UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Metals Science and Sustainability

1920-1-F5302Q013

Aims

The teaching aims to provide a broad foundational knowledge of metallurgy and metallic materials. The learning objective is acquiring a general understanding of how chemo-physical, microstructural and technological factors can impact on the final properties of metals and alloys.

Contents

The course topics can be divided into three major blocks.

The first block includes basic chemo-physical and metallurgical phenomena that are involved in the development of phases and microstructures in metals and alloys, and characterisation methods.

The second block comprises examples of technological processes used for the synthesis and transformation of metallic materials, and for the setting of their final properties.

The third block provides an overview of the main metallic material classes by composition, including classification, applications and life cycle.

Detailed program

Definition of metals and metallic materials. Description of metallic lattices. Lattice defects (point defects, dislocations, grain boundaries, twinning, stacking faults) referred to metallic materials.

Alloying. Real solutions and Hume-Rothery criteria. Examples of metallic phase diagrams and ternary phase diagrams of metallic materials.

Metal synthesis and basic solidification physics in metals. Overview of melting and casting techniques.

Dislocation physics, slip systems and plastic deformation phenomena. Strain hardening. Development of textures.

Overview of metalworking processes: roll milling, wire drawing. Annealing processes: recovery, recrystallisation and grain growth.

Effects of diffusion in metallic materials: precipitates, coarsening of second phases. Diffusion bonding, Powder Metallurgy, Carburising of steels.

Strengthening mechanisms: solution hardening, dispersion hardening, precipitation hardening, ageing.

Twinning. Diffusionless martensitic transformations.

Microstructural characterisation: X-ray diffraction, effects of microstructure on peak shape, Rietveld method, Williamson-Hall analysis, Overview of texture analysis; Metallography: light and electron microscopy. EBSD. EDX and micro-analytical techniques.

Mechanical characterisation: tensile curves for metallic materials. Anelastic effects. Creep. Hardness tests.

Overview of light alloys (Aluminium, Titanium, Magnesium): production, life cycle, compositions, classifications, applications.

Overview of copper alloys: production, life cycle, compositions, classifications, applications.

Overview of ferrous alloys: Fe-C system, cast irons and steels. Steel microstructures and properties. Steel production, life cycle, compositions, classifications, applications. Thermal treatments: TTT and CCT curves for steels.

Precious alloys.

Shape Memory Alloys.

Additive manufacturing: Selective Laser Melting.

Prerequisites

Basic knowledge of: Calculus, Thermodynamics, General Chemistry, Solid Mechanics, Crystal Structures, Elements of X-ray Diffraction, Calorimetry.

Teaching form

Taught classes.

Exercise in class about the manufacturing process of a metallic product.

In-course assignment: one group project about innovative metallic materials, processes, or process sustainability, including bibliographic research and discussing ideas for possible applications, or methods of characterisation. The project is mandatory.

Visit to a metallurgy research laboratory.

Textbook and teaching resource

The course slides are available for the students. Class attendance by the students is recommended.

The following textbooks are suggested as reference material covering the teaching contents.

General knowledge and technology

A.C. Reardon, Metallurgy for the Non-Metallurgist, 2nd Ed., ASM International, 2011 [easy textbook on metallic materials]

J.C. Warner, D.A. Brandt, Metallurgy Fundamentals, 5th Ed., Goodheart-Willcox, 2009 [easy general overview]

J.T. Black, R.A. Kohser, Materials and Processes in Manufacturing, 10th Ed., John Wiley & Sons, 2008 [overview of technology]

W. D. Callister Jr., Fundamentals of Materials Science and Engineering, 5th Ed., John Wiley & Sons, 2001

Physical Metallurgy

D.A. Porter, K. E. Easterling, Phase transformations in Metals and Alloys, 3rd Ed., Taylor & Francis Group, 2009

G. Gottstein, Physical Foundations of Materials Science, Springer Verlag, 1st Ed., 2004

R. Abbaschian, L. Abbaschian, R.E. Reed-Hill, Physical Metallurgy Principles, 4th Ed., Cengage Learning, 2009

R.E. Smallman, A.H.W. Ngan, Physical Metallurgy and Advanced Materials, 7th Ed., Elsevier, 2007 [Advanced]

R.E. Reed-Hill, Physical Metallurgy Principles, D. Van Nostran Company, 2nd Ed., 1973 [Good, but old]

R.W. Cahn, P. Haasen, Physical Metallurgy. 3 Vols., 4th Ed., North Holland, 1996 [Complete and advanced - for reference]

Metalworking and mechanical properties

G.E. Dieter, Mechanical Metallurgy, Metric Edition, McGraw-Hill, 1988

X-ray diffraction

S.J.L. Billinge,; R.E. Dinnebier, Powder Diffraction: Theory and Practice. Cambridge : Royal Society of Chemistry. 2008

Semester

The teaching is delivered during the first semester.

Assessment method

The achievement of the learning objective will be assessed in an oral exam.

Students will be asked to elaborate on a few topics drawn from the course programme. In particular, they will be evaluated considering their knowledge of the subject and their capacity to exploit notions about fundamental mechanisms to derive technical requirements for metallic materials in applications. To this purpose, they may be asked to propose and discuss examples of compositions and processes that could provide solutions for simple study cases.

They will also be asked to discuss their own In-course Project.

Office hours

Ad-hoc appointments can be made by contacting the lecturer.