UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Photovoltaics & Other Renewable Energy Technologies

2526-2-FSM01Q027

Aims

The aim of the course is the description of the structure, properties, functions and characterization of materials for solar applications and main renewable technologies. The course will also include the description of the corresponding devices.

Knowledge and understanding

At the end of the course the student knows:

• the main solar devices (photovoltaic, artificial photosynthesis, and photoelectrochemical) both commercial and in the research and development stage ;

• the main materials used in them and their main characteristics and properties.

• the main energy production technologies from renewable sources (peculiar photovoltaic applications, wind and e-fuels production , hydropower)****

Applying knowledge and understanding

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

• apply the acquired knowledge to critically evaluate the choice of materials for different solar energy devices, considering their structural, electronic, and functional properties;

• select suitable materials and technologies for specific renewable energy applications, such as photovoltaics, photoelectrochemical systems, and artificial photosynthesis;

• interpret and analyze material characterization data to assess the performance and reliability of components used in solar and renewable energy technologies;

• integrate knowledge of materials and devices to propose innovative solutions or improvements for energy conversion systems;

• apply the principles learned to real-world scenarios involving renewable energy production, including wind, hydro, and e-fuel technologies.

Making judgments

At the end of this activity, the student will have to demonstrate to be able to

• understand the operating principle of a solar device and the relationships between the efficiency of the device and the physical and chemistry 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;
• to analyze the advantages and disadvantages and the relative environmental impact of the discussed renewable energy technology.

Communication skills

Speaking orally with language properties of scientific topics of energy materials and renewable sources.

Learning skills

At the end of the course, the student is able to:
• autonomously deepen their knowledge of materials and devices for renewable energy through scientific literature and specialized resources;
• keep up with ongoing research and technological advancements in solar energy and other renewable energy sources;
• critically assess new information and data in the field to support decision-making and problem-solving;
• develop a multidisciplinary approach to studying and understanding renewable energy systems, combining principles of materials science, chemistry, and engineering;
• effectively continue learning in both academic and professional contexts, particularly in the field of sustainable energy technologies.

Contents

Description of the operating principles of a photovoltaic cell and the properties of the main photovoltaic absorbers and photovoltaic devices currently on the market and in an advanced research and development phase.
Description of the main photocatalytic and photoelectrochemical processes for the production of fuels and chemical compounds from solar energy (e-fuels).
Description of other relevant energy production technologies from renewable sources.

Detailed program

Sources of energy and renewable sources: an overview. Photovoltaic effect Photovoltaic devices: operation and photovoltaic parameters, theoretical limits of photovoltaic conversion. Measurement techniques and related methodology of analysis of photovoltaic devices (I / V curves under illumination; spectral responses)

Classes of photovoltaic materials and devices:

- Mono and multi-crystalline silicon solar cells (processes of growth and realization of the device)
- Thin film inorganic solar cells (amorphous silicon, CdTe and CIGS): deposition methods and property
- High efficiency solar cells: multi-junction solar cells and concentration systems
- Advanced design solar cells
- Organic and hybrid thin film solar cells (dye-sensitized solar cells, organic-polymeric cells, perovskite cells)
- Materials and devices for photocatalytic and (photo)electrochemical generation of e-fuels and chemical products (artificial photosynthesis, water photolysis, reduction of CO2).
- Wind Energy

Prerequisites

To optimally follow the course and pass the final exam, basic knowledge of chemistry (general chemistry, inorganic, organic, physical) and solid state physics such as those acquired in the I° study course of materials science are required . In particular, for the 2° part of the class the knowledge of the main chemistry concepts presented in the scientific courses of the first cycle and basic knowledge (structure, nomenclature, main properties, etc.) of the main chemical compounds are required.

Teaching form

Lectures in the classroom

Standard lessons supplemented by supporting multimedia tools functional to a better understanding of the practical aspects . In some classes experts coming from industrial sector will be present

23 two-hour lectures, in person, Delivered Didactics

1 two-hour MIBSOLAR laboratory visits, in person, Interactive Teaching

Textbook and teaching resource

The main texts are for the Prof. Binetti part are

-O. Isabella, K. Jäger, A. Smets , R. van Swaaij,M.Zeman "Solar Energy: The Physics and Engineering of Photovoltaic Conversion, Technologies and Systems " UIT ISBN-13: 978-1906860325 ; ISBN-10: 1906860327 (free of charge in EBOOK
-Antonio Luque, Steven Hegedus "Handbook of Photovoltaic Science and Engineering", 2nd edition 2011 John and Wiley & Sons;

Given the nature of the course, which has scientific and technological content very recent there are no exhaustive texts including all the topics.

The students should refer to the slides that the teachers discuss during lectures and which are made available to students in the e-learning platform. The slides also contain references to primary and secondary literature sources (reviews, scientific articles, books) that the student can use to deepen the subject. However, the use of this additional material is not required for passing the exam.

For the second part, held by Prof. Manfredi, the suggested textbook is "Tian H., Boschloo G., Hagfeldt A. (eds) Molecular Devices for Solar Energy Conversion and Storage. Green Chemistry and Sustainable Technology. Springer, Singapore, 2018. " and the relevant literature provided on the e-learning page of the course. It is recalled that the slides contain both the content whose knowledge is considered fundamental for the knowledge of the subject and the passing of the exam and detailed contents that are provided by the teachers in order to better illustrate the subject and support the understanding of the concepts presented. The distinction between the two types is clearly expressed during classroom lessons. In case of doubt it is strongly advised to contact the teachers to know the mandatory parts for the study within the material made available on the e-learning page of the course.

Semester

Second year, first (fall) semester

Assessment method

INTERVIEW ON THE TOPICS DEVELOPED DURING LESSONS AND ON THE EXAM TEXTBOOKS

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.
During the exam, the teacher can ask the student to write the answers on a piece of paper or on the blackboard, especially if this is necessary (material structures, mechanisms and processes, device configuration, etc.).

Given the nature of the degree course, the exam will focus on materials (structure, properties, functions and characterization) but knowledge on the general structure and characterization of the technoloy and or devices presented during the lessons will also be required.

The following level of judgment is applied in relation to the following parameters:

1. Conceptual knowledge and understanding ability
2. Ability to apply knowledge and understanding
3. Communication and argumentation skills
4. Learning, self-assessment and self-regulation skills

Grade < 18

Knowledge and Understanding

The student only partially identifies the characteristics of the concepts. The connections between the concepts are fragmented and poorly supported by theoretical knowledge.

Ability to apply knowledge and understanding

The student identifies only some relevant elements in a phenomenon, without being able to integrate them into an organic analysis.

Communication and argumentation skills

In the oral exam, the student develops an essential argument, lacking logical articulation and characterized by numerous expository inaccuracies.

Learning, self-assessment and self-regulation skills

The student is able to reconstruct only some aspects of his/her learning and professional development path.

Score 18-22

Knowledge and Understanding

The student recognizes and returns most of the conceptual characteristics and is able to provide a relatively

coherent explanation, although with some inaccuracies. Theoretical references are present but not always rigorously.

Ability to apply knowledge and understanding

The student is able to recognize a significant number of elements and provide a partial explanation, although highlighting some gaps in the analysis.

Communication and argumentation skills

In the oral exam, the student constructs a basic argument, with a minimal structure but with some inaccuracies.

Learning, self-assessment and self-regulation skills

The student demonstrates a basic awareness of his/her learning path, managing to trace essential connections between the formative experiences, although with some inaccuracies.

Score 23-27

Knowledge and Understanding

The student demonstrates an in-depth understanding of the conceptual characteristics. In the oral exam, the explanations are well-structured and supported by an adequate use of theoretical references.

Ability to apply knowledge and understanding

The student accurately identifies the essential elements of a phenomenon. The application of knowledge occurs with a methodological rigor that is not always solid.

Communication and argumentative skills

In the oral exam, the student develops a coherent and well-organised argument, demonstrating good command of the language and a solid logical-argumentative structure. Communication is clear and effective.

Learning, self-assessment and self-regulation skills

The student analyses his/her learning path in a clear and structured way, highlighting significant relationships between the different evolutionary stages and demonstrating a good capacity for critical reflection.

Score 28-30

Knowledge and Understanding

The student demonstrates a complete mastery of the concepts, articulating complex connections and providing exhaustive explanations. Theoretical references are used
with relevance and rigor.

Ability to apply knowledge and understanding

The student demonstrates an advanced ability to analyze a phenomenon, identifying and interpreting all the salient elements in an exhaustive manner. The application of knowledge occurs with methodological rigor, supported by a solid and articulated argument.

Communication and argumentative skills

In the oral exam, the student develops a solid and articulated argument, with a rigorous logical structure and a high level of textual coherence. The speech is fluid and well-structured.

Learning, self-assessment and self-regulation skills

The student demonstrates an advanced ability to self-reflect, developing a detailed and in-depth analysis of his/her own learning and professional development path. The connections between training experiences and theoretical concepts are clear, coherent and rigorous.

Office hours

All days from Monday to Friday upon e-mail request

Sustainable Development Goals

AFFORDABLE AND CLEAN ENERGY