the Fe-C phase diagram. Ceramic phase diagrams: Alumina-chromia, alumina-silica.

7. Mechanical properties. Test types: uniaxial tensile test. Stress-strain curve: elastic zone- Hooke¿s law- Young¿s modulus. Elastic deformation at atomic scale. Poisson coefficient. Plastic zone: dislocations movement. Plastic deformation in monocrystals: resolved shear stress. Stress-strain curve parameters: yield strength, security factor, tensile strength, fracture strength, ductility, toughness, resilience. True stress-strain curves. Strengthening mechanisms: Strain Hardening, Solid Solution, Precipitation, Grain Size Reduction. Dislocation interactions. Hall-Petch equation.

8. Heat treatments. Solidification: nucleation free energy, critical embryo size, homogeneous and heterogeneous nucleation, undercooling. Nucleation rate. Growth. Solidification rate. Transformation rate: isothermal and continuous cooling transformations. ITT diagrams for steel: eutectoid, hypo and hypoereutectoid. Coarse and fine pearlite. Non-equilibrium diffusional transformation: upper and lower bainite. Non-equilibrium diffusionless transformation: marteniste. Structure and properties of martensite. Factors of influence on martensitic transformation. CTT diagrams for steel: annealing, normalizing, quenching, tempering. Hardenability and hardening depth: Jominy test, critical quenching rate, severity of quenching medium, critical diameter. Influence of tempering on mechanical properties. Martempering. Austempering. Annealing. Influence of annealing on mechanical properties

9. Metals. Classification. Codes for plain carbon and low alloy steels. Low, medium and high carbon steels: properties, weldability. Microalloy steels. Stainless steels: types and properties. Titanium alloys: types, phase diagram, influence of alloying elements, phase transformations. Surface treatments of Ti alloys. Fabrication of metallic products: sand casting, continuous casting, forming processes.

10. Ceramics. Classification and general properties. Structure: a review on ionic bond, ionic packing and common ionic structures, perovskites. Covalent ceramics. Silicates: structure-islands, rings, sheets and 3D. Properties of ceramics: hardness, modulus of elasticity, fracture resistance, thermal shock. Processing of ceramics: green, slip and tape casting, uniaxial pressing, isostatic pressing, extrusion and injection molding. Glass: glass transition, constituents of glasses, models for amorphous oxide glasses. Properties of glasses: mechanical, thermal and electrical. Glass processing. Applications of ceramics in the refractory and aerospace industry.

11. Polymers. History of polymers. Basic definitions, general properties and examples. Classification. Synthesis: addition, condensation, examples. Polymer configuration: random coil concept, simple models for linear polymer chains, excluded volume concept, characteristic ratio. Tacticity. Molecular weight: number and weight averages. Crystallinity: crystalline structure in solution and in the melt. Factors that affect crystallinity: undercooling, chain flexibility, other factors. Glass rubber transition: factors that influence the Tg. Mechanical behavior of polymers: crystallinity, molecular weight, crosslinking. Stress-strain curve in polymers: necking, cold work, orientation. Deformation mechanism in crystalline polymer. Types of polymers: thermoplastic, thermosets, elastomers, comparative study of their properties. Examples: vinylic, engineering polymers, epoxy and polyester. Elastomers: vulcanization, stress-strain behavior, examples. Implant polymers: polyamides, polyethylene, polypropylene, polyacrylates and hydrogels, fluorocarbon polymers, silicones. Polymer processing: extrusion, injection, blow molding, rotational molding, thermoforming.

12. Composite materials. Definition and types. Composites in nature. Classification. Types of constituents. Fiber reinforced composites: roles of matrix and reinforcement. Types of fibers: glass, carbon, polyamides. Mechanical behavior of fibers. Structural composites: sandwich, laminates. Elastic behavior: isostress and isostrain conditions. Strength. The role of the interphase. Examples

LEARNING ACTIVITIES AND METHODOLOGY

Lectures, collective tutorials, individual tutorials, homework and writting of a term paper; oriented to attainment of theoretical knowledge.
Problem solving lectures in small groups, laboratory practicals, individual tutorials and home work; oriented to attainment of practical knowledge and skills related with the syllabus

ASSESSMENT SYSTEM

Cont. Ass.: 40% global mark
25% exercises
25% term paper presentation
50% laboratory
Attendance to Jornada de Materiales will be considered
Final exam: 60% global mark. It is necessary to obtain 4 as a minimum grade in the final exam to average with continuous assesment

% end-of-term-examination:	60
% of continuous assessment (assigments, laboratory, practicals…):	40

BASIC BIBLIOGRAPHY

- DR Askeland The Science and Engineering of Materials, PWS Pub. Co, 1984
- JF Shackelford Introduction to Materials Science for Engineers, Pearson International Edition, 2009
- MF Ashby, DR Jones Engineering Materials, Elsevier, 2010
- WF Smith and J Hashemi Foundations of Materials Science and Engineering, Ed, McGraw-Hill, 2010