PHYSICAL CHEMISTRY OF SOLID STATE AND SURFACES

Master in Sustainable Materials

CONTACT INFORMATION

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COURSE CONTENT AND INTENDED LEARNING OUTCOMES (ILOs): description of the

Relating fundamental concepts of the solid state and surface physical chemistry with applicative issues in the science and technology of semiconductors.

Knowledge and understanding

At the end of the course the student knows:

- the role of defects on material properties with a focus on semiconductors
- The main characterization techniques for material and surface properties
- the main growth processes for semiconductor (bulk material and thin films)

Applying knowledge and understanding

At the end of the course the student is able to:

- apply a method to understand and to predict the role of defects on material properties based on the chemical physics concept of solid solution
- analyze the results of surface and material characterization carried out with several characterization techniques such as SEM, EDX, XPS, SIMS
- know that any growth techniques could introduces defects which can modified the material properties and the device related performances
-recognize the role and the importance of the defects in material science

Making judgements

At the end of the course the student is able to:

- choose the best growth method and characterization techniques to be used according to the properties and functionality of the material he/she wants to have or to investigate
- avoid any contamination sources or to control them

Communication skills

The student will be able to describe and to explain orally with a suitable language the subjects of the class and to sustain a contradictory on the basis of judgment abilities developed autonomously on class topics.

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Learning skills
The student will be able to apply the acquired knowledge to contexts different from those presented during the course, and to understand the topics covered in the scientific literature concerning the defectivity in the materials, as well as the complex relationship among the growth processes and the material properties.

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

Description of how the course covers the EIT OLO(s) and EIT Thematic Areas

The course combines lectures with interactive activities on relevant research topic in the area of physical chemistry. The class presentation, prepared individually or in team made of two students, will be the base to consolidate research skills and competencies (**OLO 5**), e.g. learning how to conduct a literature survey, and the intellectual transforming skills and competencies (**OLO 6**), e.g. discussing the technological impact of specific material preparation and characterization techniques. During the lectures the teacher will also guide the students to understand how material preparation and characterization techniques can play a role in the context of developing sustainable materials (**OLO 1**). The course partially falls into the **EIT Thematic Area No. 6**: "Design of products and services for circular economy".

ASSESSMENT METHODS AND GRADING SYSTEM

The teacher assesses if and to what extent the student has reached the course objectives.
A formal knowledge-based evaluation of the general topics is delivered. The examination is performed through an oral exam, to assess **OLO 1** and **OLO 5**.

The students also perform a class presentation of about 20 minutes on a topic selected by the students from a list that the teacher will give at about the end of March of each year. This presentation will count for 30% of your final grade. The class presentation will be used to assess **OLO 5** and **OLO 6**.

During the Covid-19 emergency period, oral exams and the class presentation may be online. They will be carried out using the WebEx platform; on the e-learning page of the course there will be a public link for access to the examination of possible virtual spectators.

The grades in the Italian university system are expressed out of **30.** The passing grade is 18/30.
Here below is the breakdown of the final grade:

ASSESSMENT METHOD	WEIGHT ON FINAL GRADE
Class Presentation in a topic chosen by the students	30%
Oral exam	70%

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COURSE SESSIONS

Suggested pre-course reading materials:

- Charles Kittel "Introduction To Solid State Physics", 8th Edition, Chapter 1, 2, 3, 7 and 8.

Session 1	INTRODUCTION TO THE COURSE
Content	• Introduction to the course • Outline of the contents and the assessment methods
Readings	• S. Eliot The Physics and Chemistry of solids Wiley • J. D. Plummer , M.D. Deal, P.B. Griffin Silicon VLSI Technology Prentice Hall • J. B. Hudson Surface science an introduction • A. W. Adamson, A.P. Gast Physical Chemistry of Surfaces 6th ed. Wiley

Session 2	DEFECTS IN SOLIDS
Content	• Defects in solids • Point defects as equilibrium defects Extended defects (dislocations, grain boundaries, antiphase domains, stacking fault) Interaction of Atomic Defects with Extended Defects: Case study : oxygen in silicon Case study : Hydrogen in siicon
Readings	A.Borghesi et al " Oxygen precipitation in silicon J. Appl. Physics 77-4169 (1995) Original and historical articles on point defects : • J. E. Bauerleandi, S. Koehler Physical Review vol, 107, 1493(1957) • R. Simmons, W. Balluffi Physical Review vol. 125 , 862 (1962) • M.Doyamaandi J.S. Koehler Physical Review vol. 127, 21 (1962)
Assignment	After reading discussions in pair about the historical articles reported above.

Session 3	SURFACE AND DEFECTS CHARACTERIZATION
Content	• Principal methods and techniques of surface and defect characterization (SEM XPS, AUGER, SIMS, DLTS , BET methods) • Growth techniques of massive materials • General aspects of thin film deposition procedures and main thin film deposition techniques and relationships with material defectuality
Readings	Textbook and articles reported in the elearning page

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Session 4	SOLID SURFACES
Content	• Definition of a surface • Surface relaxation and reconstruction • Surface preparation • Thermodynamics of solid surfaces • elastic and plastic response in solids • Surface energy • Solid-solid-interfaces
Readings	• Hans-Jürgen Butt, Karlheinz Graf, Michael Kappl. Physics and Chemistry of Interfaces, 3rd Edition. • Geoffrey Barnes, Ian Gentle. Interfacial Science: An Introduction, 2nd Edition. ISBN: 9780199571185.

Session 5	ADSORPTION PHENOMENA AND SURFACE MODIFICATIONS
Content	• Adsorption • Physisorption vs chemisorption • Adsorption models, e.g. Langmuir and BET • Adsorption from liquids • Surface modification by adsorption, e.g. self-assembled molnolayers, physisorption of polymers, surface polymerization, Langmuir-Blodgett films
Readings	• Hans-Jürgen Butt, Karlheinz Graf, Michael Kappl. Physics and Chemistry of Interfaces, 3rd Edition. • Geoffrey Barnes, Ian Gentle. Interfacial Science: An Introduction, 2nd Edition. ISBN: 9780199571185.

Session 6	CLASS PRESENTATION
Content	Student, individually or in teams of 2, select and present on one of the following topics: • Silicon Etching: method and processes • Electron Beam induced Current Technique • Defect and colour centers • Electron backscatter diffraction technique • Deep Level Transient Spectorscopy (DLTS) tecnique for defects identification (point defects and dislocations) • Antiphase boundaries and other extended defects • Contact mechanics: the Hertz model • Methods to measure friction • Coatings promoting lubrication • Electrowetting • Marangoni effect • How to avoid curdled mayonnaise • Langmuir-Blodgett films • Characterization of MOFs by BET • Wear protection of solid surfaces
Readings	At least three research or review papers, relevant to the above topic
Assignment	Students select the topic, conduct a literature survey, discuss the paper selection with the instructor, prepare a 20 minute-presentation and deliver it in front of the class.

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Session 7	FINAL EXAM
Date - hours	29th June 2020 - 2.30 p.m. 13th July 2020- 2.30 p.m. 26th July 2020- 2.30 p.m. 1st September 2020 - 2.30 p.m. 21st September 2020 - 2.30 p.m. 5th February 2021 9 a.m. 10th March 2021 2.30 p.m
Content	The oral exam normally consists of at least two questions, selected from the following list: • point and extended defects; • adsorption phenomena; • surface modification techniques; • principal methods and techniques for surface and defects characterization; • Growth techniques of massive materials.

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