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| **Title of the project** | Enhanced safety materials for Li-ion batteries |
| **Short title** | ENSAMAT |
| **TRL:** | 1-3 |
| **Code:** | 09I04-03-V02-00028 |
| **Beginning of the project:** | 1.1.2025 |
| **Duration:** | 20 months |

**Interim Monitoring Report** for the period 01. 2025 to 10. 2025.

The Interim Monitoring Report for the period 01. 2025 to 10. 2025 (M1-M10) is prepared for Work Package 1 Anode and Cathode. For tasks that were completed according to the schedule, the implementation of the Project Outputs (Deliverable) is described.

**Work Package 1 (WP1) Anode and Cathode** (M1-M20)

Task 1.1 Development and Preparation of Silicon/Graphite-Based Anode (M1-M15)

Within this task, we focused on the research and development of a silicon/graphite anode prepared using ball milling of a solution of silicon and graphite particles with ethanol. The composition of the solution was determined as 20 wt% silicon plus 80 wt% graphite according to the content of active ingredients. The resulting slurry, the so-called "slurry", was then applied to a Cu substrate using the "doctor blade"/"tape casting" technology. After drying at 100 °C for 24 hours, individual anodes with a diameter of 18 mm were cut. The overall preparation procedure for the silicon/graphite-based anode is shown in Fig. 1. In the last step of the preparation, electrodes covered with a thin layer of ZnO were prepared using atomic layer deposition (ALD) technology. In the case where the FEC (fluoroethylene carbonate) additive was used for the electrolyte 1.0 M LiPF6 in EC/EMC solvent and the anode was covered with a thin layer of ZnO (20 ALD cycles, 3.4 nm), the best results were achieved. For high charging rates $C \geq 1$, the capacity of the anode with 20 wt% Si, FEC additive and ZnO covered was several times higher than the uncoated anode in the electrolyte without FEC additive, Fig. 2. The charging rate C=1 means charging the battery to full capacity in 1 hour and completely discharging the battery in 1 hour.

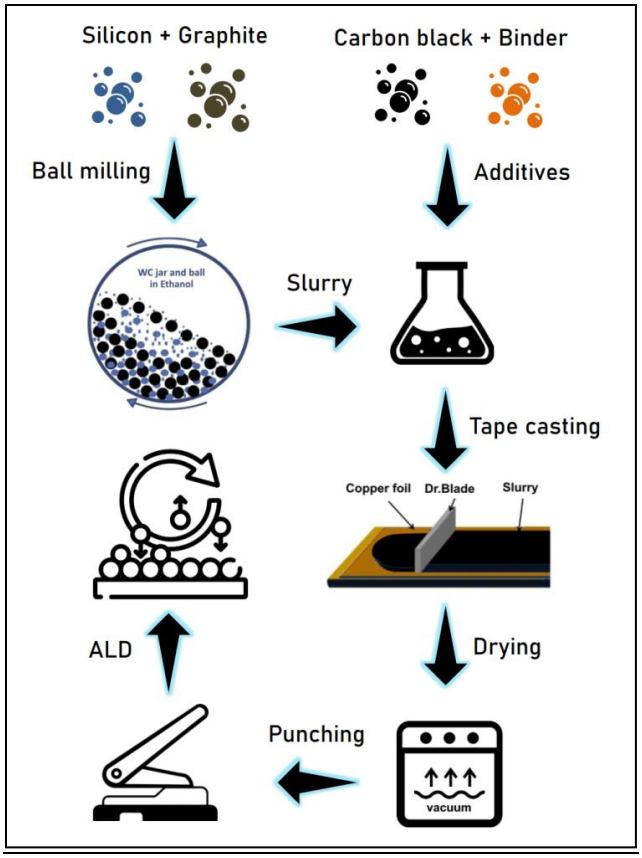



Fig. 1. Schematic outline of the preparation process for silicon/graphite-based anodes.

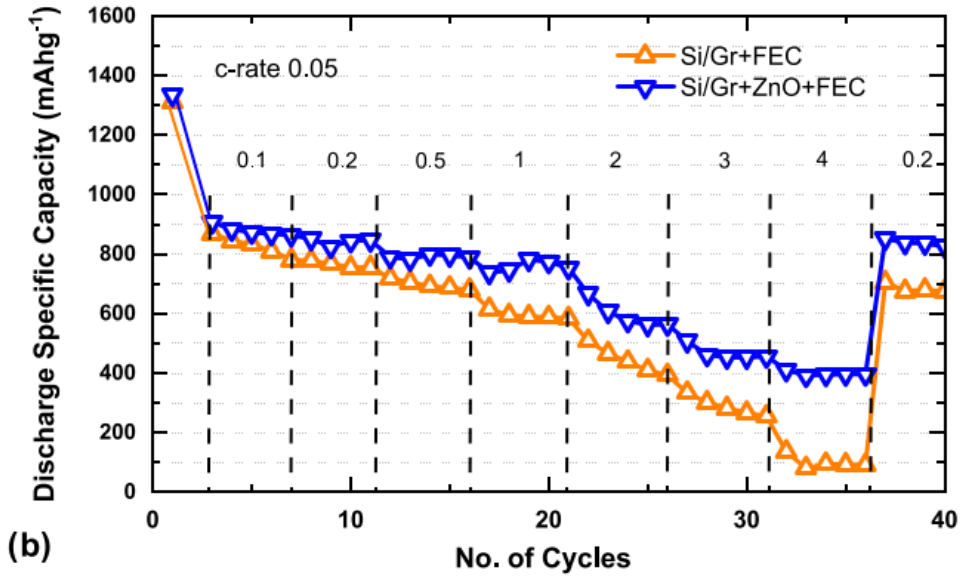



Fig. 2. Specific capacitance of the silicon/graphite anode as a function of charging cycles at different charging rates C.

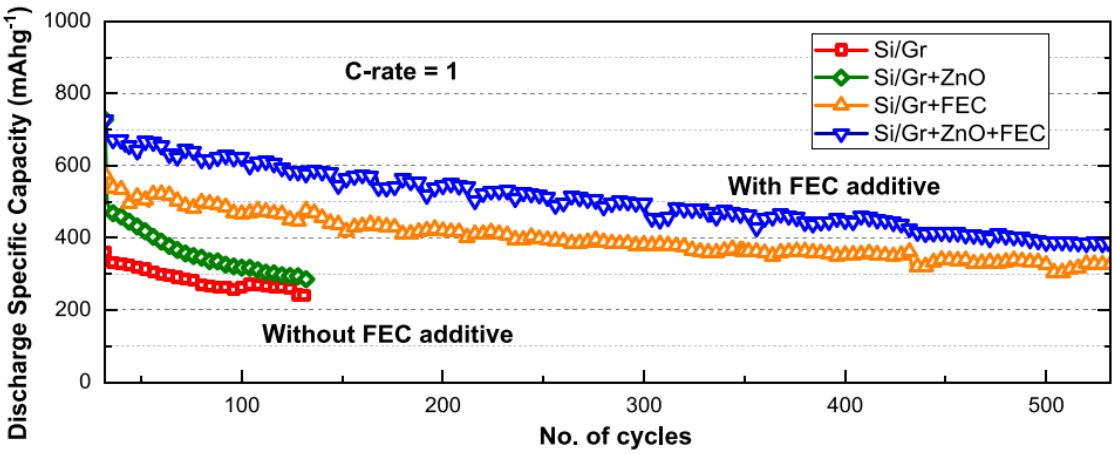



Fig. 3. Dependence of the specific capacitance of the silicon/graphite anode on the number of charging cycles for a charging rate of C=1.

In Fig. 3, the dependence of the specific capacity of a silicon/graphite anode with a silicon content of 20 wt% on the charging cycles for C=1 is shown. The anodes in the electrolyte with the FEC additive survived 500 cycles. After 500 cycles, the specific capacity reached about 60% of the original capacity. It turns out that the addition of the FEC additive to the electrolyte significantly increases the stability of the anodes during cycling. This result is close to the desired value of approximately 80% capacity after long-term cycling and is comparable to the best values in the literature for silicon/graphite anodes. The results of this study were published in the prestigious foreign journal ACS Appl. Energy Mater. in 2025 [1].

The project includes milestone M1 entitled “Mechanical properties and performance of a silicon/graphite anode with a silicon content of 30 wt%”. The milestone is related to work package WP1. The milestone had to be achieved by the time of M9 (September 2025) of the project. The achievement of the milestone needs to be verified by structural and electrochemical properties. Based on the structural properties and measurement of the specific capacity depending on the number of cycles, we can conclude that milestone M1 entitled “Mechanical properties and performance of a silicon/graphite anode with a silicon content of 30 wt%” has been successfully achieved and it is therefore possible to proceed with the preparation of a silicon/graphite anode with 50 wt% Si.

Task 1.2 Selection and Characterization of Cathodes (M1-M6)

Commercial cathodes (NIE Corporation) based on layered oxides LFP (LiFePO4) and NMC (LiNiMnCoO2) are used as comparison materials for Li-ion battery cathodes in the project. Both types of cathodes are used in today's Li-ion batteries due to their affordability and long-term cyclability (LFP) and high specific energy capacity (NMC). The electrochemical properties of the cathodes were investigated in Task 4.2. The selected cathodes were covered with thin ALD layers in Task 3.2.

Task 1.3 Preparation of the entire battery (M12-M20)

The task is scheduled to start in M12.

Odkazy na literatúru

1) P. P. Sahoo, A. Güneren, B. Hudec, M. Mičušík, P. Švec Jr., M. Precnerová, A. Nada, Z. Lenčéš, K. Fröhlich, Silicon/graphite anode performance improvement: a combination of atomic layer-deposited ZnO coatings with a fluoroethylene carbonate additive, ACS Appl. Energy Mater. 2025, 8, 6925, https://doi.org/10.1021/acsaem.4c02912.