MSE-101(b)

# Materials: from chemistry to properties

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| Cursus | Sem. | Type |
|---|---|---|
| Electrical and Electronical Engineering | BA2 | Obl. |
| Microtechnics | BA2 | Obl. |

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| Language of teaching | English |
| Coefficient | 5 |
| Session | Summer |
| Semester | Spring |
| Exam | Written |
| Workload | 150h |
| Weeks | 14 |
| **Hours** | **5 weekly** |
| Lecture | 3 weekly |
| Exercises | 2 weekly |
| **Number of positions** | |

## Summary

This class will teach the fundamental concepts regarding materials and their micro-structure, as well as the equilibrium and dynamics of chemical reactions. A link will be made between these concepts and the mechanical, thermal, electrical, magnetic and optical properties of materials.

## Content

The main topics covered in this course are:
-History and overview of the different expected functions of materials: The different classes of materials (metals, ceramics, glasses, polymers and elastomers) are quickly described in their historical and functional contexts.
-Atomistic aspects, chemical bonds, periodic table of elements, stoechiometry of basic chemical reactions.
- Structure of materials: from chemical bonds, we see how matter is organized at different structural levels: microstructure, grains, and defects.
-Mechanical properties: Whatever the application, materials must have certain mechanical properties. After introducing the concepts of elastic and plastic deformation, properties of materials such as resistance, ductility, toughness, hardness and fatigue are described.
-Principles of thermodynamics: internal energy, enthalpy, entropy and free enthalpy are introduced on the basis on the laws of thermodynamics; intensive and extensive quantities. Derivation of equilibrium condition for chemical reactions.
-Phase diagrams: The notion of thermodynamic equilibrium, and the understanding of what a phase diagram is for unary and binary components, will be discussed with their application to materials.
-Thermal properties of materials: The expansion of materials as well as their thermal properties such as thermal conductivity, specific heat and latent heat of transformation are presented.
-Chemical reactions: acid / base reactions, pH calculation, electrochemistry: redox reactions, batteries and electrolysis.
-Chemical kinetics: reaction rate, rate law, Arrhenius law.
-Electrical properties: classification of the electrical properties of materials through energy bands and the energy gap. Discussion of the properties of conductors (metals) using a simplified Drude model. Discussion of dielectrics, origin of polarization, relative dielectric constant and capacitance. Examples of the use of the electrical properties of materials.
-Magnetic properties: notions of magnetic moment, relative magnetic susceptibility, and magnetization. Classification of the magnetic properties of materials: diamagnetism, paramagnetism and ferromagnetism. Soft and hard magnets, cycles of hysteresis. Example of the use of the magnetic properties of materials.
-Optical properties: link between energy and wavelength of a photon. Optical properties of metals, ceramics and polymers in terms of reflection, transmission and absorption. Refractive indices and Beer-Lambert law.

## Keywords

Materials: Microstructures, Properties, Applications, Transformations
Chemistry: electronic structure of atoms, chemical bonds, thermodynamics, equilibria, acids and bases, redox, chemical kinetics.
Example of the use of material properties (mechanical, thermal, electrical, magnetic and optical).

## Learning Prerequisites

### Required courses

Physics, chemistry and mathematics courses of High School or equivalent.

### Recommended courses

Physics and mathematics course of the first semester of the year propaedeutic at EPFL.

### Important concepts to start the course

Elementary laws (high school level) of chemistry and physics, mechanics, electricity, optics. Mathematical concepts of high school or equivalent.

## Learning Outcomes

By the end of the course, the student must be able to:

- Explain the structure and basic properties of atoms and chemical bonds
- Apply the principles of thermodynamics to solving equilibrium problems
- Carry out calculation of physical and chemical parameters like pH
- Establish the laws of chemical and physical processes
- Formulate a problem related to materials in terms of simple equations
- Choose or select a type of material according to its specifications
- Analyze the properties of materials according to their structure and composition
- Carry out calculations of some basic properties of mechanical, thermal, optical, electrical or magnetic materials, respecting orders of magnitude and units

## Transversal skills

- Assess one's own level of skill acquisition, and plan their on-going learning goals.
- Take responsibility for environmental impacts of her/ his actions and decisions.
- Evaluate one's own performance in the team, receive and respond appropriately to feedback.
- Take account of the social and human dimensions of the engineering profession.

## Teaching methods

Ex cathedra, exercise sessions, experimental demonstrations during course

## Expected student activities

To successfully complete the course, it is necessary to: (1) read the pages indicated in the book before the course or watch the recommended videos; (2) attend class and take additional notes; (3) DO THE EXERCISES and check the solutions obtained with the answer key distributed the following week. Read the notes associated with the various developments in progress.

## Assessment methods

written exam

## Supervision

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| Office hours | No |
| Assistants | Yes |
| Forum | Yes |
| Others | presence of the teacher during exercise sessions for answers to questions. |

## Resources

### Bibliography

Materials : Engineering, science, processing and design, M. Ashby, H. Shercliff, D. Cebon, Butterworth-Elsevier, 2018.
Chemistry: Chemical Principles, The Quest for Insight, P. Atkins, L. Jones, L. Laverman, W.H. Freeman and Company, 7th edition 2016
En francais:
Traduction française, Matériaux: science, ingénierie, procédés et conception. L.Deillon, M. Rappaz, Presses Polytechniques Universitaires Romandes, 2013.
Traduction francaise: Principes de chimie, P. Atkins, L. Jones, L. Laverman, De Boeck Supérieur, 4e édition 2017

### Ressources en bibliothèque

- Materials : Engineering, science, processing and design, M. Ashby, H. Shercliff, D. Cebon
- Chemistry: Chemical Principles, The Quest for Insight, P. Atkins, L. Jones, L. Laverman, W.H. Freeman and Company
- Matériaux: science, ingénierie, procédés et conception / Deillon
- Principes de chimie, P. Atkins, L. Jones, L. Laverman

### Notes/Handbook

Slides and notes of the course are avaiable on Moodle

### Moodle Link

- https://go.epfl.ch/MSE-101_b

## Prerequisite for

MSE 214 and MSE 215: Mise en oeuvre des matériaux I + II