MATERIALS ENGINEERING AND NANOTECHNOLOGY (LM56)

(Lecce - Università degli Studi)

Teaching METALLURGICAL TECHNIQUES AND INSTRUMENTATION

GenCod A003983

Owner professor Benedetto BOZZINI

Teaching in italian METALLURGICAL TECHNIQUES AND INSTRUMENTATION

Teaching METALLURGICAL TECHNIQUES AND INSTRUMENTATION

SSD code ING-IND/21

Reference course MATERIALS ENGINEERING AND

Course type Laurea Magistrale

Credits 9.0

Teaching hours Front activity hours: 81.0

For enrolled in 2018/2019

Taught in 2018/2019

Course year 1

Language ENGLISH

Curriculum PERCORSO COMUNE

Location Lecce

Semester First Semester

Exam type Oral

Assessment Final grade

Course timetable https://easyroom.unisalento.it/Orario

BRIEF COURSE DESCRIPTION

Overview

This is a methodological course focussing on master-level metallurgical conceptual tools, integrated by foundations of laboratory instrumentation and data processing. The aim is to offer to the students a self-contained, close-knit body of concepts, enabling them to face advanced topics in theoretical and experimental metallurgy. The course will provide a firm basis of general value, liable to provide a strong theoretical toolbox to face state-of-the-art and next-generation challenges in technological and research fields in which metals play a key role. The contents of this course have been specifically designed in order to provide the students with enough background and guidelines to act independently in completely novel industrial and research tasks.

REQUIREMENTS

Prerequisite: Sufficiency in calculus, physics, chemistry and basic metallurgy.

COURSE AIMS

Learning Outcomes; after the course the student should be able to

*Describe processes in which metallic materials – as such or in as far as reagents and/or products – are involved in terms of thermodynamic, kinetic and mass-transport equations and integrate these equations in a selection of technologically relevant situations. Describe, in general, classes of experimental set-ups and reactors relevant to the study or synthesis/modification of metallic materials. Describe collection and processing actions for data generated in the activities described in the previous point.

*Formulate and solve simple design tasks for metallurgical structures and experiments.

*Derive quantitative relationships to predict simple cases of trasformation of metallurgical structures as well as structure-property relationships.

TEACHING METHODOLOGY

Teaching Methods: The course provides the basic physics and engineering tools to define and carry out materials science design tasks, including thermodynamics, kinetics and fabrication devices. Moreover, elementary, but effective data acquisition and analysis tools are provided. After a fundamental assessment, technological aspects are addresses and a selection of case-studies is analyzed in depth. Constant reference is made throughout the course to physical meaning, experimental aspects and practical engineering problems. The key methodological highlight of the course is the unceasing tension to rationalise each content and each conceptual step expounded and to represent an attitude to the quantification with fully formalized approaches, though with simplification and approximations appropriate for the knowledge level of the Students.

ASSESSMENT TYPE

Examination: written and oral.

The written part of the exams consists in carrying out simple computational tasks, designed to assess that the Student has a solid conceptual and quantitative grasp of the of key topics of the course.

The oral part of the exam consists of an oral interview (typical duration 45 min) in which the student will be asked to expound three topics: two of them of theoretical content and one of them of experimental nature. The purpose of the first three questions is to assess the ability to identify and use the contents expounded in the course to formulate responses to technological problems in structural or process metallurgy. The fourth question will deal with a case study and will be aimed at giving the student a chance to prove her/his problem solving abilities and the capacity to integrate different concepts and formal tools.

FULL SYLLABUS

Course Contents

Hour 1) Introduction to the course: illustration of the significance abd contents.

Hour 2) Detailed presentation of the index of the course. Metallurgical thermodynamics, metallutgical kinetics, metallurgical reactor theory, mathematical & statistical tools for metallurgical instrumentation, fundamental laboratory instrumentation.

Hour 3) Key concepts of metallurgical thermodynamics: System, state of a system, generalised forces and displacements, generalised energy.

Hour 4) Transformation theory, mathematical framework and examples. Equilibrium, reversible and irreversible transformation.

Hour 5) State and process functions, State equations, coupling of system to environment.

Hour 6) Balance equation: deduction in the general case, approximations, engineering expressions for the flux terms.

Hour 7) From the balance equation to the generalised first principle of thermodynamics.

Hours 8-10) Thermodinamic potential for complex systems: definition, mathematical machinery, expressions for popular system-environment couplings.

Hour 11) Effective work: theory and applications.

Hour 12) Chemical potential deduced from effective work theory.

Hour 13) Path independent integration of thermodynamic potentials. Partial derivative relationships derived from themodynamic potentials.

Hour 14) Maxwell's relationships for a simple and complex systems.

Hour 15) i) Equilibrium conditions: general treatment. ii) Equilibrium conditions: systems with decoupled coordinates. iii) Equilibrium conditions: formal approach to systems with coupled coordinates.

Hour 16) Coupled 2D-mechanical and 3D-mechanical works.

Hours 17-18) Graphical analysis of multiphase chemical equilibrium for a pure species.

Hours 19-20) The generalised Clausius-Clapeyron equation with applications.

Hour 21) Equilibrium conditions for a chemically reacting mixture: monovariant case.

Hour 22) Deduction of consequences relevant for materials science of equilibrium conditions for a monovariant chemically reacting mixture.

Hour 23) Equilibrium conditions for a chemically reacting mixture: bivariant case.

Hour 24) Theory of solutions: fundamental definitions and equations.

Hour 25) The mixing process and mixing effects.

Hour 26) Constitutive equation for an ideal solution.

Hour 27) Component properties as a function of solution properties for a binary solution.

Hours 28-29) Ideal solutions and simple non-idealities. Regular solution model and applications.

Hour 30) Changes in reference levels for pure species in Dgmix(x) curve

Hour 31) Mathematicals tools for the manipulation of Dgmix curves in the compositional region outside of the common-trangent range.

Hours 32-33) Critical revision of the toolbox for the manipulation of Dgmix(x) curves in view of the construction of binary phase diagrams.

Hour 34) Commont tangent construction and application to multiphase equilibria. Spinodal decomposition.

Hours 35-36) Discussion of prototypical binary phase diagrams.

Hour 37) Intermetallics.

Hour 38) Generalities on the formation of metallurgical structures resulting from reaction-diffusion processes.

Hours 39-40) Theory of eutectic morphologies and morphology development.

Hour 41) Morphologies resulting from peritectoidic transformations: qualitative treatment.

Hours 42-48) Role and impact of dentritic structures in metallurgical processes. Morphology development from growth instabilitity processes. – Statement of the problem, geometrty, equations and itegration domain. Flux BCs. Interfacial temperatute BCs. Changes of variables and

adimensionalisation. Compatibility conditions for tentative functions and their physical meaning. Application of the BCs and derivation of instability conditions.
Hours 49-50) Equilibrium in multiphase reacting systems. The monovariant case: introduction to graphical expressions of the reacting equilibirum conditions
Hours 51-54) Ellingham diagrams. Expressions of the reacting equilibirum conditions in terms of DGo(T). The machinery of Ellingham diagrams. Discussion.
Hour 55) Pourbaix diagrams for oxidation at high-T.
Hour 56) Predominance diagrams with two compositional coordinates.
Hour 57) Introduction to kinetics.
Hour 58) Phenomenological kinetics.
Hours 59-60) Chemical reactions from the kinetic point of view, rate equations and their polynomial expansions.
Hour 61) Basic reaction mechanisms and their combination in series and in parallel.
Deduction of a selection of reaction rates for prototypical reaction types.
Hours 62-63) The Rate Determining Step approximation: discussion and examples.
Hours 64-67) Surface kinetics. Langmuir adsorption isotherm. Examples of notable surface reaction models: (i) Adsorptive decomposition, (ii) Langmuir-Hinshelwood mechanism.
Hours 68-69) Reaction kinetics coupled to mass transport: 1D case, stationary and with linearised concentration gradient. Concentration profile within a catalyst partice.
Hours 70-71) Metallurgical reactory theory: introduction, ideal reactor models: batch, CSTR, PFR.
Hour 72) Introduction to the Section of the Course on Data Processing and Analysis and Fundamentals of Laboratory Instrumentation.
Hours 73-76) Basic MATLAB commands and guidelines for data elaboration
Hours 77-78) Notions of sample statistics. Test for the null hypothesis with applications.
Hour 79) Factorial design of experiments. Linear least squares fitting
Hour 80) Electronic acquisition chains and feedback. Voltage generator with feedback.
Hour 81) Data sampling and data filtering

REFERENCE TEXT BOOKS

References
[1] Handouts (this above in this menu).
[2] R.T. DeHoff. "Thermodunamics in materials science" McGraw-Hill (ed. 1993)
[3] M.J. Pilling, P.W. Seakins. "Reaction Kinetics" Oxford University Press (ed. 1995)
[4] V. Kafarov. "Cybernetic methods in chemistry & chemical engineering" Mir (ed. 1976)