240033 - Materials

Coordinating unit: 240 - ETSEIB - Barcelona School of Industrial Engineering
Teaching unit: 702 - CMEM - Department of Materials Science and Metallurgy
Academic year: 2018
Degree: BACHELOR'S DEGREE IN CHEMICAL ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGY ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
ECTS credits: 4,5

Teaching languages: Catalan, Spanish

Teaching staff
Coordinator: Santana Perez, Orlando
Others: Alcala Cabrelles, Jorge
Fernandez Aguado, Enrique
Maspoch Ruldua, Maria Lluïsa
Calero Martinez, José Antonio
Santana Perez, Orlando

Degree competences to which the subject contributes

Specific:
1. Knowledge of science, technology and materials' chemistry fundamentals. Understanding the relation between microstructure, synthesis or processing and materials' properties.

Teaching methodology

During the course, theory and exercise lectures and laboratory practices are given, as well as independent learning, relating the acquired knowledge in the practices with the theoretical. Two exams and a final presentation.

Attendance hours:
Theory + problems: 33 h (3h/week = 2 sessions of 1.5h)
Lab: 12h. (4 sessions of 3 hours, 1 session per week). Groups of 15 at most.

Learning objectives of the subject

By the end of the course students should be able to:
- Distinguishing and relating materials' structure and their mechanical and physical properties.
- Acquiring knowledge with respect to criteria to select the type of material depending on their more relevant properties with an industrial application.
## Study load

<table>
<thead>
<tr>
<th>Total learning time: 112h 30m</th>
<th>Hours large group:</th>
<th>36h</th>
<th>32.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours medium group:</td>
<td>0h</td>
<td></td>
<td>0.00%</td>
</tr>
<tr>
<td>Hours small group:</td>
<td>9h</td>
<td></td>
<td>8.00%</td>
</tr>
<tr>
<td>Guided activities:</td>
<td>0h</td>
<td></td>
<td>0.00%</td>
</tr>
<tr>
<td>Self study:</td>
<td>67h 30m</td>
<td></td>
<td>60.00%</td>
</tr>
</tbody>
</table>
## Content

### Topic 1: INTRODUCTION

**Learning time:** 3h 30m  
Theory classes: 1h 30m  
Self study : 2h

**Description:**  
- Subject's presentation and delivery of information sheet referent to evaluation and expected calendar.  
- Materials' families and main properties.  
- Relating type of family with the type of binding they present.  
- Crystalline material (metals and ceramics) and amorphous materials (glass and polymers *).  
- Relating the type of material family and density in terms of elements that conform them and the type of dominant binding.

### Topic 2: STRUCTURE OF METALS AND CERAMICS

**Learning time:** 4h 30m  
Theory classes: 1h 30m  
Self study : 3h

**Description:**  
- "Theoretical" density vs. "experimental" density in metals and ceramics (crystalline materials).  
- Solidification process stages in metals and crystalline ceramics.  
- Defects in the crystalline net: Punctual (vacancies, interstitials, impurities substitution and interstitials), linear (Dislocations) and surface (volume) (grain borders, twinning limits, porous, etc).  
- Transition temperatures of materials states: Crystallisation temperature (Tc), Fusion temperature (TF) and Glass Transition temperature (Tg)  
- Stage transformation in solid state: Allotropy.

### Topic 3: POLYMER STRUCTURES

**Learning time:** 13h  
Theory classes: 3h  
Laboratory classes: 3h  
Self study : 7h

**Description:**  
- What is a polymer? How are they obtained? Polymerisation types: in chain (Addition), by stages (Condensation). What is a copolymer?  
- How long is a chain? Molecular masses in polymers.  
- Identifying types of molecular architecture: linear, ramified and reticulated. Relating with the properties they present.  
- Classifying types of polymers depending on molecular architecture relation and thermal behaviour: Thermoplastics, Thermostables and Elastomers.  
- Crystalline structures in polymers.  
- Identifying aggregate state diagrams (viscous liquid, rubbery, flexible solid and glassy) depending on temperature and molecular mass for the different types of polymers (Thermoplastics, Thermostables and Elastomers).
# 240033 - Materials

## Topic 4: FUSION PROCESS IN MATERIALS

| Description: |
| - Why does diffusion appear?  
- Types of diffusion: vacancy, interstitial.  
- Factors which affect diffusion: Type of crystalline net and temperature.  
- Diffusion in metals, ceramics and polymers. |
| Learning time: 4h 30m |
| Theory classes: 1h 30m |
| Self study: 3h |

## Topic 5: CONSTITUTION OF ALLOYS

| Description: |
| - Alloy definitions. Types of alloys (homogeneous and heterogeneous)  
- Differences between: pure material, solid solutions (substitutional and interstitial) and composites. Heat curves they present.  
- Solubility criteria in solids: Hume's and Rothery's rules. |
| Learning time: 3h 30m |
| Theory classes: 1h 30m |
| Self study: 2h |

## Topic 6: DIAGRAMS EQUILIBRIUM PHASE

| Description: |
| - How are they built? Balance cooling (very slow)  
- How are BINARY phase diagrams analysed?: o Identifying existing phases depending on temperature.  
   o Chemical composition of phases depending on temperature (Rule I): How much of element A and of element B is there in each phase?  
   o Proportion of existing phase under a certain temperature (Rule II, reverse lever): What amount of alloy forms the phase?  
- Consequences of an unbalanced cooling (chemical segregation, crystalline gradients).  
- Phase diagrams among elements with limited solubility and with intermetallic compounds. Transformations.  
- What is an invariant reaction? Types of invariant reactions: EUTECTIC, PERITECTIC, EUTECTOID, PERITECTOID.  
- Solidification analysis of several types of alloys in a phase diagram with invariant reactions: cooling/heating curves, microstructural evolution and quantitative analysis (chemical composition and phases proportion).  
- Phases diagrams Fe-C: Steals, casts. Martensitic transformation. |
| Learning time: 20h 30m |
| Theory classes: 4h 30m |
| Practical classes: 1h 30m |
| Laboratory classes: 3h |
| Self study: 11h 30m |
Topic 8: MECHANICAL PROPERTIES OF MATERIALS

Description:
- What is tension and deformation?
- What characteristic has a tensile test? What differences are there between an "engineering" and a "true" Tension-Deformation curve?
- Which are the parameters used to quantify the mechanical properties of several deformation regimes?
  o Elastic regime:
    - What characterises it?
    - What is Young's modulus and what is the physical sense? Which is the tendency depending on the material family?
    - What is Poisson's coefficient and what is the physical sense?
  o Plastic regime:
    - What characterises it?
    - What is the Elastic limit and what physical sense does it have?
    - What is tensile strength?
    - What is ductility and sharpness? What is a "Fragile" fracture and a "Ductile" fracture? Which is the tendency depending on the material family?
    - What is tensile toughness?
- What are Hardness tests? Which is the tendency depending on the material family?, hat advantages does it have with respect to Tensile strength tests?
- Plastic deformation and hardening mechanisms in crystalline materials. Thermal treatment to restore and anneal. Plastic conformation design in metals (Cold work).
- Tension curves vs. engineering deformation and deformation mechanisms for polymeric materials. Molecular parameters which influence behaviour.
- Thermofluency and slow fluency in materials.
## Topic 9: ELECTRIC, MAGNETIC AND THERMAL PROPERTIES CONTROL IN MATERIALS

<table>
<thead>
<tr>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetic behaviour of materials:</td>
</tr>
<tr>
<td>- What parameter are used to quantify the magnetic behaviour of materials?: Magnetic susceptibility, magnetic permeability, Magnetization.</td>
</tr>
<tr>
<td>- Which are the characteristics of the different types of magnetism?: Diamagnetism, Paramagnetism, Ferromagnetism, Ferrimagnetism and Antiferromagnetism.</td>
</tr>
<tr>
<td>- Temperature effect in the magnetic behaviour: Curie's temperature.</td>
</tr>
<tr>
<td>- HYSTERESIS curves in ferromagnetic and ferromagnetic materials. Parameter which quantify it: Remanence, Coercitivity.</td>
</tr>
</tbody>
</table>

| Electric conductivity of materials: |
| - Which are the types of conduction? What does the energy band theory establish? How does this theory explain conduction?: Conductor, semiconductor and insulating materials. |
| - Which are the factors that affect conductivity in a conductor? |
| - What is an intrinsic semiconductor and an extrinsic semiconductor (Type P and Type N)? |
| - Which is temperature's effect and impurities concentration effect in a semiconductor? |

| Optical behaviour of materials: |
| - What are photons? |
| - How does light interact with bodies? How is this interaction quantified? |
| - Transmittance, absorbance and Reflectance. |
| - What is refraction? What is internal reflexion? How is this raised in terms of the band theory? How does a "detector" of optical temperature act? |
| - What is colour? What is selective and non-selective absorption? |
| - What characterises the optical behaviour of the different material families? |

| Optical behaviour of materials: |
| - What are phonons? |
| - How does a phonon interact with a material? How is this interaction quantified? |
| - Calorific capacity |
| - Thermal conductivity: What does Wiedemann Franz's law states? In what materials is this applied? |
| - Thermal dilatation coefficient |
| - What is the tendency of this parameters for the different material families? |
## Topic 10: COMPOSITES

### Description:
- What is a composite material?
- Constituents:
  - Matrix and Disperse phase: dispersion, distribution and orientation
  - What does the Mixtures Law establish?
  - Disperse phase: General considerations
  - How does it mechanically work?
  - What is "slenderness" (Aspect Ratio) and how does it influence in the mechanical performance?
  - How are Composite Materials classified?
- Composite materials with a polymeric base. Why are we centred in them?
- Widely used disperse phases to reinforce:
  - Fibres: glass, Carbon, Aramide: Characteristics, advantages and disadvantages among them.
  - Laminar particles: Micro and Nano scale.
  - Low "slenderness" particles
  - Mechanical aspects to reinforce fibres
  - Length, fibre-matrix adhesion, orientation effect
  - Prediction of mechanical behaviour in fibre composites (effect of the fibre content): Elastic range:
    - Isotension model.
    - Isodeformation model.
  - What effect has the fibre's length and its disposition (orientation) in the prediction made by the models?
- What criteria are established to select the constituents of a composite material? Practical problems.

## Topic 7: MAIN CONFORMING METHODS

### Description:
- Defining main processing methods of the several material families, enumerating main advantages and disadvantages, as well as defects that appear in the product.
  - "Amorphous" ceramics (glass): Continuous stretching.
  - "Crystalline" ceramics
  - "Dry": Sintering.
  - "Humid": Hydroplastic conformation (Extrusion): Moulding with Barbotine. Importance of drying and cooking.
  - Metals:
  - Polymers
  - Continuous: Extrusion and techniques based in this.
  - Dynamic-Discontinuous: Injection moulding.
  - "In a pseudo-solid state": Thermo-conforming.
### Topic 11: CRITICAL SELECTION ANALYSIS OF A MATERIAL IN A FUNCTIONAL DESIGN

<table>
<thead>
<tr>
<th>Learning time: 0h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory classes: 0h</td>
</tr>
<tr>
<td>Self study: 0h</td>
</tr>
</tbody>
</table>

#### Description:

The compulsory activity will consist in preparing a presentation of maximum 15 minutes in small groups, with a previous selection of a work-part compound for each group. It will be necessary to explain (spokenly present) and discuss (in a roundtable with the other integrants of the session) why has the material been chosen, manufacturing method, possible substitution alternative in a justified way.

Work groups will consist of 3 students each, with a total of 5 groups per session.

Work groups are recommended to visit a company of the sector to obtain more updated information about its production. Technical quality and effective spoken communication will be valued.
### Planning of activities

<table>
<thead>
<tr>
<th>LABORATORY PRACTICES</th>
<th>Hours: 9h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Laboratory classes: 9h</td>
</tr>
</tbody>
</table>

**Description:**
The following compulsory practices will take place:
1. Characterisation of plastic materials (related with topics: 1, 3 and 10)
2. Metalographic analysis (related with Topic 6)
3. Evaluation of the thermal shock phenomena in ceramics (related with topics: 8 and 9)

**Descriptions of the assignments due and their relation to the assessment:**
Each one of them will have 3 hour duration. In work groups previously made at the beginning of the course and taking into account the indications of the teacher (maximum of 10 teams per group of big theory) a joint report (according to a template previously supplied) will be delivered in the last will be prepared week of the course. Effective written communication and analytical skills of the observations will be evaluated.

<table>
<thead>
<tr>
<th>PARTIAL EXAM</th>
<th>Hours: 9h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 1h 30m</td>
<td></td>
</tr>
</tbody>
</table>

**Description:**
Assessment of knowledge.

**Descriptions of the assignments due and their relation to the assessment:**
Solved exam.

<table>
<thead>
<tr>
<th>FINAL EXAM</th>
<th>Hours: 1h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 1h 30m</td>
<td></td>
</tr>
</tbody>
</table>

**Description:**
Assessment of knowledge.

**Descriptions of the assignments due and their relation to the assessment:**
Solved exam.

<table>
<thead>
<tr>
<th>Practical activities exam</th>
<th>Hours: 0h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 0h 30m</td>
<td></td>
</tr>
</tbody>
</table>

**Description:**
Practice activities exam dealing with procedure and main results.
1. A compulsory partial exam (PP) at mid semester with a duration of 1 hour.
2. A compulsory final exam (EF) by the end of the semester, with a duration of 1.5h.
3. A compulsory final report of practical work will be accomplished (NICP)

All the evaluations are in a scale of 10.
The final mark (NF) will be calculated from the following expression:
NF = 0.45* NEF + 0.40* NPP + 0.15* NAP
NAP = Mark of the practical evaluation according to the following equation:
NAP = 0.5NICP + 0.5NEAP

A recovery exam (re-evaluation) will be made for students where NF < 5 at July. In this case, the value of this exam will substitute for NF in the above calculation.

REPEATER STUDENTS:
For the students repeater, having performed and evaluated practical sessions in previous quarter, they are given as an alternative option for the calculation of the final grade for the course:
NF = 0.50 + 0.50 NEF NPP

If the student does not want this alternative, its system for evaluating student will be enrolling for the first time, with all that implies.

Regulations for carrying out activities

Laboratory Sessions: Assistance to sessions corresponding to Activities 1 and 3 (practices and roundtable) in the established date is compulsory.
Project + spoken exposition + Roundtable: Execution (in groups of 3 and 4 students) and assistance the sessions established for this activity is compulsory. The project's topic will be proposed by the work-group in the 3 first weeks of the semester.
Partial test: Compulsory. Duration 1 h. Aspects related to Topics 1 and 7 will be evaluated. Notes are not allowed to be used. Restricted use of calculators "programmable" or included in mobile phone devices.
Final-exam: Compulsory. Duration 1.5 h. All topics seen in class will be evaluated. Notes are not allowed to be used. Restricted use of calculators "programmable" or included in mobile phone devices.
Not attending to any of the compulsory activities will automatically invalidate the evaluation row to which it affects (see next section).
Bibliography

Basic:


Complementary:


Others resources:

Slides used by each group¿s professor (Campus Digital).
Selected videos of the documentary series: How its made.
http://science.discovery.com/tv/how-its-made/