METALS SCIENCE AND SUSTAINABILITY

Master in Sustainable Materials

CONTACT INFORMATION

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COURSE CONTENT AND INTENDED LEARNING OUTCOMES (ILOs):

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. A first course 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. A 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.

At the end of the course, the student will be able to:

- tailor microstructural characteristics to obtain application-oriented properties in metallic materials.
- develop diverse technological routes to optimise microstructure and properties.
- choose appropriate characterisation techniques to investigate microstructures and mechanical properties in metallic materials.
- identify major sustainability issues and research environmental and political strategies for metallic material use

Aligning with the EIT OLOs:
1 = peripherally relevant to the course content; 2 = highly relevant to course content.

- [x] EIT OLO 1 - Making value judgments and sustainability competencies - 2
- [ ] EIT OLO 2 - Entrepreneurship skills and competencies
- [x] EIT OLO 3 - Creativity skills and competencies - 2
- [x] EIT OLO 4 - Innovation skills and competencies - 2
- [x] EIT OLO 5 - Research skills and competencies - 2
- [ ] EIT OLO 6 - Intellectual transforming skills and competencies
- [x] EIT OLO 7 - Leadership skills and competencies - 2

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Description of <u>how</u> the course covers the EIT OLO(s) and EIT Thematic Areas

Alongside the taught lectures, the course includes the discussion in class of a relevant case study about the complete manufacturing process of a challenging metallic product, stimulating the ability to consider product design, as well as industrial and environmental requirements in view of choosing and improving materials and processes (**OLO 4** and **OLO 1**). Moreover, the course includes a visit to a metallurgy research laboratory, with demonstration of experiments and procedures, to arouse interest and discussion about cutting-edge research objectives and methods (**OLO 5**). As a fundamental part of the course, students are given an interdisciplinary group assignment to creatively structure, write and publicly present (**OLO 3** and **OLO 7**) a review on innovative metallic materials (**OLO 5**), processes (**OLO 4**, **OLO 5**), or process sustainability (**OLO 1**, **OLO 4**) topics, not explicitly presented during the lectures. Both in the taught lectures – especially those on processes and material classes – and in the group presentations, the current hot topics about environmental and geopolitical sustainability of metallic material supply (**OLO 1**), recovery and recycling are addressed. The course can thus be included in the **EIT Thematic Areas No. 1**: "Exploration and raw materials resource assessment"; **No. 3** "Increased resource efficiency in mineral and metallurgical processes"; **No. 4** "Recycling and material chain optimization for end-of-life products"; **No. 5**: "Substitution of critical and toxic materials in products and for optimal performance"; and **No. 6**: "Design of products and services for circular economy".

ASSESSMENT METHODS AND GRADING SYSTEM

The final assessment is based on an interview in which different student abilities are evaluated.

- During the assessment, the student must demonstrate appropriate knowledge of the main physical and metallurgical phaenomena, metalworking and heat treating processes, characterisation methods and classification of metallic materials (content-based assessment),
- Students must also show they are able to discuss how the acquired knowledge can be used as a tool for imparting relevant properties to metals and alloys and verify the achievement of that aim (competence-based assessment, also evaluating **OLO 3**, **OLO 4** and **OLO 5**).
- Part of the assessment comprises the student's contribution to the group assignment, including originality of the review scope, quality of the essay, presentation skills and knowledge learnt (competence-based and impact-based assessment, also evaluating **OLO 3**, **OLO 5**, **OLO 7**).
- Students must be able to discuss the sustainability of the studied metallurgical processes, as well as the supply and recyclability issues of different alloy classes (content-based, competence-based and impact-based assessment, also evaluating **OLO 1**).

The grades in the Italian university system are expressed out of 30. The passing grade is 18/30.

An example of the breakdown of a hypothetical final grade may be as follows:

ASSESSMENT METHOD	WEIGHT ON FINAL GRADE
Class participation	0%
Lab / on-the-field task	0%
Written output(s) (essay, position papers, case study, final exam etc.)	25%
Oral exam	75%

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COURSE SESSIONS

Session 1	INTRODUCTION TO THE COURSE METALS, ALLOYS AND PHASE DIAGRAMS
Content	• Introduction and outline of the course • Definition of metals and metallic materials. Description of metallic lattices. Lattice defects. • Alloying. Real solutions and Hume-Rothery criteria. Examples of metallic phase diagrams and ternary phase diagrams of metallic materials.
Readings	• D.A. Porter, K. E. Easterling, Phase transformations in Metals and Alloys, 3rd Ed., Taylor & Francis Group, 2009

Session 2	METALLURGICAL PHAENOMENA
Content	• Metal synthesis and basic solidification physics in metals. • Dislocations, slip systems and plastic deformation phenomena. • Strain hardening. Development of textures. • Recovery, recrystallisation and grain growth. • Precipitates, coarsening of second phases. • Strengthening mechanisms: solution hardening, dispersion hardening, precipitation hardening, ageing. • Twinning. Diffusionless martensitic transformations.
Readings	• 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

Session 3	METAL PROCESSING
Content	• Overview of melting and casting techniques. • Overview of metalworking processes: roll milling, wire drawing. • Thermal treatments: TTT and CCT curves for steels. • Powder Metallurgy and additive manufacturing • Case study about metallic material product
Readings	• G.E. Dieter, Mechanical Metallurgy, Metric Edition, McGraw-Hill, 1988 • A.C. Reardon, Metallurgy for the Non-Metallurgist, 2nd Ed., ASM International, 2011 • J.T. Black, R.A. Kohser, Materials and Processes in Manufacturing, 10th Ed., John Wiley & Sons, 2008
Assignment	• Joint discussion in class about the case study

Session 4	METALLIC MATERIAL CHARACTERISATION
Content	• 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.
Readings	• G. Gottstein, Physical Foundations of Materials Science, Springer Verlag, 1st Ed., 2004 • S.J.L. Billinge,; R.E. Dinnebier, Powder Diffraction: Theory and Practice. Cambridge : Royal Society of Chemistry. 2008

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Session 5	METALLIC MATERIAL CLASSES: SUPPLY, RECYCLING, PROCESSING AND APPLICATIONS
Content	• Overview of light alloys (Aluminium, Titanium, Magnesium): production, processing, life cycle, compositions, classifications, applications. • Overview of ferrous alloys: Fe-C system, cast irons and steels. Steel microstructures and properties. Steel production, processing, life cycle, compositions, classifications, applications. • Shape Memory Alloys.
Readings	• A.C. Reardon, Metallurgy for the Non-Metallurgist, 2nd Ed., ASM International, 2011 • J.T. Black, R.A. Kohser, Materials and Processes in Manufacturing, 10th Ed., John Wiley & Sons, 2008

Session 6	GROUP ASSIGNMENT
Content	• Forming groups and organizing group work • Choosing a general topic, researching the literature, and deciding a title and a point of view for the review. • Structuring and writing a scientific essay (literature review). • Preparing a captivating short presentation for a course conference • Delivering the presentation – each student in the group will present a part.
Readings	• Scientific literature researched by the group
Assignment	• Essay • Presentation

Session 7	FINAL EXAM
Dates	JAN 2021, FEB 2021, MAR 2021, APR 2021, MAY 2021, JUN 2021, JUL 2021, SEP 2021
Content	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 Group Assignment.

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