MATERIALS AND DEVICES FOR ENERGY ENGINEERING

Master in Sustainable Materials

CONTACT INFORMATION

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COURSE CONTENT AND INTENDED LEARNING OUTCOMES (ILOs):

The aim of the course is the description of the structure, properties, functions and characterization of materials for solar applications. The course will also include the description of the corresponding devices. At the end of the course the student knows: i. the main solar devices (photovoltaic, artificial photosynthesis, photocatalysis and photoelectrochemical) both commercial and in the research and development stage; ii. the main energy materials, of historical value and of recent literature, and their main features and properties.

At the end of this formative activity, the student will be able to:

- understand the operating principle of a solar device and the relationships between the efficiency of the device and the chemical properties of the materials used in the device itself;
- understand the main structural characteristics and other properties of the materials used in solar devices;
- critically analyze the reference literature;
- analyze the advantages and disadvantages and the relative environmental impact of each solar technology.
- apply the acquired knowledge on the relationships between material properties and solar device efficiency to examples other than those presented during the course, and to understand the topics covered in the scientific literature concerning materials for energy applications
- discuss with a correct use of scientific language in the field of energy materials

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
- [ ] EIT OLO 4 - Innovation skills and competencies

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- ☐ EIT OLO 5 - Research skills and competencies
- ☐ EIT OLO 6 - Intellectual transforming skills and competencies
- ☐ EIT OLO 7 - Leadership skills and competencies

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

Lectures and interactive activities are proposed in the field of renewable energy (specifically solar energy and hydrogen production), stimulating the creative merging of different topics and previously acquired competences (**OLO 3**). The proposed technological target represents a typical application in cross-disciplinary areas, suitable and stimulating students with different background – with degree in Physics, Chemistry, Engineering – to interact to each other. During the lectures students focus their attention – with the guidance of the teacher and the acquired knowledge on critical raw materials – on sustainable technological solutions, evaluating substitution or reduction of critical elements (**OLO 1**). The course falls into the **EIT Thematic Area No. 5**: "Substitution of critical and toxic materials in products and for optimal performance".

ASSESSMENT METHODS AND GRADING SYSTEM

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

A part of the exam consists of an oral test on all the topics covered in class and reported in the material (slides of the lessons and reference texts) provided to students through the Moodle platform.

Then during the interview, the following student abilities are evaluated.
• During the assessment, the student must demonstrate to know the main principles of working of a solar cell
• The student must also show how the acquired knowledge can be used as a tool for the analysis and the design of new materials suitable for solar energy production and hydrogen production
• Part of the assessment comprises the analysis of an example of material system, so as to allow the student to demonstrate skills in applying the acquired knowledge for solving a real technological problem according to a sustainable strategy (impact-based assessment, also evaluating **OLO 3** and **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:

ASSESSMENT METHOD	WEIGHT ON FINAL GRADE
Class participation	5%
Lab / on-the-field task	0%
Presentation of a position paper chosen by the students	30%
Oral exam	65%

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COURSE SESSIONS

Session 1	ENERGY ANS RENEWABLES : STATUS ; TRENDS ; CHALLENGES s
Content	• Introduction to the course • Outline of the contents and the assessment methods • Introduction of the climate change issues and the energy sources renewable and no renewable
Readings	IEA Key World Energy Statistics 2020 report ; Photovoltaics-Report Fraunhofer Institute for Solar Energy Systems 2020; Global Energy Review 2020
Assignment	• Homework : exercises and questions about " Energy situation in your country"

Session 2	THE PHYSIC OF SOLAR CELL
Content	• Background of the properties of semiconductor • Solar spectrum and air mass concepts • The working principle of a p-n junction • The I/V curves in dark and under illumination • Instruments and standard condition • Losses and efficiency limits
Readings	Textbook Solar Energy: The physics and engineering of photovoltaic conversion, technologies and systems A Smets, K Jäger, O Isabella, R van Swaaij, M Zeman UIT Cambridge Limited - (from chapter 4 to chapter 10)

Session 3	PV TECHNOLOGY (FIRST PART)
Content	• Crystalline silicon solar cells: history and forecast • Production of silicon wafer • Fabricating c-Si solar cells • Advantages of silicon solar cells • Recycling of end of life silicon modules
Readings	Textbook Solar Energy: The physics and engineering of photovoltaic conversion, technologies and systems A Smets, K Jäger, O Isabella, R van Swaaij, M Zeman UIT Cambridge Limited - (from chapter 12) Handbook of Photovoltaic Science and Engineering" Antonio Luque,Steven Hegedus (chapter 5 &6)
Assignment	.

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Session 4	PV TECHNOLOGY (SECOND PART)
Content	• Thin film solar cells: an overview • Amorphous Silicon–based Solar Cells • Cu(InGa)Se2 Solar Cells (and CZTS) • Cadmium Telluride Solar Cells • Enviromental problem and critical raw materials for each of the discussed PV technologies
Readings	Textbook Solar Energy: The physics and engineering of photovoltaic conversion, technologies and systems A Smets, K Jäger, O Isabella, R van Swaaij, M Zeman UIT Cambridge Limited - (chapter 13) Handbook of Photovoltaic Science and Engineering" Antonio Luque,Steven Hegedus (chapter 12, 13, 14)

Session 5	HIGH-EFFICIENCY III-V MULTIJUNCTION SOLAR CELLS: AND NEW CONCEPT SOLAR CELL
Content	• Multijunction concepts • New concept; • CZTS solar cells: substitution of critical elements
Readings	Handbook of Photovoltaic Science and Engineering" Antonio Luque,Steven Hegedus (chapter 9 & 10) Armaroli et al-2016-Chemistry - A European Journal

Session 6	MOLECULAR MATERIALS AND DEVICES FOR LAST-GENERATION SOLAR CELLS AND SOLAR FUELS
Content	General introduction to molecular solar devices Dye-sensitized solar cells (DSSC) Perovskite solar cells (PSC) Organic photovoltaics (OPV) Solar fuels and chemicals (photoinduced reduction of water and carbon dioxide)
Readings	Dye-sensitized Solar Cells (From " Handbook of Photovoltaic Science and Engineering" Antonio Luque,Steven Hegedus; Ch. 15)File 2018 Tian H., Boschloo G., Hagfeldt A. (eds) Molecular Devices for Solar Energy Conversion and Storage. Green Chemistry and Sustainable Technology. Springer, Singapore.

Session 7	FINAL EXAM
Date - hours	4th February 2021 2.30 p.m 25th February 2021 2.30 p.m 11th March 2021 2.30 p.m 14th April 2021 2.30 p.m
Content	First part; questions related to the program presented during classrooms (This part is worth 65% of the final grade) Second part: a presentation from the student about the content of a scientific articles published in peer review Scientific Journal a list is given to the students and uploaded in the moodle page) in 2020. The article will be selected by the students and should be related to any type of solar devices discussed in the class. The student in the second part of the oral exam will present the content of the article with few slides in no more than 10 minutes. (This part is worth 30% of the final grade)

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