Course guide
295769 - 295EM132 - Plasticity, Defects and Microstructure

Last modified: 26/06/2025

Unit in charge: Barcelona East School of Engineering
Teaching unit: 702 - CEM - Department of Materials Science and Engineering.

Degree: MASTER'S DEGREE IN MATERIALS SCIENCE AND ADVANCED MATERIALS ENGINEERING (Syllabus 2019). (Optional subject).
ERASMUS MUNDUS MASTER'S DEGREE IN ADVANCED MATERIALS SCIENCE AND ENGINEERING (Syllabus 2021). (Optional subject).

Academic year: 2025 **ECTS Credits:** 6.0 **Languages:** Spanish

LECTURER

Coordinating lecturer: JORGE ALCALA CABRELLES

Others: Primer quadrimestre:
JORGE ALCALA CABRELLES - Grup: T1

PRIOR SKILLS

Basic knowledge of physical metallurgy.

TEACHING METHODOLOGY

Face-to-face master classes. Lectures are supported by videos uploaded to the ATENEA platform (in spanish). A book is provided on the preliminary issues concerning continuum mechanics and elasticity.

LEARNING OBJECTIVES OF THE SUBJECT

To understand the fundamental dislocation glide and interaction mechanisms that occur in metallic materials and alloys.
To understand the fundamental differences between the stress-strain curves of metallic materials as a function of the underlying, distinct dislocation glide processes.
To understand the fundamental assumptions employed in the simulation of plastic deformation processes from the materials science and continuum mechanics perspectives
To understand and model the influence of microstructure and microstructural barriers on the plastic deformation of metals and alloys.
To Understand and model the hardening mechanisms in metals and alloys.
To understand the role of confined sample dimensions on plastic deformation processes. To furnish an insight into such small-scale plasticity responses. through nanoindentation and micropillar compression tests.

STUDY LOAD

Type	Hours	Percentage
Hours small group	14,0	9.33
Self study	108,0	72.00
Hours large group	28,0	18.67

Total learning time: 150 h

CONTENTS

Introduction to dislocations, twins and elasticity theory

Description:
Dislocations; burgers and dislocation line vectors; slip systems in FCC, BCC and HCP crystals. Twining and twin morphology.
Stress tensor; generalized computation of the resolved shear stress.
Strain tensor; deformation gradient tensor and the micromechanics of plastic deformation.
Linear elasticity. Elasticity tensor. Crystal symmetry and elastic anisotropy.
Stress fields around dislocations
Elastic strain energy and the line tension around dislocations.

Specific objectives:
To revise basic concepts from continuum mechanics from previous, introductory courses. To apply these concepts to the micromechanical description of plasticity
To revise basic concepts associated with dislocations and twins.
To show basic results that emerge from the use of elasticity theory in the study of dislocations.

Full-or-part-time: 15h
Theory classes: 6h
Self study : 9h

Plasticity in FCC metals and continuum mechanics descriptions

Description:
Dislocation decomposition into Shockley partials
Staking fault energy
Twin formation
Dislocation junctions
Peach-Koehler equation and the expansion of a Frank-Read source
Dislocation density and dislocation density increase during plastic deformation.
The line tension model
Cross-slip
Continuum crystal plasticity descriptions: mean free path length travelled by the dislocations and the storage-recovery model.
Construction of the strain tensor. Latent hardening description.
The stages of single-crystal plastic deformation
Kinks and jogs.

Specific objectives:
To gain insights into the fundamental strain hardening mechanisms that occur in metallic materials
To understand classic dislocation glide processes.
To establish the basic elements upon which continuum crystal plasticity analyses are lain.
To understand and model the plastic response of single crystals subjected to uniaxial loading.

Full-or-part-time: 35h
Theory classes: 15h
Self study : 20h

Plasticity in BCC metals

Description:
Dislocations in BCC metals: generalities.
The Peierls barrier.
Thermally activated glide of screw dislocations: double kinking mechanisms.
Twin formation.
The dislocation core structure.

Specific objectives:
To understand the basic differences between dislocation glide processes in FCC and BCC metals.
To undertand the concept of the Peierls barrier.
To undestand the distinct underlying phenomenology to the stress-strain curve in FCC and BCC metals.

Full-or-part-time: 6h
Theory classes: 3h
Self study : 3h

Grain boundaries, interfaces and dislocations

Description:
Classification of tilt and twist interfaces
The Read-Shockley model and the grain boundary energy
Coherency, semicoherency and incoherency of interfaces. Examples and associated surface energy. Sigma interfaces.

Specific objectives:
To understand interface morphology and energy
To conceptualize grain boundaries in terms of dislocation pileups.
To characterize interfaces in metallic materials as a function of energy and relative coherency.

Full-or-part-time: 6h
Theory classes: 3h
Self study : 3h

Hardening mechanisms in metals and modeling approaches

Description:
Solid solution hardening: mechanisms and models
Dislocations in high entropy alloys
Precipitation hardening and associated dislocation line tension models
Grain boundary hardening and softening: mechanisms and modeling
Applications to steels and aluminum alloys.

Specific objectives:
To apply previous notions of dislocation glide to the modeling of the hardening mechanisms that develop in pure metals and alloys.
Microstructural tailoring against plastic deformation.

Full-or-part-time: 12h
Theory classes: 6h
Self study : 6h

Continuum plasticity in macroscopic material length scales

Description:
Yield surfaces: Tresca and Von Mises
J2 flow and deformation theories of plasticity
Kinematic hardening
Pressure-dependent plasticity: plasticity in glasses and phase transformation induced plasticity. Drucker-Praguer and Mohr-Coulomb models.

Specific objectives:
To provide a solid continuum mechanics foundation to the investigation and modeling of plastic deformation processes
To understand the micromechanical and phenomenological foundation to the modeling of plastic deformation processes through continuum plasticity theories.
To furnish useful criteria in the selection of suitable constitutive models and plasticity theories in the computational modeling of plastic deformation processes.

Full-or-part-time: 15h
Theory classes: 6h
Self study : 9h

Small-scale plasticity

Description:
Plastic intermittencies and dislocation avalanches
Dislocation starvation
Micropillar compression tests
Nanoindentation: dislocation nucleation and hardness evolutions.

Specific objectives:
To undestand the underlying micromechanics to the "smaller is stronger" paradigm.
To furnish a micromechanical basis to the comprehension of micropillar compression and nanoindentation experiments.

Full-or-part-time: 6h
Theory classes: 3h
Self study : 3h

GRADING SYSTEM

2 Activities agreed with the student to expand knowledge or solve problems addressed in class. 1 monographic essay