GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Electrode materials and their recycling, PG_00058364		
Field of study	Hydrogen Technologies and Electromobility		
Date of commencement of studies	October 2023	Academic year of realisation of subject	2026/2027
Education level	first-cycle studies	Subject group	Obligatory subject group in the field of study Subject group related to scientific research in the field of study
Mode of study	Full-time studies	Mode of delivery	at the university
Year of study	4	Language of instruction	Polish
Semester of study	7	ECTS credits	3.0
Learning profile	general academic profile	Assessment form	assessment
Conducting unit	Department of Corrosion and Electrochemistry -> Faculty of Chemistry -> Faculties of Gdańsk University of Technology		
Name and surname of lecturer (lecturers)	Subject supervisor	dr inż. Zuzanna Zarach	
	Teachers	dr inż. Zuzanna Zarach	

Lesson types

Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
Number of study hours	15.0	0.0	15.0	0.0	0.0	30

E-learning hours included: 0.0

Learning activity and number of study hours

Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
Number of study hours	30	6.0	39.0	75

Subject objectives

The aim of the course is to provide students with comprehensive knowledge of the electrode materials, their properties and recycling methods used in modern electrochemical systems, such as lithium-ion batteries, electrochemical capacitors, and fuel cells. Particular emphasis is placed on issues related to the selection and optimization of anode and cathode materials, their degradation processes during operation, and the factors affecting their durability and performance. An integral part of the course is the study of recycling and the recovery of critical raw materials from end-of-life electrochemical devices, taking into account technological, environmental, and economic aspects.

Learning outcomes

Course outcome	Subject outcome	Method of verification
[K6_U02] can work individually and in a team, can communicate using various techniques in a professional environment, as well as document and analyze the results of their work, can estimate the time needed to perform the entrusted task	The student can work individually and in a team when conducting experiments/projects related to electrode materials and recycling. They can effectively communicate using various techniques for presenting results, as well as document and analyze the outcomes of their work, while planning and assessing the time required for research tasks.	[SU1] Assessment of task fulfilment [SU4] Assessment of ability to use methods and tools [SU5] Assessment of ability to present the results of task
[K6_W04] knows the properties of materials used in solving simple engineering tasks related to the field of study, in particular has knowledge in the field of materials science and is able to relate the properties of materials with their structure and composition, knows the theoretical description of phenomena occurring in materials subjected to external factors	The student knows the basic properties of materials used in electrochemical systems, can relate their structure and chemical composition to their functional properties, and understands the influence of external factors on the processes that occur, including degradation and recycling potential.	[SW3] Assessment of knowledge contained in written work and projects [SW1] Assessment of factual knowledge
[K6_W19] has knowledge of the properties of electrolyte solutions, electrode processes and some electrochemical processes relevant to industrial practice and the application of electrochemistry in practice	The student knows the properties of electrolyte solutions, electrode processes, and selected electrochemical processes relevant to industrial practice, and understands their significance in the operation and recycling of modern electrochemical systems.	[SW1] Assessment of factual knowledge [SW3] Assessment of knowledge contained in written work and projects

Subject contents

Course content – lecture

1. Introduction to electrode materials in electrochemical systems.

2. Classification and properties of anode and cathode materials.

3. Primary and secondary galvanic cells.

4. Electrode materials used in primary alkaline cells.

5. Degradation processes of electrode materials during the operation of electrochemical devices.

6. Electrochemical characterization of electrode materials.

7. Lithium-ion batteries: anode and cathode materials.

8. Alternative technologies to lithium-ion batteries.

9. Critical raw materials in electrochemical systems: significance and availability.

10. Recycling of lithium-ion batteries.

11. Recycling of lead–acid batteries.

12. Environmental and economic aspects of recycling electrochemical systems.

Course content – laboratory

Lithium-ion battery recycling methods (mechanical, hydrometallurgical, and pyrometallurgical). Recovery of lithium, cobalt, nickel, and other critical raw materials (e.g. graphite). Methods for the synthesis and fabrication of advanced electrode materials and the use of materials recovered through recycling.

Prerequisites and co-requisites

Assessment methods and criteria			
	Subject passing criteria	Passing threshold	Percentage of the final grade
	Lecture	60.0%	70.0%
	Laboratory	60.0%	30.0%
Recommended reading	Basic literature	1. Kebede M. A., Ezema F. I. (red.), *Electrode Materials for Energy Storage and Conversion*, CRC Press, Boca Raton, 2021. 2. Breitkopf C., Swider-Lyons K. (red.), *Springer Handbook of Electrochemical Energy*, Springer, Berlin–Heidelberg, 2017. 3. Nölle R., Beltrop K., Holtstiege F., Kasnatscheew J., Placke T., Winter M., "A Reality Check and Tutorial on Electrochemical Characterization of Battery Cell Materials: How to Choose the Appropriate Cell Setup", *Materials Today*, 2020, 32, 131–146. 4. Baum Z. J., Bird R. E., Yu X., Ma J., "Lithium-Ion Battery Recycling—Overview of Techniques and Trends", *ACS Energy Letters*, 2022, 7(2), 712–719. 5. Thompson D. L., Hartley J. M., Lambert S. M., Shiref M., Harper G. D. J., Kendrick E., Anderson P., Ryder K. S., Gaines L., Abbott A. P., "The Importance of Design in Lithium-Ion Battery Recycling—A Critical Review", *Green Chemistry*, 2020, 22(22), 7585–7603.
	Supplementary literature	1. Yanamandra K., Pinisetty D., Daoud A., Gupta N., "Recycling of Li-Ion and Lead-Acid Batteries: A Review", *Journal of the Indian Institute of Science*, 2022, 102(1), 281–295. 2. Ma X., Meng Z., Bellonia M. V., Spangenberger J., Harper G., Gratz E., Olivetti E., Arsenault R., Wang Y., "The Evolution of Lithium-Ion Battery Recycling", *Nature Reviews Clean Technology*, 2025, 1(1), 75–94.
	eResources addresses	Basic https://doi.org/10.1007/978-3-662-46657-5 - https://doi.org/10.1201/9781003145585 - https://doi.org/10.1016/j.mattod.2019.07.002 - https://doi.org/10.1021/acsenergylett.1c02602 - https://doi.org/10.1039/D0GC02745F - Supplementary https://doi.org/10.1007/s41745-021-00269-7 - https://doi.org/10.1038/s44359-024-00010-4 -
Example issues/ example questions/ tasks being completed	1. Properties and degradation mechanisms of electrode materials used in lithium-ion batteries. 2. Lithium-ion battery recycling methods: characterization and comparison of mechanical, hydrometallurgical, and pyrometallurgical processes. 3. Structure, properties, and applications of NMC-type cathode materials.		
Practical activites within the subject	Not applicable		

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