



# Materials and Devices for Electrochemical Energy Storage and Conversion

## Course description sheet

### Basic information

<b>Field of study</b> Materials Science	<b>Didactic cycle</b> 2024/2025	
<b>Major</b> All	<b>Course code</b> CIMAS.IIi1.15862.24	
<b>Organisational unit</b> Faculty of Materials Science and Ceramics	<b>Lecture languages</b> English	
<b>Study level</b> Second-cycle (engineer) programme	<b>Mandatoriness</b> Obligatory	
<b>Form of study</b> Full-time studies	<b>Block</b> Major Modules	
<b>Profile</b> General academic	<b>Course related to scientific research</b> Yes	
<b>Course coordinator</b>	Paweł Pasierb	
<b>Lecturer</b>	Paweł Pasierb, Tomasz Brylewski	
<b>Period</b> Semester 1	<b>Method of verification of the learning outcomes</b> Exam	<b>Number of ECTS credits</b> 4
	<b>Activities and hours</b> Lectures: 15 Laboratory classes: 15 Workshop classes: 15	

### Goals

C1	To provide a fundamental understanding of the scientific principles and new strategies to transfer, capture, and store energy derived from various resources (e.g., solar, wind, geothermal, and biomass), the latest developments, and the materials challenges for energy storage, conversion, and harvesting.
C2	To emphasize guidelines for the rational design of new materials for a clean and secure energy future.

## Course's learning outcomes

Code	Outcomes in terms of	Learning outcomes prescribed to a field of study	Methods of verification
<b>Knowledge - Student knows and understands:</b>			
W1	The student has expanded knowledge on the physics and chemistry of solid bodies, which is indispensable for understanding phenomena observed when investigating ceramic materials with certain optical, electrical, thermal, mechanical, and magnetic properties.	IMT2A_W01	Participation in a discussion, Examination
W2	The student has expanded knowledge on the technologies of producing new ceramic materials applied in devices used for energy conversion and storage.	IMT2A_W03	Participation in a discussion, Examination
<b>Skills - Student can:</b>			
U1	The student is able to make use of the data available in both Polish and foreign literature in order to indicate directions which can be taken to develop new materials.	IMT2A_U01	Execution of a project, Execution of laboratory classes, Examination, Completion of laboratory classes
U2	The student can assess the usefulness and limitations of energy conversion and storage technologies based on chemical processes.	IMT2A_U03	Execution of a project, Execution of laboratory classes, Examination, Completion of laboratory classes
U3	The student is able to manufacture and test the electrochemical device for energy conversion or storage.	IMT2A_U04	Execution of a project, Execution of laboratory classes, Examination, Completion of laboratory classes
<b>Social competences - Student is ready to:</b>			
K1	The student understands the significance of materials engineering for the development on modern technologies related to renewable energy sources.	IMT2A_K03	Examination, Involvement in teamwork
K2	The student is aware of the economic implications of new technologies and their impact on the environment.	IMT2A_K01, IMT2A_K03	Examination, Involvement in teamwork

### Program content ensuring the achievement of the learning outcomes prescribed to the module

The lectures and workshop classes conducted as part of the module will allow the students to gain knowledge of the scientific principles of transferring, capturing, and storing energy obtained via renewable energy sources, and familiarise themselves with this subject's current approaches, strategies, developments and challenges. The laboratory classes will allow students to gain skills in electrochemical device manufacture and testing.

### Student workload

Activity form	Average amount of hours* needed to complete each activity form

Lectures	15
Laboratory classes	15
Workshop classes	15
Examination or final test/colloquium	2
Contact hours	5
Preparation of project, presentation, essay, report	24
Realization of independently performed tasks	24
<b>Student workload</b>	<b>Hours</b> 100
<b>Workload involving teacher</b>	<b>Hours</b> 45

\* hour means 45 minutes

### Program content

No.	Program content	Course's learning outcomes	Activities
1.	The lecture covers: - Forms of energy - Systems and materials for processing and storing various forms of energy, including in particular: Fuel cells and materials used in their construction, Electrochemical cells and batteries, Capacitors and supercapacitors, Other systems and materials used to convert and store energy in various forms.	W1, W2, K1	Lectures
2.	During the workshop classes the selected issues related to the properties of materials and their optimization in terms of applications are discussed. The students propose the composition and describe in detail the selected electrochemical devices based on selected materials. During the workshop classes, the discussion of other material issues related to the subject of energy acquisition and storage, as proposed by students, is possible.	U1, K2	Workshop classes
3.	During the laboratory classes students prepare and test (perform the measurements of) the selected electrochemical device for energy storage or conversion.	U2, U3	Laboratory classes

### Extended information/Additional elements

#### Teaching methods and techniques :

Workshop, Group work, Lectures, Discussion, E-learning, Case study, Design thinking, Work with source text

<b>Activities</b>	<b>Methods of verification</b>	<b>Credit conditions</b>
Lectures	Examination	A prerequisite for admission to the exam is obtaining positive grades from the laboratory and workshop classes
Lab. classes	Execution of laboratory classes, Completion of laboratory classes	Participation in Lab. classes is obligatory
Workshop	Participation in a discussion, Execution of a project, Involvement in teamwork	Participation in the workshop is obligatory

### **Conditions and the manner of completing each form of classes, including the rules of making retakes, as well as the conditions for admission to the exam**

Lecture:

the exam covers the knowledge obtained during lectures workshop classes and laboratory classes.

Workshop classes: performance of design works in accordance with the issues formulated by the lecturer, positive grade for a written report on the completed project tasks, scale in accordance with the AGH Study Regulations, and the activity in class is subject to assessment.

Laboratory classes: performing practical exercises in accordance with the instructions, positive assessment of the written test (colloquium) covering the issues listed in the curriculum of laboratory exercises, scale in accordance with the Regulations of AGH studies, a positive grade from a written report on laboratory exercises.

### **Method of determining the final grade**

A prerequisite for admission to the exam is obtaining positive grades from the laboratory and workshop classes.

The final grade will be a weighted average of the grades from the exam (with a weight of 0.4), laboratory classes (with a weight of 0.3) and workshop classes (with a weight of 0.3).

### **Manner and mode of making up for the backlog caused by a student justified absence from classes**

In the case of excused absences, the tutor agrees individually with the student on how to compensate arrears, e.g. additional classes during contact hours, additional colloquium.

## **Prerequisites and additional requirements**

Basic knowledge of physics, chemistry, physical chemistry.

### **Rules of participation in given classes, indicating whether student presence at the lecture is obligatory**

Participation in lectures is not obligatory. Participation in laboratory classes and workshop classes is obligatory.

## Literature

### Obligatory

1. Electrochemical technologies for energy storage and conversion. Vol. 1 / ed. by Ru-Shi Liu, et al., Weinheim, Wiley-VCH Verlag & Co. KGaA, 2012.
2. Electrochemical technologies for energy storage and conversion. Vol. 2 / ed. by Ru-Shi Liu, et al., Weinheim, Wiley-VCH Verlag & Co. KGaA, 2012.

### Optional

1. Electrochemical supercapacitors for energy storage and delivery: fundamentals and applications / Aiping Yu, Victor Chabot and JiuJun Zhang. Boca Raton, CRC Press/Taylor & Francis Group, 2013.
2. Renewable energy conversion, transmission and storage / Bent Sørensen. Amsterdam, Elsevier/Academic Press, 2007.

## Scientific research and publications

### Research

1. Determination of electrical properties of materials
2. Determination of physicochemical properties of materials
3. Selected synthesis methods of materials

### Publications

1. [1] M. Mączka, M. Mosiałek, P. Pasierb, "Carbon tungsten oxide composite cathode materials for aluminum-ion batteries", *Electrochimica Acta* 424 (2022) 1-8
2. [2] A. Popardowski, P. Pasierb, "Influence of electrolyte and redox active electrode materials properties on working mechanism and performance of manganese oxide-based supercapacitors", *Electrochimica Acta* 416 (2022) 1-10
3. [3] L. P. Bakos, [et al.], P. Pasierb, "Photocatalytic and gas sensitive multiwalled carbon nanotube TiO<sub>2</sub>-ZnO and ZnO-TiO<sub>2</sub> composites prepared by atomic layer deposition", *Nanomaterials* 10 [2] (2020) 1-14
4. [4] T. Nagyné-Kovács, L. Studnicka, I. E. Lukács, K. László, Paweł Pasierb, I. M. Szilágyi, G. Pokol, "Hydrothermal synthesis and gas sensing of monoclinic MoO<sub>3</sub> nanosheets", *Nanomaterials* 10 [5] (2020) 1-12
5. [5] K. Silarska, K. Cholewa-Kowalska, P. Jeleń, P. Pasierb, "Preparation and properties of BaCe<sub>1-x</sub>Y<sub>x</sub>O<sub>3</sub> - based composites with Ba-Ce-Y-Si-P-O glass", *Ceramics International* 46 [11] (2020) 17224-17232
6. [6] Ł. Łańcucki, R. Lach, P. Nieroda, E. Drożdż, P. Pasierb, "Impact of calcium doping on structure, catalytic and conductive properties of lanthanum strontium iron oxide", *Processing and Application of Ceramics* 13 [4] (2019) 411-417
7. [7] M. Jasiński, K. Ziewiec, M. Wojciechowska, P. Pasierb, "In situ infrared thermography of full-scale solid oxide fuel cell", *Journal of Power Sources* 442 (2019) 1-7
8. [8] Magda Mączka, Paweł Pasierb, "Sol-gel synthesis of metal (V, W, Zn) oxide - carbon nanocomposites as cathode materials for Al-ion batteries", *Ceramics International* 45 [8] (2019) 11041-11049
9. [9] K. Silarska, M. Środa, P. Pasierb, "Application of DTA/DSC and dilatometry for optimization of Ba-Ce-Y-P-Si-O glass phase for composite protonic conductors based on BaCe<sub>0.9</sub>Y<sub>0.1</sub>O<sub>3</sub>", *Journal of Thermal Analysis and Calorimetry* 133 [1] (2018) 87-93

## Learning outcomes prescribed to a field of study

Code	Content
IMT2A_K01	Rozumie potrzebę dokształcania się oraz podnoszenia swoich kompetencji zawodowych i społecznych oraz potrafi w sposób zrozumiały przekazywać informacje i krytyczne opinie dotyczące inżynierii materiałowej
IMT2A_K03	Ma świadomość ważności i zrozumienia pozatechnicznych aspektów i skutków działalności inżynierskiej, w tym jej wpływu na środowisko i związanej z tym odpowiedzialności za podejmowane decyzje, przestrzega zasady etyki zawodowej oraz rozumie znaczenie wpływu inżynierii materiałowej na rozwój nowoczesnych technologii
IMT2A_U01	Potrafi pozyskiwać informacje z literatury, baz danych i innych źródeł; potrafi integrować uzyskane informacje, dokonywać ich interpretacji i krytycznej oceny, a także wyciągać wnioski oraz formułować i wyczerpująco uzasadniać opinie
IMT2A_U03	Potrafi przeprowadzić ocenę uwarunkowań ekonomicznych prostego procesu technologicznego oraz zna zasady bezpieczeństwa związane z tą pracą
IMT2A_U04	Potrafi optymalnie dobrać metody i narzędzia służące do rozwiązania zadań typowych dla inżynierii materiałowej uwzględniających kryteria doboru materiału i procesu wytwórczego
IMT2A_W01	Ma poszerzoną i pogłębioną wiedzę w zakresie nauk podstawowych niezbędną do zrozumienia zjawisk występujących przy wytwarzaniu, badaniu oraz eksploatacji materiałów inżynierskich
IMT2A_W03	Ma pogłębioną, podbudowaną teoretycznie wiedzę w zakresie inżynierii materiałowej oraz ma poszerzoną wiedzę z zakresu projektowania materiałowego produktów o założonej strukturze i właściwościach użytkowych oraz modelowaniu procesów