GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	, PG_00067222						
Field of study	Praca Dyplomowa Magisterska						
Date of commencement of studies	February 2024		Academic year of realisation of subject	2024/2025			
Education level	second-cycle studies		Subject group				
Mode of study	Full-time studies		Mode of delivery	at the university			
Year of study	2		Language of instruction	Polish			
Semester of study	3		ECTS credits	20.0			
Learning profile	practical profile		Assessment form	assessment			
Conducting unit	Department of Energy Conversion and Storage -> Faculty of Chemistry -> Wydziały Politechniki Gdańskiej						
Name and surname of lecturer (lecturers)	Subject supervisor		dr hab. inż. Monika Wilamowska-Zawłocka				
	Teachers						
Lesson types	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	0.0	0.0	0.0	0.0	0.0	0
	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	0	0.0	0.0	0

Subject objectives	The aim of the course is the independent development and execution of a research project related to a selected issue within materials science, chemistry, chemical engineering and technology, including the planning and performance of experiments, interpretation of results, and formulation of conclusions. The student develops skills in critical analysis, synthesis of specialized knowledge, and application of modern research methods, as well as gains experience in presenting and defending research findings.

Learning outcomes

Course outcome	Subject outcome	Method of verification
K7_U04	The student is able to evaluate the applicability of modern direct recycling methods for NMC cathodes, taking into account the efficiency of delamination techniques and lithium reinsertion methods. The student can critically analyze the potential of available technologies for the recovery and reuse of electrode materials, identifying their advantages, limitations, and implementation potential.	[SU4] Ocena umiejętności korzystania z metod i narzędzi [SU3] Ocena umiejętności wykorzystania wiedzy uzyskanej w ramach przedmiotu [SU1] Ocena realizacji zadania
K7_W01	The student knows and understands the mechanisms of processes related to the pretreatment of NMC cathodes, including delamination and removal of binder materials (thermal treatment, chemical treatment, and solvent-based methods). The student has advanced knowledge of lithium reinsertion processes into active materials (hydrothermal and solid-state methods) and understands their impact on the structural, morphological, and electrochemical properties of cathodes. The student is familiar with current trends in battery recycling technologies and their role in the circular economy and energy carrier production.	[SW3] Ocena wiedzy zawartej w opracowaniu tekstowym i projektowym [SW1] Ocena wiedzy faktograficznej
K7_W05	The student knows and understands the processes taking place in devices and systems used for energy conversion and storage in lithium-ion batteries, with particular focus on the role of cathode materials. The student has advanced knowledge of mechanisms of energy storage in NMC cathodes and methods of improving their performance through lithium reinsertion. The student understands the importance of direct cathode recycling for the development of sustainable energy technologies and is familiar with current trends in energy efficiency improvement and the use of recycled materials in the context of the circular economy.	[SW3] Ocena wiedzy zawartej w opracowaniu tekstowym i projektowym [SW1] Ocena wiedzy faktograficznej
K7_W07	The student knows and understands the processes occurring in devices and measurement systems used for characterizing cathode materials after recycling. The student has in-depth knowledge of analytical techniques applied in quality assessment of recovered materials (including X-ray diffraction, electron microscopy, Raman spectroscopy, Inductively Coupled Plasma – Optical Emission Spectrometry and electrochemical testing). The student understands the physicochemical phenomena underlying these methods and their importance for quality control of electrode materials and their suitability for reuse in lithium-ion batteries.	[SW3] Ocena wiedzy zawartej w opracowaniu tekstowym i projektowym [SW2] Ocena wiedzy zawartej w prezentacji [SW1] Ocena wiedzy faktograficznej

Course outcome	Subject outcome	Method of verification
K7_U01	The student is able to design and conduct experiments related to cathode pretreatment and lithium reinsertion, and select appropriate analytical methods to assess the properties of the recovered materials (structural, morphological, and electrochemical characterization). The student can interpret experimental results, formulate hypotheses on the mechanisms of the studied processes, and draw conclusions regarding the impact of applied methods on recycling efficiency and cathode performance.	[SU5] Ocena umiejętności zaprezentowania wyników realizacji zadania [SU4] Ocena umiejętności korzystania z metod i narzędzi [SU3] Ocena umiejętności wykorzystania wiedzy uzyskanej w ramach przedmiotu

Subject contents

Prerequisites and co-requisites

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
theoretical study	60.0%	50.0%
experimental works	60.0%	50.0%

Recommended reading

Basic literature	H. Bae et al., Technologies of lithium recycling from waste lithium ion batteries: a review, Mater. Adv., 2 (2021) 3234. L. L. Driscoll et al., Phase-selective recovery and regeneration of end-of-life electric vehicle blended cathodes via selective leaching and direct recycling, Joule, 8 (2024) 2735. G. Jiang et al., Acetone as an agent for PVDF recovery and delamination of lithium-ion battery electrodes, Resources, Conservation & Recycling 209 (2024) 107778. L. E. Sita et al., Direct Recycling of LixNi0.5Mn0.3Co0.2O2 from Production Scrap and End-Of-Life Batteries, Using Solid-State Relithiation, Batteries & Supercaps 2024, e202400536 (1 of 14)
Supplementary literature	J. P. Pender et al., Electrode Degradation in Lithium-Ion Batteries, ACS Nano 2020, 14, 12431295 P. Zhu et al., Direct reuse of aluminium and copper current collectors from spent lithium-ion batteries, Green Chem., 2023, 25, 3503. A. Zorin et al., Acid-Assisted Separation of Cathodic Material from Spent Electric Vehicle Batteries for Recycling, Metals 2023, 13, 1276.
eResources addresses	

Example issues/ example questions/ tasks being completed

1) Pre-treatment of NMC cathodes
- What are the advantages and limitations of different delamination methods (thermal treatment, organic solvents i.e. NMP or acetone)?
- How do process parameters affect the effectiveness of binder removal and active material recovery?

2) Lithium reinsertion processes
- What is the mechanism of hydrothermal lithium reinsertion and what are its limitations?
- How does the solid-state reaction proceed in the context of cathode structure restoration?
- Does the combination of hydrothermal and solid-phase methods improve material properties?

3) Characteristics of recycled materials
- What analytical methods are used to study the structural and morphological properties of cathodes (XRD, SEM, spectroscopic methods)?
- How can the impact of the recycling process on the electrochemical properties of recovered materials be assessed?

4) The importance of direct recycling
- What are the differences between direct recycling and hydrometallurgical and pyrometallurgical methods?
- How can direct recycling contribute to the development of a circular economy?
- What are the main challenges associated with the industrial implementation of such processes?

5) Practical and research skills
- Designing an experiment to investigate the influence of process parameters on the properties of cathode material.
- Comparative analysis of results obtained for different delamination and reinsertion methods.
- Formulating research hypotheses and verifying them based on measurement results.
- Preparing and defending a presentation of research results in written and oral form.

Practical activites within the subject

Not applicable

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